



## **Co-Evolution of Systems of Innovation**

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## **Introduction**

My purpose in this opening session is to outline of some of the problems and challenges that arise in relation to a programme of research on innovation in the modern economy. Because the questions that define any programme are not independent of wider frameworks of interpretation I shall devote some attention to one particular framework, the development of which appears to have considerable promise. This framework is captured in my title and brings together two of the principal ideas within an emerging approach to the study of innovation, namely those of evolutionary processes and instituted economic processes. In these two concepts we can bring together a dynamic perspective on how and why the economic world changes and a parallel perspective on the social and economic division of labour in the production and application of useful knowledge.

My treatment of topics is necessarily selective and I do not attempt at all to cover all the issues that could define the innovation research agenda. Instead I focus on those challenges that put innovation studies in a wider context.

First some remarks on the current state of our understanding of innovation.

### **On the Current State of Knowledge**

That innovation is central to the operation of modern capitalism should not need restating. The relation between economic growth and technological advance is well, although not completely understood, as is the role of competition in stimulating and translating innovation into productivity growth. That these processes are uncertain in their operation and unpredictable in their outcomes is well understood too. Equally clear is the fact that these processes are very uneven in their incidence. Indeed it is the uneven nature of evolutionary development that creates the principal ethical issues of modern capitalism.

More recently, the idea of the knowledge economy and knowledge based economic growth has permeated discussion of a new economic age based on the twin technologies of information and modern biology. Yet all economies are knowledge-based economies indeed they could not be otherwise. So the question arises of what is different about the current notion of knowledge dependence? Is it that the knowledge is different? Is it that it is accumulated by new kinds of process? Is it that the rate of development is quicker than in the past? Is it that new sectors are in the vanguard of innovation? Is it that the conditions of exploitation are different from the past, perhaps reflecting the more open nature of economies to trade and investment? Is it that nothing is different and we are simply beguiled by the current events?

Answers to these questions cannot avoid confronting the complexities of modern capitalist economies. They are institutionally rich, they are always changing in their structure and they exhibit a close interdependence between economic activity, narrowly defined, and wider social and political frameworks that frame and support those economic activities. If these matters were at all straightforward, they would have been understood long ago. I shall suggest that one important reason for the complexity of capitalism is that it is never in equilibrium in the sense of a state of rest. Rather, capitalist economies are restless economies and for two powerful reasons. They have decentralised, unco-ordinated innovation processes reflecting the cumulative nature of the growth of knowledge, the essential characteristic of which is its autocatalytic nature – one idea inevitably leads to another idea without end. The economic consequences of the new knowledge are strongly co-ordinated by the operation of market and other processes, the role of which is to produce order and pattern but not equilibrium. *To understand more deeply the empirical and theoretical foundations of knowledge based capitalism is my central challenge.*

To address these questions requires careful attention to method. No single discipline can expect to cope with the complexities of the processes of innovation and the diffusion of innovation. Economics, sociology, business and management studies, technological, social and economic history, politics and policy studies, ethics, psychology, and geography, and indeed engineering, medicine and science all have a claim to inclusion in the understanding of innovation. Yet the whole remains less than the sum of the parts unless the different contributions combine together to generate new insights that could not emerge from a single disciplinary perspective. This is a

very demanding task and it is unlikely to bear fruit if the research questions are not formulated in terms of **problems that cut across disciplinary boundaries**. Policy problems and management problems often fit into this co-disciplinary category, the challenge is to define the scientific problems in the same terms.

In fact innovation scholars have had considerable success in doing this. Often their work does not fit easily with mainstream disciplinary studies, new journals have been established to publish their research, and new communities of practitioners have formed to promote the academic division of labour. This does not mean that a great deal more can be done or that there are not dangers in research strategies becoming too divorced from the main underpinning disciplines. In this regard there is much merit in the view of Gibbons and colleagues (1994) that the study of innovation is itself a natural Mode 2 form of knowledge accumulation.

A second methodological issue is *the importance of the comparative element in innovation studies*. Whether we take the unit of study to be the innovating firm, the innovating or inventing individual, or the innovation itself, we miss much of the story if we do not ask, ‘Why other firms failed to innovate?’ or ‘Which other innovators and innovations were contesting for the same economic purpose at the same time?’ It is all too easy and all too misleading simply to focus on the apparent successes and lose sight of the fact that their success was conditioned by the presence of rival alternatives. This issue becomes particularly important when we try to assess the comparative innovative performance of different regions or countries. There is not a single model of capitalism, in one sense there is competition between the different models of capitalism and the comparative assessment of their innovative performance must be high on any research agenda. That this agenda should be extended to the study of innovation processes in developing economies, I think, is obvious.

A third issue relates to the kind of evidence that can illuminate the innovation agenda. Again I suggest that no single approach is sufficient for this purpose. Econometric studies and other forms of statistical analysis play a role but so do case studies and wider historical studies of the different units of innovation analysis. The innovation literature is rich in these different approaches and this raises the question of *how we combine together the results of the different*

*methods to gain a deeper understanding.* This is not unrelated to the difficult problems that rise in developing good metrics for the innovation process and its outcomes. Since innovation entails qualitative variation of some kind this means that aggregates of innovation inputs or outputs should always be treated carefully. Since statistics cannot be produced at zero cost, it follows that the data will always be more or less satisfactory approximations to the underlying situation, as we see, for example, in the attempts to measure the real output of computer and IT services in the advanced economies. For this reason the case for data pluralism is very strong. ***How then are we to design research programmes in which the different forms of evidence can be mutually supportive?***

At this point a very brief review of some findings of recent innovation research may be helpful. If we take the innovation as a unit of analysis, we know that most innovations are not isolated phenomena rather they are events within a stream of related developments that explore a particular set of technological opportunities. Sometimes it is useful to consider the first innovation as the radical beginning of an incremental sequence of improvements within an innovation trajectory. Whatever, the point is the extended time lapse taken for an innovation to reach its full potential. Innovations are almost without exception underdeveloped at the outset and it is the related and often cumulative sequence of improvements that should be the focus of attention. One consequence of this is that innovation sequences can be said to co-evolve with the market activities through which they are exploited. Of equal significance is the finding that complementary innovations are frequently required for any given innovation sequence to reach its full potential, and that these complementary developments often depend on different areas of technology and science. Innovation processes are discovery processes, unpredictable and wasteful, and it is this creative dimension that is crucial to understanding how capitalism operates.

If we take the innovating firm as the unit of analysis we can divide the important issues into four categories: the resources available to invest in innovation, the incentives to make the investment, the opportunities open for innovative investment, and the capabilities to identify and manage the innovation process. The economics of innovation literature is very much focused on the first two of these questions. Studies of R&D expenditure or of the returns to R&D or of the relation

between R&D investments and productivity growth fall under the first issue, while studies of patenting activity and of knowledge spillover fall within the second. The management literature has a great deal to say about the fourth issue either in terms of the management of technology or the relation between company strategy and the innovation process. More recently there has been a fruitful cross-disciplinary development with economists and management scholars jointly contributing to a capabilities theory of the firm. The third issue, that of the opportunities to innovate is a most difficult one to deal with since it is closely connected to the dynamics of the growth, combination and spread of knowledge. It is the third and fourth issues that fit most naturally with an innovations system perspective.

The development of an innovation systems perspective has been one of the more important developments of the recent literature. The key point is to recognise that all but the trivial innovative efforts of firms are likely to be embedded in a wider matrix of interactions with other knowledge generating organisations whether they be users, suppliers, competitors, universities or other research bodies. The innovative record of a firm then depends not only on its internal efforts but also on its external organisation, how it makes use of and manages its interaction with the wider innovation system. When originally formulated, this idea was focused around national level organisation and institutions. Now it is recognised that a sectoral perspective is often more fruitful and that sectoral innovation systems frequently transcend national boundaries. Trans-national companies certainly play a role in this but so do the institutions of modern science and basic technology that are naturally international in their operation.

A related feature of the study of innovation is its almost exclusive supply side emphasis. Ever since Schumpeter's Theory of Economic Development, the consumer or user has been given a rather passive role in the explanation of innovation. The study of user-supplier interaction within the innovation systems literature has begun to remedy this defect but much more remains to be done particularly in relation to the role of the final consumer. Indeed this is an area where the sociology of innovation has been ahead of the economics. Related to this is the relative neglect of the public sector in influencing the demand for innovation, despite, for example, the role this played in the development of microelectronics and health technologies in the USA.

From this brief overview, it may be useful to briefly sketch the main argument which is that the innovation process can be studied beneficially by bringing together two research traditions, in relation to evolutionary processes and in relation to the instituted nature of economic processes. The first can be found in the Schumpeterian tradition, the second in the less well developed Polanyian tradition of economic sociology. The combination of the two schemes of thought provides a powerful basis for the study of economic and social change in relation to innovation, and the consequences of innovation, and for connecting to the literature on the management of innovation. This leads me to an emphasis the division of labour in the innovation process, to the innovation systems perspective, and to the idea of distributed innovation processes.

The advantages that follow from the combination of these traditions are I believe compelling. The evolutionary approach is naturally concerned with dynamic questions and, since it requires qualitative variation to work at all, it is a natural way to approach the study of innovation and its consequences. Market processes are correctly interpreted as selection processes and innovation systems provide the context for development processes. Neither the former nor the latter can be understood in terms of economic activities alone both are instituted in sets of social relations, whether networks or communities of practitioners or agreed rules of the game such as standards. *However innovation systems are not naturally given.* They are constructed and instituted outcomes of individual behaviours that are shaped by wider instituted processes, and their development is frequently a by-product of activities carried out for other purposes. The important issue to understand is the dynamic of innovation system development at a multiplicity of levels from the firm to the national economy. In short we need to understand the development of the division of labour in the innovation process, to see how a particular innovation system is initiated, grows stabilises and even declines alongside the growth of the market for that innovation sequence.

### **Economic Growth and Restless Capitalism.**

The first challenge to consider is that between innovation and economic growth. How are we to connect the rich cross-disciplinary literatures that study innovation and its management, the history of technology, the capabilities of firms and the growth of knowledge with the broad

movements in per capita income of macro economies? A closely related question is ‘How are we to connect the related ideas of enterprise and entrepreneurship with the growth process?’. ***How, in short can we capture the creative element in economic change? This is, I believe, a central issue for the European economy.***

The starting point is the restless nature of capitalism that I suggested above arises from, two attributes of modern capitalism. The highly decentralized nature of creative, innovative activity and the localized conditions for the accumulation of knowledge mean that economic behaviours mutate and mutate unpredictably. Neither investment nor innovation, nor indeed any aspect of enterprise, proceeds in entirely smooth, predictable ways, they are noisy determinants of economic growth. The pattern of economic activity is continually changing; it is never in a steady state of growth as this is usually conceived, there are always reasons to promote change. It is this microdiversity of behaviour which is the basis for competition, for structural change and for economic growth. Capitalism is restless because of its unlimited capacity to generate new knowledge and new behaviours and it is this consequent propensity for variation which makes it so dynamic, such that economies may be completely transformed in structure over relatively short periods of historical time. But variety and change in variety alone is only part of the picture. Equally important is the co-ordination of variety by market institutions to determine how differences in behaviour are resolved into evolving patterns of economic activity.

Scholars of modern economic growth have explored this theme under the general heading of endogenous growth but have chosen to do so from a macroeconomic perspective. ***The major challenge here is to step back from this macro perspective. The underlying motivation is that any macroeconomic approach hides more than it illuminates about the process of knowledge-based growth in capitalist economies. We can certainly measure at the macro level but to do so inevitably hides the diversity of conditions upon which the growth of the system depends.*** From this follow the patterns of structural change which are a defining, emergent feature of modern capitalism. Such economies are never in states of steady growth; and the more we disaggregate the greater the evidence we find for diversity of growth experience; conversely, the more we aggregate the more we hide, by averaging way, this essentially evolutionary

phenomena. We can measure and observe patterns at the macro level but our understanding necessarily flows from the interactions between varieties of micro behaviour.

Aggregate growth is an emergent property built upon the co-ordination of diverse micro behaviours, and it is through the interaction of the micro behaviours that the dynamics of change occur. Indeed, the chief distinguishing feature of the evolutionary approach is the relation to differential growth not balanced, uniform growth. Moreover, the growth rates of firms differ not only because of differences in the enterprise characteristics but also because the consequential behaviours are co-ordinated by competitive market processes. Co-ordination is central to the understanding of growth but co-ordination is not equilibrium, it is order, and in knowledge-driven economies order is ever changing (Loasby, 2000). The rules of co-ordination are important for another reason; they provide the basis for aggregation of micro diversity into macro outcomes. Innovation dynamics and market dynamics are inseparable.

The evolutionary perspective on growth and transformation brings into the picture three broad classes of enterprise phenomena: the behaviours of profit-seeking firms in relation to their efficiency, capital accumulation and innovation; the co-ordination of those behaviours through market processes, capital markets and labour markets as well as product markets; and, the rules for aggregating firms into sectors and sectors into whole economies. It is a perspective in which innovations at the micro level are translated into economic growth at successively higher levels of aggregation.

It is a characteristic of the evolutionary approach that no formal role is given to the idea of optimizing behaviour as a heuristic device, and this requires some comment. It is, of course, taken for granted that individuals and firms seek to do the best they can in the circumstances they face. But what is best and what are the relevant circumstances are not always transparent (the bounded rationality point) and more fundamentally differ from firm to firm (the creativity point). It is the emphasis on different, individual behaviours that replaces the emphasis upon optimization and which is enshrined in the idea of diversity in behavioural rules (Nelson and Winter, 1982). Thus what it is important to abandon is not maximization, that is not the significant step, but rather the idea of uniform behaviour. Indeed, to invoke uniform behaviour

in a world of innovation would involve an immediate contradiction with the facts. A world of representative, uniform agents is simply not the place to undertake any study of the accumulation of knowledge and its connection with economic growth. Once uniformity is abandoned the consequence is profound. For what is now to be meant by representative behaviour (mean, median, mode or whatever) cannot be determined a priori, it is an outcome of the analysis. Consequently, we find the next challenge, *is to discover and interpret the variety of rules and strategies that firms follow in practice in relation to their innovative activities.*

Notice also that, while it is commonplace to associate capitalism with strong property rights in relation to material goods, capitalism as a system is capable of enterprise only to the degree that intellectual property rights are weak. Patents and related rules are not unimportant but it is essential to my reading that they provide only local protection in the space of inventive possibilities. Copying they protect against but not countervailing innovation. No productive combination is free from innovative challenge and that is crucial to the dynamics of capitalism. As a result the formulation of property right regimes for new practical ideas is of great importance, and particularly so for many service related activities, of which the music industry is a topical example.

### **Competing Concepts of Competition.**

Just as the evolutionary and instituted perspectives provide new insights into the growth process so they enable us to identify new challenges in the study of competition. Two challenges are central here. *The first is to develop the view of competition as a process, in which competition occurs at different interacting levels and is driven by the differences in behaviour between rival producers.* In this view the accumulation of capacity and innovation play the key dynamic roles while market processes provide the context in which innovation and accumulation of capital transform those differences between firms into patterns of economic change. We explore this in more detail below and turn to the second of the central ideas. *This is that market frameworks are not external, given data, rather they are instituted in the competitive process and co-evolve in the competitive process.* Thus market processes have to be instituted and in many cases it is the firms in the market that invest the resources to create the market. In the

process, rules emerge that serve to institute the market's activity. Among these rules and practices are those developed to facilitate co-operation between firm, including co-operation in the process of innovation. Thus we frequently observe rivals engaging in the joint production of shared knowledge assets which facilitate the development of their markets. This raises a very interesting set of questions in relation to *the nature of the competitive unit*. In many cases it is clearly not the individual firm, rather it extends to supporting systems of innovation for the firm. Furthermore this means that the management of the external organisation of the firm is a key element in its competitive performance.

### **Evolution, Selection and Development**

Now evolving systems are systems which change according to particular kinds of process, and two processes take pride of place; selection processes and developmental processes. All evolutionary models are based at least on the first and all the more sophisticated evolutionary models necessarily combine the two. Such evolutionary systems are characterised by three important properties: they are naturally dynamic, evolutionary theory is naturally "growth" theory; they may involve selection and development at a multiplicity of distinct, interdependent levels; and, they give rise to the possibility of positive, reinforcing feedback behaviours with all that implies for path dependency and history proper.

The central evolutionary issue is not being but becoming, why is it that the world changes in the way it does with respect to rate and direction? For the economist or economic historian, the development of evolutionary thinking in relation to economic activity has provided a powerful set of ideas to make sense of innovation (social, technical, whatever) and its relation to economic growth, structural change and competitive processes.

I propose to develop these general themes in two broad stages, viz:

- the interdependence between selection and development in evolutionary processes
- the division of labour as the key element in the process of knowledge accumulation

Here I need to distinguish two-stage from three-stage models of evolution (Figure 1). In traditional evolutionary theory a two-step framework is often used to spell out the main elements in the approach. This starts from the idea of variety in the characteristics of a population of selection units and combines this with a process of selection that evaluates the characteristics to create a “fitness” score. From this there follows a pattern of change in the relative importance of the selection units; the fitter than average increasing in relative importance and conversely for the less fit than average.

Several aspects of this two-stage scheme are worth noting. First fitness is not an attribute of any selective unit, it is a derived consequence of interaction within a given environmental context. No question of tautology arises in this respect. Secondly, the ideas of fitness, adaptation, unit of selection and selection environment form a unity, one cannot have one without the others. Thirdly, fitness is a dynamic concept that relates to the growth rates of the competing units of selection. In a nutshell, evolutionary explanations are explanations of differential fitness, and they are inherently dynamic.

It is not surprising that students of innovation and of technology more generally have found this a congenial framework within which to work. Innovations in products, organizations and methods of production generate variety, market processes evaluate that variety and translate it into differential profitability and the competitive dynamic translates profitability into differential growth (Nelson and Winter, 1982; Dosi et al, 1988; Saviotti, 1996; Metcalfe, 1998).

One intriguing aspect of evolution is that it consumes its own fuel. Processes of competitive selection necessarily destroy (or rather absorb) the very variety on which evolution depends. Unless this variety is replenished evolution will come to an end and this is the limitation of the two-stage schema. We need to move to a three-stage scheme – variety, selection and the regeneration of variety. This requires a serious treatment of developmental processes in terms of the origins of variety and the endogenous recreation of variety. By developmental processes we mean processes which revise, add to or subtract from the distinctive units of selection in a population. In economic terms we see these as innovative processes broadly defined. It is the

study of development processes that opens up the possibility of the detailed examination of the instituted foundations of competition and competitiveness.

### The Three-Stage Scheme

No one should pretend that the study of economic and social development processes will be straightforward. There are good grounds for believing that the innovation black box will remain partially closed. To reinforce what was said in the opening paragraph a predictive theory of novelty is not in our grasp. Consequently, while the learning economy is a useful metaphor it must not be at the expense of a proper understanding of the unpredictable role of creativity and imagination in human affairs. Nonetheless a great deal remains to be said.

One way forward is to treat innovation processes as akin to random mutation or copy-error processes. This is the traditional Darwinian scheme – chance and necessity, random variation combined with deterministic selection. Of course, variety cannot be completely random, for randomized processes drift, they do not evolve according to selection. Randomness must remain at the margin.

Now in the economic and social sphere, the random hypothesis hardly seems adequate. Random processes are too slow to explain the observed rates of economic and social development; the range of combinatorial possibilities arising from the interconnection of established ideas is simply too vast to contemplate. Much more credence can be placed on the idea of constraints on the development process. The rate of progress is what it is largely because it reflects guided variation within conceptual schemes that channel explorative, creative enquiry in particular directions. In so doing they create opportunities and rule out opportunities. This is the substantial grain of truth behind the idea of technological paradigms, design configurations, focusing devices and technological heuristics on which evolutionary students of innovation depend. Within these constraints, randomness can be given a proper place (Allen, 1988). Of course, all variation is in Campbell's terms, blind variation, it necessarily deals in the unknowable consequences of present decision, it is in Shackle's terms the imagined deemed possible (Loasby, 2000).

In taking this idea further more needs to be said in the production of knowledge and the division of labour.

### **Division of Labour and the Growth of Knowledge**

My claim here is that a central challenge in the study of innovation is *to understand the way in which the division of labour in the production and application of knowledge is instituted as an economic process and how this division of labour changes over time.*

I shall elaborate upon the point that the distinctive, complex, evolutionary property of economic and social systems is that they are knowledge-based and that the primary interactions within them are exchanges of information. Because of this economic systems are necessarily restless. As Marshall in 1898 and Popper much more recently (1996) recognised, economic activity changes knowledge directly and indirectly and every change in knowledge opens up the conditions for changes in activity and thus further changes in knowledge an infinitum. Economic systems are open, the clock can never be turned back (Foster, 1993) and these features are uniquely associated with the capitalist institutions of economic organisation. *Thus the crucial attribute of economic agents is not their rational search for efficiency but rather their imaginative construction of future, alternative economic worlds (Loasby, 2000).* It is vastly more productive to ask “How is ignorance overcome?” than to postulate perfect foresight as the basis for economic reasoning.

One immediate casualty of this perspective is any resort to equilibrium based reasoning, whether or not it is based on Olympian notions of rationality. Restless systems are co-ordinated but know no equilibria. This is clearly a radical step, for it involves the claim that the idea of economic equilibrium be abandoned, and equilibrium is the central organising precept of mainstream economics. Several fundamental issues need to be unravelled here. The first is that the dominant issue in economic organisation is not equilibrium but co-ordination, how activities interact and to what effect. There is nothing wrong in referring to this as a temporary equilibrium providing we do realise its transient nature. But it is far better to refer to it as a temporary *order*, a mutually interdependent pattern of economic outcomes, for that is what co-

ordination through prices leads to, order not equilibrium (Loasby, 2000). What is inadmissible is the claim that a knowledge-based economy can ever be in a state of rest, a state with no internally generated disturbing forces. Thus to use a concept of equilibrium is to accept that the disturbing forces are outwith the system and thus that the origins of change are non-economic.

It follows that every position of temporary economic order creates within it the conditions to change that order, and this is especially true of knowledge accumulated in the pursuit of innovation. As Schumpeter was especially keen to emphasise, and for very good reason, the development of capitalism arises from within. This restless perspective is reinforced when we recognise that all economic processes take place in real time, subjective time, and that the mere passage of time means experiencing events and thus gaining new information. On both these counts it is particularly problematic if we try to posit some equilibrium economic state that is invariant to the motion towards it, for this is tantamount to holding knowledge (and the real time of human experience) constant while we get to equilibrium. In equilibrium, clock time passes but nothing changes, cause and effect evaporate. This makes no sense other than in a formal way to avoid the problem. In short when economies are out of equilibrium they stay out of equilibrium. But they always exhibit order and that order reflects, and might be measured in terms of processes of interaction and the patterns of co-ordination that ensue. Notice that this point runs much deeper than that of path dependence of outcomes in the presence of positive feedback processes. It is the point made by Kaldor (1934) and it arises even when all production and marketing processes are of the constant returns to scale kind, in the conventional sense. One cannot have economic activity without a change of knowledge (Metcalf *et al*, 2000).

A second consequence is a clear acceptance of the inherently unpredictable nature of imaginative, creative processes. A predictive theory of novelty is simply a contradiction in terms – that is the bargain we make as evolutionists in betting our theoretical chips on the question of why and how the world changes. A third consequence is the loss of foundations for the normative appraisal of systems pathologies (Brian Loasby's imaginative term). Restless systems have about them a sense of unease, of hopes dashed, of capital and skills devalued and expectations falsified for better or worse. Life is not entirely comfortable, however wealthy one might be. There is creation and there is destruction at economic and social levels, and the beliefs so engendered play a key role in the evolution of the system. [As one aside, this suggests to me

that the study of economic growth is seriously incomplete without a complementary investigation of economic decline.] Now this line of thought raises some very interesting questions about the role of public policy in evolving economies to which I return in the concluding remarks

*Distributed Innovation Processes: The Dynamics of Innovation Systems*

In recent theoretical and empirical work on innovation the idea of innovation systems has justifiably occupied a position of prominence (Freeman, 1987; Nelson, 1993; Carlsson, 1995; Edquist, 1996). These ideas can be traced back of course to Adam Smith and his powerful insight that the production of knowledge reflects a division of labour in which special importance attaches to “philosophers and men of speculation”. In modern innovation systems this is reflected in an increasingly roundabout process of producing practically useful knowledge in which there is specialisation of institution, specialisation of discipline and the combination of an increasingly wide range of knowledge types to the selection of practical problems. Knowledge generation and application systems raise several interesting avenues for exploration.

Seen in this light, innovative systems may be defined at various levels at which the national is only one possibility. More importantly the relevant evolutionary issues push one to a dynamic perspective. This involves two challenges for research. ***How does an innovation system make a difference to the rate and direction of innovation?*** How do the systemic attributes influence the selection of inventive ideas, how do they influence the translation of invention into innovation? ***How is the innovation system created and how does it evolve over time?*** How do innovation systems emerge as a consequence of higher order development processes, how do they grow, how do they decline? How fluid are the relations between component elements? A systems approach with its potential for distinguishing between changes of components and changes in connections seems a natural way forward. Selection and development apply within components in the system just as they do in relation to the connectivity between components in the system.

Two further points are worth making to develop this systems approach to the division of labour on knowledge production. One is the significance of distinguishing between different kinds of knowledge each with their institutional setup in relation to accumulation and dissemination. That science is fundamentally different from engineering, that technology is not merely applied science, that much scientific work is not purely motivated but undertaken with practical objectives in mind (Stokes, 1996) are points well-established in the relevant literatures. Clearly, the codified/tacit dimension is only part of the relevant set of distinctions. There are multiple knowledge-generating systems and how they connect and when is a natural systemic question.

The second is the importance of not being overly beguiled by formal (science, technology) knowledge in the innovation process. Here I want to press for the significance of less formal business knowledge of market demand and organization. These kinds of knowledge are conjecture-based like all knowledge, and are subject to refutation or conformation on a trial and error basis but they do not constitute formal, theoretical knowledge. They should be given full weight in any evolutionary account of knowledge and its relation to development processes. In turn, this suggests that the knowledge of consumers/users needs to be given more weight in our study of innovation. Pace Schumpeter there are obvious dangers in giving the consumer/user too low a weight in the study of innovation.

### **Innovation in Services: A Medical Innovation.**

One of the central features of the innovation literature is its focus on manufacturing innovation and the production of physical artefacts. From the study of the industrial revolution onwards it has been the relation between technology and physical transformation that scholars have focused upon. Yet in modern economies some 70% of employment and economic activity is devoted to the production and use of services. It is something of a paradox that the study of innovation in service activities has only recently begun to receive the attention it deserves. *A major challenge is to develop the detailed study of innovation processes in relation to service activities.*

An important aspect of this new literature is its analysis of the role of service activities in the innovation process. (Metcalf and Miles, 2000) Whether we consider the production of medical services, the production of transport and logistics services, or of telecommunication services we find rich areas of innovative activity in which there are strong complementarities between the service in question and a related manufacturing supply chain. If we are to understand what is distinctive about the knowledge based economy serious attention will have to be devoted to services innovation.

As an example of innovation in services that has led to substantial economic and social transformation it is instructive to briefly consider one of the more significant medical innovations of the past half century, the intraocular lens. This illustrates many of the challenges facing the study of innovation with the close interaction between the development of the innovation and the development of the market and in terms of the way that market has been instituted.

Intraocular lenses are a solution to a common problem of ageing, the formation of cataracts in the eye that progressively impair vision and ultimately result in loss of sight – even in individuals who are otherwise active. The traditional solution to this problem is and remains ophthalmic surgery but up to 1949 the patient was left with unfocused sight after the operation. Then an English surgeon, Harold Ridley, conceived the idea of placing the equivalent of a plastic contact lens in the chamber of the eye where the cataractous lens had been located. Thus began a medical transformation in which the insertion of an intraocular lens is now the most frequently performed medical procedure in the USA. What does this case tell us about the innovation process?

First and foremost it is a service innovation that originated with clinicians and has been developed in close collaboration with medical supply companies. The initial innovations in lenses and surgical methods were made by individual clinicians but the growth and acceptance of the innovation had to wait for its commercialisation in the early 1970s, some twenty years after the original innovation.

Secondly, the IOL has brought great benefits to patients in terms of post-operative quality of vision and in terms of greatly reduced operation times. From an operation that routinely required up to two weeks hospitalisation in the 1970s it is now the case that over 95% of cases in the UK and USA are performed on a day case basis. Given the rate at which the population is ageing in the advanced countries the significance of these gains in productivity cannot be overestimated, although they do not appear in the productivity statistics.

Behind these advances, we find a long period of trial and error experimentation in which numerous complementary innovations in materials and operative techniques were necessary to stabilise the innovation and permit its widespread use. Many of these innovations failed and frequently the costs of experimentation were born by the unfortunate patients.

Two factors appear of prime importance to the development of the innovation system supporting IOL technology. The first is the scale and growth of demand and the role of clinical convention in shaping the relation between patient need and demand for the treatment. Different financing and resource allocation regimes play an important role too in mediating this relationship. Demand is crucial through the incentives it provides for the division of labour in this area of ophthalmology. The second is the way firms in this industry assemble their own specific innovation systems in the search for competitive advantage. National level medical resources are thus combined together primarily through interaction between firms and clinicians to create competing innovation chains. Thus the connection between competition and innovation systems is found at different levels and in two-way relationships.

### **Innovation Policy: New Insights**

The central thrust of the argument so far is that the dynamic features of modern capitalist economies depend crucially upon their capacities as **experimental systems**; systems that continually generate new varieties of behaviour to be tested, adopted or rejected in the economic and social spheres. Innovation qua variety generation combined with the properties of selective processes makes competition an adaptive, evolutionary process. We have explored this idea by making the distinction between selection processes and development processes and their

interaction. From this comes our next challenge, ‘*What has this distinction to contribute to the formulation of innovation policies and for the management of innovation systems?*’

The first step is to see that it provides an alternative to the dependence of policy on market failure arguments. The idea of knowledge as a public good, the idea of imperfect property rights in knowledge, and the importance of uncertainty have all contributed to the view that knowledge markets will fail to produce optimal outcomes. The role of policy is to correct for these failures. By contrast the evolutionary focus on development systems and their embeddedness in wider social and political frameworks leads us to the contrasting notion of systems failure as the rationale for policy. The role of policy is here more constructive to create viable innovation systems, a policy that can be summarised in two brief questions. Are the knowledge generating organisations in place? Do they interconnect in ways that support the innovative efforts of firms?

This reflects directly the importance of the division of labour in knowledge production and the increasingly transdisciplinary and combinatorial nature of innovation processes. Firms must necessarily look beyond their formal boundaries for complementary knowledge. The need for an external organisation helps explain the recent rapid growth of innovation webs at many levels, from bilateral collaborations, to research clubs, to the formation of large scale joint research institutions involving universities, government laboratories, users and suppliers as well as the innovating firms. These linkages, it is argued, enhance the knowledge base of innovating firms, enabling them to produce superior innovations more quickly than would otherwise be possible (Katz and Martin, 1997). They are essentially devices for generating as well as managing flows of information.

One of the more powerful ideas in the study of innovation relates to the idea that knowledge can be used any number of times in the process of production of conventional goods and services *and further knowledge*. Like a more conventional public good it is used but not consumed. But one cannot infer from this that knowledge is invariably in the public domain, that it is ‘in the air’ at zero cost to anyone who wishes to use it, or that spillovers weaken property rights and limit the private incentives for knowledge generation. The problem here is confusing knowledge with

information. While the latter can be public the former is always private. Information flows but the changes in knowledge that are produced are idiosyncratic and private. This involves much more than the distinction between codified and tacit information. It points to the fact that the reading of information depends on prior states of knowledge, on the idea of absorptive capacity. How this is distributed across an innovation system has major consequences for its effectiveness. Similarly, spillovers do not occur naturally, they depend on explicit interactions between the agents and thus on the nature of the relations between them. A major challenge here is *to understand the diversity of micro processes of knowledge accumulation and the ways in which information flows can be stimulated between different kinds of organisation.*

Many of the collaborative arrangements that characterise a distributed innovation process can be interpreted as a process of spontaneous order at work. The webs of market and non market arrangements are formed from below, they do not arise by chance alone but because there is commercial merit in knowing what is happening beyond the boundaries of the firm. Does this mean that there are grounds for policy concern? The answer is, I think, yes. There are clear reasons to identify “system failures” in the innovation process, that is situations where the spontaneous order of web formation will not produce appropriate innovation systems. The problems to be addressed involve not only the production of knowledge but also the degree of utilisation of existing knowledge and the combination together of different kinds of knowledge produced in different contexts.

The reasons behind system failures are complex but may be stated briefly as follows.

The first lies in the domain of the bounded nature of intelligence, that it is increasingly costly to acquire knowledge beyond ones immediate domain of competence and experience, and this is itself a direct consequence of the division of labour. As individuals we know more and more about less and less. Organizations seek to combat this by combining the skills of teams of individuals but they too develop collective competences and a trained incapacity to think beyond the familiar. It is not by accident that major innovators are often outsiders, intellectually if not socially.

The second reason lies in the nature of increasingly roundabout knowledge production processes and their location in specialised institutions. Specialisations create their own languages, their own cultures of interaction that create barriers to easy communication with other specialised institutions. Consequently, communication between different knowledge bases is increasingly costly and firms find that they need to engage in fundamental research simply to participate in the wider conversation (Mowery and Rosenberg, 1989; Veugelers, 1997).

Thirdly, an infrastructure that facilitates joint research has the properties of a collective good. If it is to be privately funded it must be constituted as a club with unavoidable entry costs. This is not difficult to do but there is every expectation that the membership of the club may be too narrow from a wider point of view. The efficacy of such arrangements whether formal or informal depends greatly on the range of interests involved. Too diverse and they may stifle the innovation process; too uniform and they may lead to no progress at all. Competition considerations loom large here and it may be the case that spontaneous clubs become devices by which incumbents suppress competitive threats.

The final aspect of collective arrangements is that they are costly to establish and maintain, costs that may weigh particularly heavily on SMEs and non-commercial organizations, who yet may contribute significantly to the development of innovation.

From the adaptive policy viewpoint it follows that the principal task is to stimulate the formation of innovation webs and to create bridging processes within those webs which better combine and utilize knowledge to further the innovation process. These policies work in terms of the relevant communities of practitioners whether in firms, their suppliers or customers, higher education institutions or public and private research, development and design laboratories. A first policy requirement is to know this community, its institutions and the way they connect simply because it is through the community that policy effects will be channelled. A second policy requirement is to emphasise the guided nature of the growth of innovation related knowledge. Its accumulation is not random but proceeds within the constraints of cognitive frameworks which underpin the knowledge acquisition process. These cognitive frameworks provide a natural focus around which governments can stimulate network formation but they also raise the

possibility of conflicting national support policies. The degree to which national innovation policies can be and should be co-ordinated will remain an interesting question.

The final point to emphasise is the need for the relevant communities to involve the transfer sciences within the relevant innovation networks. They not only provide much of the fundamental application knowledge but also provide the bridge to the purer kinds of research in universities. Since government laboratories often have a high transfer science content to their work it is particularly important that they be open to network membership.

## **Conclusions**

I have suggested that the innovation research agenda is appropriately framed within the context of the evolutionary, experimental nature of capitalism. In this view economic activities and innovation systems co-evolve and both are shaped by instituted rules and behaviours. I have suggested a number of challenges that fit with this perspective. My central claim is the need for multi-disciplinary and comparative work which focuses upon the development of innovation processes in different firms, sectors, regions and economies. From this will follow new perspectives on innovation policy and the management of technology. The important point is to be clear on why innovation matters and it matters because it is central to the idea of restless capitalism.

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