CRIC

KNOWLEDGE OF GROWTH AND THE GROWTH OF KNOWLEDGE

J S METCALFE

CENTRE FOR RESEARCH ON INNOVATION AND COMPETITION
AND
SCHOOL OF ECONOMIC STUDIES

UNIVERSITY OF MANCHESTER

August 22nd, 2001

This is a revised version of my Presidential Address delivered at the 8th International J.A.Schumpeter Society Conference held at the University of Manchester, 28th June – 1st July 2000. It is written more or less as delivered and I hope will be read with that in mind. I thank my colleagues Ronnie Ramlogan and Sharon Hammond for help with the first draft. The Final Draft was finished during the tenure of a Visiting Professorship at the University of Queensland. I am grateful to Professor John Foster and colleagues for their comments on this draft.

THE UNIVERSITY of MANCHESTER

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

UMIST

1. Knowledge of Growth and the Growth of Knowledge

The central theme of this address is the double-sided relation between the growth of an economy and the growth of knowledge in general and practical knowledge in particular. This relation is at the core of Schumpeterian perspectives on economic transformation even though in Schumpeter's work it was subsumed within his general concept of entrepreneurship. It is equally central to modern evolutionary accounts of economic growth and to neoclassical theories of endogenous growth, although, in each case, from a quite different standpoint with regard to the nature of knowledge and the processes by which it is accumulated and directed to economic ends. I shall explore this theme with the help of a single concept, "restless capitalism" which I use to capture the idea that capitalism in equilibrium is a contradiction in terms precisely because the growth of knowledge cannot be formulated meaningfully as the outcome of a constellation of equilibrating forces. I shall begin with a discussion of how growth accounting underestimates the role of technical progress in economic growth, move on to outline the nature of growth in relation to innovation markets and institutions more generally, and then I introduce some growth theory from the 1930s that captures the relevant features of restless capitalism and economic transformation. I conclude with a discussion of innovation in relation to the growth of medical knowledge to highlight the theme of ongoing transformation and structural change.

2. Growth and Technical Progress

Modern interest in the growth-knowledge relationship dates from the development of growth accounting and the discovery that the rate of tangible capital accumulation could only account for a small proportion of measured economic expansion. The initial studies of Schmookler and Abramovitz, subsequently refined by Solow, Kendrick, Dennison and others

all pointed in the same direction. To put it in Solow's terms, measured *shifts in* the production function were far more important than *factor substitution around* a given production function as an accounting explanation of economic growth. Following these initial studies a great deal of effort has been devoted to refining measures of input and output with the purpose of eliminating as far as is possible the residual element in economic growth, and for a good reason. To the extent that the residual reflects the growth and application of a multiplicity of kinds of new knowledge then we have to admit that our understanding of it lies beyond the scope of existing methods of analysis. There is no doubt that this motivated Jorgensen and Griliches to conduct their pioneering attempts to tame the residual, effectively but wrongly, claiming that it could be reduced to a series of measurement errors. Notice though that they did not claim that the growth of knowledge was not central to the growth process, rather that its application to the economy depended on processes of investment in equipment and human skills – the so-called embodiment hypothesis. Now the attempt to shift the balance of explanatory power between "shifts in" and "movements around" an aggregate production function, is not simply an empirical problem. More fundamentally, the method of treating the two contributions as independent and additive (Nelson, 1982) is open to an obvious objection. Namely, that measured capital deepening is not necessarily an independent contributor to growth, rather it is contingent upon prior shifts in the production function, that is to say the rate of technical progress. Consequently, to deduct the capital deepening effect from measured growth in labour productivity, however measured, is to systematically underestimate the contribution of technical progress to economic growth. This is the return of a "measure of ignorance" with a vengeance, or as Usher (1980) put it so effectively, no progress means no growth. All measured growth in this view involves an alteration in input:output relationships, that is to say it requires changes in the application of knowledge broadly defined. The point is very simple and involves nothing more than

realising that the answer to the question, "How much has technical progress shifted the production function?" is not the same as the answer to the question, "How much has technical progress contributed to economic growth?". To see this, consider the conventional model of an aggregate economy in steady growth according to the stylised facts with a constant saving ratio, constant distributive shares and a constant capital:output ratio. Suspend for present purposes any deeper objections to the idea of an aggregate production function and the notion that factor prices measure marginal products.

In such a configuration it is easy to see that the rate of capital deepening is not independent of the shift in the production function. We can express this idea either in terms of the extra saving per head, which is made possible by the shift in the production function, or, if we recognise that capital goods are necessarily produced means of production, then technical progress means that a given rate of saving commands a greater effective labour force employed in the production of capital goods (Rymes, 1971). At the risk of belabouring the point let $\hat{q}$, $\hat{k}$, $\hat{A}$ be respectively the logarithmic rates of increase of output per head, capital per head, and the shift factor for the production function (technical progress), and let β be the share of capital income in total product. Then the formula

$$\hat{A} = \hat{q} - \beta\hat{k}$$

in principle is the growth accounting measure of the shift in the production function. However this shift understates the contribution of technical progress to growth. Let this be measured by $\hat{T}$ then we should write

$$\hat{T} = \hat{q} - \beta\left(\hat{k} - \hat{T}\right)$$

to reflect the fact that only that amount of capital deepening that is independent of technical progress should be given an independent explanatory role. In steady growth it follows immediately that

$$\hat{T} = \hat{q} = \hat{k}$$

and that

$$\hat{A} = (1 - \beta)\hat{T}$$

In short, all measured growth, in these conditions, is due to shifts in the production function, and the conventional residual underestimates the contribution of technical progress to economic growth. Moreover, the greater is the measured capital share in final output, the greater is the degree of understatement. The rate of growth of labour productivity is the proper measure of technical progress, as it should be when labour is the only primary factor of production. Consequently, there are grounds for claiming that the growth of knowledge is more important to economic growth than the growth accounting approach recognises. Out of steady growth, with a varying saving ratio, the story would be different but the evidence apparently does not support the idea of strong independent saving effects (Prescott, 1998).

Side by side with the development in productivity accounting, growth theorists of various persuasions had assembled a theory of economic growth but not a theory of the growth rate. Whether we take the Meade, Solow, Swann approach or that associated with Kaldor, Pasinetti and Robinson we find models of the properties of steadily growing economies, not models of

the growth rate. The determinants of the latter, population growth and Harrod-neutral technical progress, were left unexplained. It is to fill this vacuum that a range of theories of endogenous growth have been developed (Aghion and Howitt, 1999).

Schumpeterian evolutionary theories are certainly of this kind but they are fundamentally different from the theories developed by endogenous growth economists of whom I take the work of Jones (1995) as representative. What is central to his approach is the idea of a production function for ideas, in which the rate of increase in the stock of ideas is dependent upon current research effort and the existing stock of ideas. Now this is not a new approach, Machlup sketched out the principle elements of it in 1962. Put briefly, there are diminishing returns, after a point, to current research effort, with the existing stock of ideas acting as the 'fixed factor' in the knowledge production process. New ideas in the output of research change the stock of solved problems, so shifting the marginal relations between research input and the output of knowledge. Machlup suggested that this could happen in one of two broad ways, either by reducing or enhancing the research agenda that is derived from the existing stock of ideas. It is this model of knowledge accumulation that Jones deploys in his analysis, and in so doing he is right to try and capture the autocatalytic nature of knowledge accumulation. However, he does so in a way that, to my view, stands in the way of understanding the knowledge-growth relationship. In particular, he works with an aggregate stock of ideas and looks for the conditions under which this stock, and of necessity all its component elements, are growing at the same steady rate. It is this double condition, required to service the idea of equilibrium growth, that Schumpeterian and evolutionary proponents of growth will find so unacceptable as a basis for understanding capitalism as a knowledge-based economy. The steady state accumulation of knowledge is for them an idea too far.

I now want to explore this claim in a number of ways. First, in terms of the internal problems with this approach and how it hides the central element of knowledge-based growth, namely, pervasive structural change, or flux and economic transformation. Secondly, and following the theme of structural change, the dominant role of service activities in modern economies suggests that our understanding of growth should give a prominent role to innovation and knowledge accumulation in relation to services. This does not mean that we downplay manufacturing innovation but rather focus on the interaction between services and manufacturing in the process of productivity growth (Metcalfe and Miles, 2000). I will illustrate this second theme with a brief outline of a particular medical innovation, the intra-ocular lens that has transformed the delivery of ophthalmic services for cataract patients. It is through detailed comparative and historical studies of this kind that I claim we will better understand the knowledge-growth relationship.

3. The Conceptual Problems

What kinds of analytical frameworks will help to unravel the knowledge-growth relationship? It seems clear that the answer to this question will not be found in economics alone. Rather the most useful frameworks will enable effective dialogue with the work of historians, sociologists, political scientists, and management scholars, reflecting the fact that knowledge advances more rapidly when the connecting principles between a variety of perspectives are strong. However, from an economic view the relevant frameworks are likely to display several defining characteristics.

Firstly, they will encompass ongoing structural change; that is to say, they will provide explanations for the diversity of growth rates in the economy and not assume their uniformity. Equilibrium growth, every activity expanding at the same geometric rate, is a device for avoiding this most pervasive of all the stylized facts of modern growth. Growth involves transformation, transformation leads to development and capitalism in steady growth is a contradiction in terms. Whatever steady state growth theory is about it is not obviously knowledge-based capitalism. Secondly, while we can measure at the macro economic level we cannot comprehend the growth process in these terms. It is not simply the statistical truism that macro aggregates are constructed by averaging away the diversity in patterns of economic change. It is a much deeper point; aggregation hides the evolutionary process that generated the aggregates in question. Evolutionary growth processes depend on the existence of variety on the relative spread or diffusion of rival products and methods of production and these essential elements are written out of the aggregate picture. Only when the elements in an economy grow at the same rate do macro aggregates have a clear meaning, but when the micro growth rates are different the interpretation of the changes any aggregate is far more opaque. Quite what does it mean to say that measured GDP in country X is Y% higher today than 10, 20, 50 years ago, when the bundle of economic activities differs structurally and qualitatively between the various dates? Thus a knowledge-growth framework not only begins at the micro level and formulates appropriate rules for aggregation, it also explains how the composition of those aggregates changes in a systematic fashion in the course of economic development.

Thirdly, the problem of aggregation cannot be solved unless we understand the process of interaction between micro agents and this takes us directly to the problem of co-ordination

and the role of market processes. Markets are the central instituted form by which economic order and changes in order are generated within capitalism. Order produces pattern, order is not equilibrium in the sense of a state of rest from which there is no internally generated tendency to depart. In this sense equilibrium, which can only mean an equilibrium of beliefs, surely means that history has come to a stop since there cannot be internally generated reasons for beliefs to change, in equilibrium time passes but nothing happens. As Schumpeter remarked, to understand capitalism you have to understand its capacity to transform itself from within and this requires an understanding of why the economy is “far from equilibrium’ as a modern physicist might put it. In this regard knowledge is like energy it defies equilibrium by maintaining a potential for change that is ever present.

Of course, not all the relevant co-ordinating institutions fall into the market category. In relation to the production of knowledge in particular, networks and communities of practitioners and practice play very important roles. Indeed, one of the major conceptual and empirical challenges is to integrate more closely these differently instituted forms of co-ordination to explain how each is embedded in the other.

From the perspective of the growth–knowledge relation, markets take on a new light. We see them not as devices to optimally allocate given resources to given ends but as institutions to facilitate change, to permit entrepreneurship, to encourage challenges to the established order. Thus they are devices for keeping the economy ordered but out of equilibrium, they are the frameworks which shape ongoing structural change. Nor are market institutions given. They have to be established and their establishment, growth, stabilisation and decline involve the investment of real resources in market making activity. It is surely somewhat shocking that the detailed understanding of markets and their formation plays so little role in the modern theory of growth of any persuasion.

Fourthly, it is clear that a serious attempt to link growth and transformation means abandoning the device of the representative agent. Rather more accurately it involves abandoning any attempt to theorise in terms of the uniform agent. Indeed, the Marshallian notion of a representative unit of behaviour, the firm in his case, was a device for coping with economic evolution, not economic equilibrium. In evolutionary theory a representative agent need not correspond to any actual agent in the relevant population nor can its attributes be determined a priori. What is representative is the emergent outcome of the economic process not a precondition of it. What is representative depends on the manner of co-ordination of the relevant behaviours, and hence it will change with the economic process even when the

individual behaviours of the "real" agents are fixed. I need hardly mention the difficulties that arise in introducing innovation and change of knowledge into the world of the uniform agent. Again it is the macro perspective that has led us astray. For the device of the uniform agent is merely a way of having the micro conform to a prior conception of the macro.

What kinds of frameworks will help us to meet these difficulties? They will be evolutionary and adaptive simply because evolutionary theory is naturally about growth rates and is premised on the micro diversity that characterises a knowledge-based economy. They will emphasise market co-ordination as a selective process because it is through co-ordination that growth is created. Growth rates appear as emergent phenomena, that is to say, they are not intrinsic properties of agents such as firms; rather they are properties that emerge as a result of the interaction between firms in the market selection process. However, selection is not enough because, left to themselves, selection processes destroy the microdiversity in economic attributes upon which evolution depends. Variety needs to be replenished for growth and transformation to continue and this requires that development processes be given equal weight with selection processes (Foster and Metcalfe, 2001). Now, development processes are deeply connected to the growth of knowledge and by this I do not only mean the formal knowledge associated with science and technology. Practically useful knowledge cannot be so circumscribed, knowledge of organisation, knowledge of market and social knowledge of how to interact must be given due weight. Clearly these different kinds of knowledge are accumulated and diffused by very different kinds of development processes. Moreover, in so far as market experience is a key element in the growth of knowledge, this implies that the process of selection and the process of development are inseparable and mutually determining (Dosi, 1997). The competitive process depends on microdiversity and the generation of microdiversity reflects the competitive process. Change the working of

market processes and you change the way practical knowledge is accumulated. All of this puts the modus operandi of markets at the centre of the growth process while recognising that the way markets work is contingent upon wider sets of institutional factors. It is surely not an accident that many of the scholars who have contributed to the innovation systems literature are also the scholars who have developed a Schumpeterian perspective on the market process. For Schumpeter's theory of development joins innovation and markets, development and selection, in the medium of the entrepreneur; and I need not remind this audience that entrepreneurship is impossible in equilibrium.

Another aspect of this approach is that the treatment of co-ordination processes means that the demand side of the innovation process needs more attention than it has thus far received. Perhaps because of Schumpeter's view on the passivity of consumers in the innovation process we have ended with a perspective dominated by supply side considerations. However, there is a growing body of evidence, much of it from the pen of technology historians, which gives the consumer/user a very active role in shaping innovation. Not only through Lundvall's supplier–user interaction, for example, but also in the conceiving of new applications for products quite different from those conceived of by the original designers and entrepreneurs. Susan Douglas's study of the radio industry (1987) provides a fine example of this kind of influence showing how the radio evolved from a means of maritime communication to a means of mass entertainment. Thus, a knowledge-based theory of growth will emphasise the link between the micro diversity of behaviours and processes of creativity and the formulation of novelty by consumers as much as by firms. Indeed it is the continual generation of novelty on both sides of the market relationship that underpins the idea of restless capitalism and keeps capitalism "far from equilibrium". Consequently the dynamics of the growth process cannot be governed by a process of convergence to

equilibrium states, for the states of rest are continually being redefined by the accumulation of consumer and producer knowledge that occurs in the market process (Kaldor, 1954).

The technicalities of this market-based approach are, in my view, best handled by a general class of processes under the broad label of replicator dynamics. They have a potentially important property, namely that the dynamics of the process are governed by the distribution of behaviours around population averages (representative behaviours!) not by the distance of the system from some long-period attractor (Iwai, 1974; Metcalfe, 1998; Dosi, 1997). It is this feature, which corresponds to the idea of open-ended, adaptive, evolutionary development. The system evolves and in the process grows but not by chasing states of rest; so avoiding the embarrassment of multiple equilibria or equilibria that are changing more quickly than the process of convergence can accommodate to. The fundamental reason for this historical indeterminacy is to be found in the nature of knowledge and its accumulation processes. It is the characteristic of knowledge that one idea leads to another in typically unpredictable ways (Popper, 1996) reflecting the immense possibilities for the recombination of ideas and the use of ideas. It is because knowledge is used but not used up, that ideas feed inexorably on ideas, which make increasing returns in the production of ideas to be of far greater importance than increasing returns in the production of goods and services. Whether this can be encompassed in the idea of a knowledge production function I have very severe doubts. How is the stock of ideas to be defined? Is it the simple sum, the product, the union, the intersection or the combinatorial combination of individual ideas? Since ideas are not obviously commensurable, by what weights are we to combine one idea with another? If these are value weights, how are the relevant rates of exchange to be determined? Surely not by market prices. There is a very real prospect that the idea of a stock of knowledge capital will fall prey to exactly the same logical difficulties that destroyed the idea of a productive

input called aggregate capital. The specification of inventive labour will prove just as problematic for it is obviously not homogeneous as Machlup (1962) rightly insisted. The production function route is perhaps best avoided unless we are prepared to emphasise the extreme micro heterogeneity of the underlying inventive processes.

4. Alternative Foundations for the Knowledge/Growth Relationship.

If we step back to the growth economists of the 1920s and 1930s, not only Schumpeter but also scholars such as Arthur Burns, Simon Kuznets and Allyn Young, we find the beginnings of an empirically grounded non-aggregative growth theory that meets many of the requirements outlined above. These contributions were swept aside by the Keynesian revolution when growth theory went macro but they fit extremely well with our growth-knowledge perspective and with the idea of growth as transformation.

In his comprehensive review of modern economic growth Abramovitz (1989) identified structural change and a tendency towards retardation in the growth of output as two salient empirical generalisations about the process of economic growth. Structural change is, of course, a necessary reflection of diversity in the growth rates of different activities. Retardation, however, is a different phenomenon, the systematic tendency for rates of growth of specific entities or their ensemble to decline with the passage of time. To anyone brought up on the economics of uniformly expanding economies, whose structure cannot change over time and whose rate of growth is constant, neither of these propositions will have much resonance. Yet they are central to the literature to which Abramovitz is referring, in particular to the work of the two principal retardation theorists, namely A.F. Burns and S. Kuznets. Both are concerned with the measurement and explanation of secular or long time movements in the volume of economic activity. Accepting that the modern economic system is 'characterised by ceaseless change', neither could proceed with an aggregate analysis of growth nor accept the idea of uniform progress in all branches of activity.

Let us begin with A.F. Burns's detailed study of American economic growth in the period 1880-1937. Burns gathered a great deal of evidence to establish that a central feature of modern economic development is the diversity of growth rates of output across different sub-sectors and industries in the economy. What might appear to be smooth progress of production and trade in the aggregate hides a considerable diversity of experience. His list of diversity creating factors has a thoroughly modern ring to it: new commodities; new raw materials; changes in methods of production; new methods for the recovery of waste products; changes in forms of industrial organisation; increases in the number of uses of given materials and in the number of materials put to a given use; and, finally, the emergence of what he calls learning products and style goods. In sum, Burns claims that "These changes have resulted in an increasing divergence of production trends for they have served to

stimulate or depress but to an unequal extent, the development of various industries" (p. 63). Furthermore, what makes an economy progressive is not diversity *per se* but a positive skew to the distribution of growth rates . Thus the focus was on the micro diversity of industrial growth experience and what he called his "law of industrial growth", that individual growth rates are subject to retardation and ultimate decadence. That is to say, for any industry its percentage growth rate declines with time eventually becoming negative, for a given parcel of activities.

> Apparently, just as the forces making for growth of individual industries have dominated in the American system over the forces making for decline, so have the forces making for retardation in the growth of individual industries dominated in the system over the forces making for acceleration" (p.122).

This he claimed was a characteristic feature of a progressive economy, an economy in a perpetual state of flux qualitatively as well as quantitatively.

Simon Kuznets too had explored independently the same themes (1929, 1954) and from a broadly similar perspective, and he stated the problem clearly as follows,

> 'As we observe various industries within a given national economy, we see that the lead in development shifts from one branch to another. A rapidly developing industry does not retain its vigorous growth forever but slackens and is overtaken by others whose period of rapid development is beginning. Within one country we can observe a succession of different branches of activity in the vanguard of the country's economic development, and within each industry we can notice a conspicuous slackening in the rate of increase' (Kuznets, 1929/1954, p. 254).

Of course, the long secular movements of the shares of agriculture, industry and service sectors in total output provide confirmation at higher levels of aggregation of the enduring

presence of growth rate diversity and structural change. As do the shifting rural-urban balance of the population, changes in working hours and changes in the pattern of household consumption. Indeed the long swing of development must have been marked by as much change of consumption behaviour and pattern of demand as change of industry.

Alongside Burns and Kuznts equal attention should also be paid to Allyn Young (1928). His central concern was the link between productivity growth and the extension of the division of labour within and between industries. Crucially, this led him to emphasise the role of demand and how demand considerations lead to the interdependence of productivity growth rates between industries. What he didn't say, for he had no need to, was that this interdependence precludes any simple adding up of sectoral productivity growth rates to explain the economy wide rate of productivity increase

The point is that, Young along with Burns and Kuznets, articulated a theory of growth that were non-aggregative in character, that depended on the details of market co-ordination and that emphasised the dynamics of knowledge accumulation at the level of individual sectors and firms. Schumpeter surely would have found this agreeable and evolutionary growth theorists can find much of value in this literature to underpin their interest in agent- based models of growth. Perhaps there is no better way to summarise this than with Eliasson's (1990) notion of an experimentally organised economy.

5. The IOL Story: Competition and the Institution of Innovation Systems

I turn now to my final theme in this discussion of economic transformation, that of the growth of the service economy and its relative neglect by economists interested in innovation and the knowledge growth dynamic. This neglect is problematic for we all recognise the

predominant role of service production in the modern economy. If we are to make sense of the relation between knowledge and growth then the process of innovation in the service economy needs far more attention. This is a large topic (Metcalfe and Miles, 2000) and so I shall use a particular case of innovation in medicine to capture some of the main themes. I shall be brief because I want to get to the main point, which is the interaction between selection processes and development processes in relation to economic growth and the complementarities between services and manufacturing, between intangibles and artefacts.

The medical service innovation in question is the removal of cataract and the restoration of functional sight in individuals afflicted with this condition. The new service depends on a particular artefact innovation, the intra-ocular lens. The intra-ocular lens (IOL) is the solution to a pressing medical condition, age related cataracts, that affect over half the population of people over fifty – the fastest growing population cohort in the OECD countries. The traditional treatment involved removal of the cataract-damaged lens from the eye, so leaving the patient severely disabled visually. In 1949 a British clinician, Harold Ridley, set in motion a train of events that by 1980 had resolved this problem. His innovation was the insertion of a plastic lens within the eye, "where nature intended", in the place formerly occupied by the defective natural lens. What was for Ridley, and the patient, a hazardous procedure has now become a routine operation, the most frequently performed operation in the over-50s age cohort. This is not the place to dwell on the ins and outs of this fascinating case of knowledge accumulation and application (Metcalfe and James 2001). It involved hostility to the original innovation by the established ophthalmic profession and a "swarm" of following imitators in true Schumpeterian fashion. It involved extended sequences of innovation along a design trajectory, as Dosi suggested, with important complementary innovations in materials, lens design and operative technique along the way.

Moreover, not only has the treatment of patients been transformed, there is a new division of labour being created in this medical service activity. A treatment that formerly involved extended hospitalisation is now carried out on an ambulatory basis, in many settings the procedure is organised as an effective production line.

Important though these aspects are, they are not what I want to emphasise. For Ridley and his immediate followers and imitators were "hero-surgeons" working in clinical contexts, governed by the selection processes of instituted practices and resource allocation in publicly funded health services in Europe. By the 1980s the locus of innovation and development had shifted to a medical-industrial complex dominated by five or six transnational companies located in the USA. These companies, as a matter of policy, build very close working relations with the present generation of ophthalmic clinicians and fund a great deal of the R&D activity. What they have done is to have created a new kind of innovation system in the search for competitive advantage. In so doing they join together the processes of selection and development on which the growth of this particular activity depends. This takes us to an interesting perspective on the emergence and development of systems of innovation, namely that innovation systems are not natural givens, they have to be constructed and they are constructed around specific innovation problems. In the process the system and the problem co-evolve.

Here is a sketch of the argument. At the national level there are sets of knowledge accumulating, storing and transmitting capabilities, in universities, hospitals and research institutes. In medicine, these capabilities are connected by a range of informal and formal, national and international practitioner networks. However, these constellations of capabilities do not constitute an innovation system, they are at best a science system or a technological

system in Carlsson's sense (1995). To translate latent capabilities into an innovation system requires the activities of for profit firms, focussed upon specific classes of innovation problem, for example, IOL devices and surgical techniques, for a specific purpose, to gain competitive advantage in the market process. Firms play the key role in constructing an innovation system, making the connections between different actors to focus attention on the solution to problems they define, and articulating and combining together the multiple bands of knowledge required for innovation. In its combinatorial role the firm is a unique organisation within innovation systems. Thus the development system for a particular class of problems is not there naturally, it is assembled within the competitive process and competition leads to connection and connection to collaboration. It is not simply that the innovation processes are distributed across multiple agencies and actors, it is much more that they are embedded in market selection processes and that the associated very specific innovation system constitutes the external organisation of the firms. By virtue of this link with the competitive process we are dealing with rival innovation systems as fluid as the competitive processes that underpin them. Connections are made and broken as commercial advantage dictates. Such systems are certainly not monolithic, they are created, grow, stabilise and decline, and they involve, as in the IOL case, a subtle and changing interaction between public capability and private action. But that is the exactly the point, the link between competition and innovation is multi-faceted. Innovation creates diversity and diversity, in true evolutionary fashion, makes competition feasible. Competition in turn stimulates the search for innovation based advantage and in the process, we suggest, creates innovation systems from general capabilities. Thus the relation between the knowledge of growth and the growth of knowledge really is double-sided. But so then is the relation between the service and the manufacturing elements in this story, in this extended division of labour where the one ends and the other begins is not obvious. This particular service

economy is not separable from the associated manufacturing economy and neither are the associated innovation processes.

6. Conclusion

I have suggested that the Schumpeterian perspective on the knowledge growth relationship cannot usefully be treated in macroeconomic terms, that the economy is an ensemble of connected elements not an aggregate entity. Rather an emphasis on the micro diversity of behaviours and their co-ordination by market and other instituted processes is the route to understanding the knowledge-growth relation and the transformations it implies. For this reason, I have argued that capitalist economies are restless, they never are, indeed never can be in equilibrium, and they are driven at root by experiments in novelty creation. Markets and other instituted arrangements provide the connections that influence the ongoing growth of knowledge. To understand their workings requires much more than knowledge of economic relationships narrowly defined and it requires greater recognition of the dominant role of service activities in the modern economy. This is a co-disciplinary endeavour, and the frameworks we deploy must be open to the cross fertilisation of ideas. Schumpeter might, I think, have approved, he was after all as much a sociologist, as he was an economist. He warned continually of the link between progress and the break with existing instituted patterns in economy and society. Our task is neither to copy, nor to imitate but to develop this idea.

References

Abramovitz, M., 1989, Thinking About Growth, Cambridge University Press.

Aghion, P. and Howitt, P., 1999, Endogenous Growth Theory, MIT Press, Boston.

Burns, A.F., 1934, Production Trends in the United States Since 1870, NBER, New York.

Carlsson, B., 1995, Technological Systems and Economic Performance: The Case of Factory Automation, Kluwer, Dordrecht.

Dosi, G., 1997, 'Opportunities, Incentives and the Collective Pattern of Technological Change', Economic Journal, Vol. 107, pp.1530-1547.

Douglas, S., 1987, Inventing American Broadcasting 1899-1922, Johns Hopkins University Press, Baltimore.

Eliasson, G., 1990, The Knowledge Based Information Economy, Industrial Institute for Economic and Social Research, Stockholm.

Foster, J. and Metcalfe, J.S. (eds.), 2001, Frontiers of Evolutionary Economics, Edward Elgar, Cheltenham.

Iwai, K., 1974, 'Schumpeterian Dynamics Part II', Journal of Economic Behaviour and Organisation, Vol.5, pp.321-351.

Jones, C., 1995, 'R&D-based Models of Economic Growth', Journal of Political Economy, Vol.103, pp.759-804.

Kaldor, N., 1954, 'A classificatory Note on the Determinateness of Equilibrium', Review of Economic Studies, Vol.1, pp.122-136.

Kuznets, S., 1929, Secular Movements in Production and Prices, NBER, Boston.

Kuznets, S., 1954, Economic Change, Heinemann, London.

Machlup, F., 1962, 'The Supply of Inventors and Inventions' in Nelson, R. (ed.), The Rate and Direction of Inventive Activity, NBER, Princeton University Press.

Metcalfe, J.S., 1998, Evolutionary Economics and Creative Destruction, Routledge, London.

Metcalfe, J.S. and James, A., 2000, 'Emergent Innovation Systems and the Delivery of Clinical Services: the Case of Intra-Ocular Lenses', CRIC Discussion Paper, University of Manchester.

Metcalfe, J.S. and Miles, I., 2000, Innovation Systems in the Service Economy, Kluwer, Dordrecht.

Nelson, R., 1982, 'Research on Productivity Growth and Productivity Differences: Dead Ends and New Departures', Journal of Economic Literature, Vol.12, pp.1029-1064.

Popper, K.R., 1996, A World of Propensities, Thoemmes, Bristol.

Prescott, E.C., 1998, 'Needed: A Theory of Total Factor Productivity', International Economic Review, Vol. 39, pp. 525-551.

Rymes, T.K., 1971, On Concepts of Capital and Technical Change, Cambridge University Press.

Usher, D., 1980, The Measurement of Economic Growth, Blackwell, Oxford.

Young, A.A., 1928, 'Increasing Returns and Economic Progress', Economic Journal, Vol. 38, pp.527-542.