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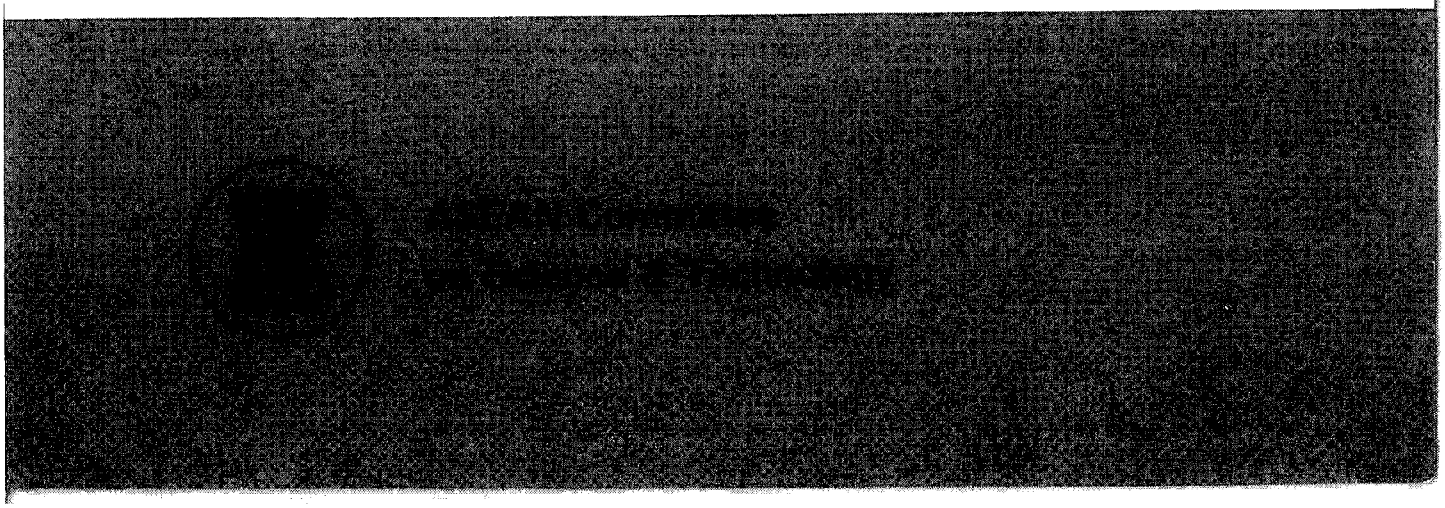

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INNOVATION THEORY: DEVELOPMENTS IN THE 1980s AND POLICY FOR THE 1990s

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ABSTRACT

The twentieth century has seen three major phases in the harnessing of science and technology for economic development: the emergence and spread of corporate R&D laboratories from the 1920s; the era of major public R&D programs in the 1950s; and the management of continuous innovation beginning in Japanese firms in the 1960s and since diffusing widely. A fourth phase is now emerging. This combines the strengths of each of these three phases but also opens new directions in the management of innovation: recognition of the evolutionary nature of technological and economic change; the rise of technology strategy as a central concern for firm level management; internationalisation of technology markets and firms; and national policies to build structural competitiveness. These changes signal the need to re-assess priorities but more importantly they indicate the need to take a fresh look at our assumptions about innovation and innovation policy.

INTRODUCTION

"[The study of innovation] is highly fragmented. It has not been adopted by any discipline as its own, and is in need of integration both with theory and other fields of study. A good deal of thought and effort is now under way to re-define and reformulate the field, through conferences and publications. A wider, more holistic appreciation is required of the phenomena involved. This requires moving beyond units of analysis such as the individual group, project or innovation to comprehend change at the level of the firm, and to encompass changes in software, services and management within the framework as well. It requires that we focus on interactions between firms and among collections of firms as our aim is to understand strategic points of leverage in the process, and it requires that we look at the changes in and interaction among variables over time."[1]

Notwithstanding these shortcomings, the theories and models of innovation have advanced significantly in the period since 1984 when Rothwell and Zegveld's *Reindustrialisation and Technology*[2] was published. A number of major features

have emerged which are indicative of the kind of shifts.

First, there has been a remarkable convergence in a variety of disciplines. In particular, the literatures concerned with management, organisation design and innovation have recognised areas of mutual interest, and valuable theoretical interaction.

Second, there has been a shift of analysis from static categories to dynamic processes. Thus the emphasis of the literature of the 1970s and early 1980s on the relative importance of, for example, "technology push" versus "demand pull" or big versus small organisations, or radical versus incremental innovations to economic development has been displaced. New forms of analysis which emphasise the *process* of innovation have emerged.

Third, the essentially scientistic or empiricist approach of the past has been moderated by the introduction of an element of historical contingency. The goal is no longer to find the one correct model or theory of innovation; rather it is now recognised that innovation is itself a historically contingent process which will vary in time and space.

The acceptance of historical contingency is connected with a fourth change, the recognition of heterogeneity in the field of innovation. Different kinds of innovation process may operate in different industries or with regard to different technologies in different nations and at different times. This has led to the need to develop a more complex picture of innovation to displace excessively simplistic general models.

Fifth, there has been an emphasis, partly linked with the convergence mentioned above, on the firm as the environment in which innovation takes place. Innovations are no longer regarded as 'black boxes' occurring in some abstract space. They are produced within organisations and the relationship between the nature and structure and values of the organisation and the innovations produced has become one of the focussing devices for analysis. A firm-centred approach also has the effect of producing information of more immediate value to policy and decision makers because an understanding of the relationship between the behaviour of an innovative firm and its environment clearly provides a basis for policy initiatives.

Sixth, a perspective is emerging that emphasises the systemic characteristics of much innovation and technical change. From this view clusters of technically linked firms (e.g., suppliers and users) and often related research institutions, constitute spheres of innovative activity within which knowledge accumulation and technological development takes place. Evolution of technologies and levels of

firm competitiveness arise as much from the structure and dynamics of these 'systems' as the capabilities and strategies of individual firms. The characteristics and ultimately the competitiveness of firms also derive substantially from wider aspects of the local technical, economic and social context. The spread and significance of new generic technologies underlines the often critical importance of "structural competitiveness".

It is interesting to speculate on what might have been the cause of these substantial changes in the study of innovation. This literature has previously been described as a loose incoherent body of unconnected empirical results in search of a purpose. It may be simply that the field is beginning to achieve a certain degree of intellectual maturity through the emergence of a number of broadly accepted theoretical concepts and tools. While this is probably true, it is also possible to argue that it is the growing importance of innovation in economic performance and in transforming the global economy that has produced a demand for better analysis. In other words, what is happening in innovation studies is a product of what is happening in the real world with the emergence and importance of technology strategy. In simple terms, innovation studies have shifted from an almost exclusively knowledge-driven activity to a market-driven activity.

The growing importance of innovation policy for governments and the central role of technology in economic growth has also led to innovation policy becoming far too important to be treated in isolation. Hence, there has been a general move to integrate knowledge of innovation with technology policy and to more effectively relate their operation with industrial and economic policies; in other words, to bring innovation into a mainstream relationship with these policies. This new relationship would appear to have had some influence on the study of the innovation process.[3]

Four thematic areas have the greatest significance within innovation theory at present. These are:

1. Technology, Firm and Industry Evolution
2. Technology and Competitive Strategy
3. Internationalisation
4. Structural Competitiveness

TECHNOLOGY, FIRM AND INDUSTRY EVOLUTION

1. Learning and innovation

There has been much emphasis on the discontinuous nature of innovation, particularly with the revival of interest in Schumpeter's theories. However, evolutionary aspects of innovation are also of great importance. Evolutionary theories of innovation emphasise the key role of learning processes at the firm and industry level.[4]

Knowledge acquisition occurs through various types of learning, ranging from formal R&D to learning-by-doing. There are complementarities between different types of learning and knowledge. The relative significance for innovation of these various types of learning varies among industries and within industries across time. In some industries, contrary to the assumptions of many policies, inhouse R&D is a minor source of the new knowledge required for innovation compared with experience-based sources. Learning of all types can contribute to the accumulation of firms' "intangible assets" — assets which are a vital source of competitive advantage, underpinning innovation, management, marketing and other capabilities.[5]

From this perspective the vital importance of managing *all* types of learning becomes clear. Indeed, more systematic and strategic approaches to the "management of learning" have become a feature of good management in leading companies.

2. Diffusion

Previous studies of diffusion have portrayed it as an essentially discrete process determined by the demand of end-users. In contrast, diffusion should be seen as the process whereby technological innovation is absorbed into the economic structure.

"It is not the initial event but rather the subsequent sequence of interrelated innovations which distinguish the important from the economically inconsequential in the realm of technological development."[6]

Furthermore, diffusion is not a passive process. The role of supply factors have been almost entirely neglected and consequently important interactions between growth in demand and growth of productive potential have been ignored.[7]

This development draws post innovation improvements more squarely into general innovation theory. Diffusion is not a process which occurs *after* innovation but an integral phase of the process of technological development.

3. Cycle Theory

Cycle theories have been the source of a powerful set of theoretical concepts for innovation theory. They provided the major theoretical framework for Rothwell and Zegveld's treatment of technology, industry and trade.

They have been applied to products technologies and industries. The essential feature is a regular life cycle with different but regular characteristics at different stages of evolution.

Particular characteristics of the different stages of the life cycle have proven to be valuable for decision makers and policy makers. The types of R&D firms perform, the sorts of institutional structures which are most appropriate, the kinds of skills, capital and marketing techniques that are needed all vary over the lifetime of the cycle.

A number of specific applications of life cycle theory have emerged. Firstly, there has been considerable emphasis on the general conditions for avoiding the transition from maturity into decline. Abernathy[8], in particular, has used the resurgence of the world motor vehicle industry, brought on by the intervention of the Japanese, as an example of the "dematuring" of an industry through which a cycle takes off into a new set of growth paths, largely through the introduction of new technology.[9,10]

The implication that emerges is that different kinds of innovation, appropriate to different phases of industry, require different kinds of organisational environments and different managerial skills. Again, the emphasis is on the heterogeneity of innovation and supporting structures, and the need for decision - and policy-makers to tailor their actions accordingly.

However, the life cycle has been shown to be not always a reliable predictor of technological evolution. Pavitt[5] has developed the concept of "characteristic sectoral technology trajectories" to capture significant variations between sectors, arguing that the patterns of innovation in an industry are strongly influenced by sources of technology, users' requirements, and means of appropriation. Three types of firm emerge from his analysis: supplier-dominated, production-intensive, and science-based. Each of these types of industries will display different characteristic life cycles, and be more or less shaped by different influences.[5]

We conclude that the integration of analyses of the various forms of learning, of diffusion and of the patterns of technological change is producing new perspectives on the evolution of technology. The development of models incorporating change at the level of the firm, the industry, and the interindustry cluster, and of the dynamics of innovation, diffusion, competition and evolution, is leading towards theories of innovation which have greater explanatory power, and subtlety, but at the price of great complexity.[11]

TECHNOLOGY AND COMPETITIVE STRATEGY

The centrality of technology as a determinant of industrial competitiveness has become a major theme of the innovation literature. The practical recognition of the key role of technology arose in large part from the transformation in the inter-

national industrial system in recent years and the emergence of new technology-based industries. As a consequence, technology has become the subject of management, and strategic planning.[1,12]

Porter has developed reasonably comprehensive frameworks for analysing the role of technology in competition and for assessing alternative technology strategies. Growing recognition of the significance of technology strategy and the utility of new analytical frameworks has led to increasing corporate demand for improved understanding of effective technology strategy formation.[13,14]

The linking of technology strategy with other elements of a competitive strategy has led to new conceptualisations of innovation, e.g., away from a technical of investment problem to one of managing organisations that transform knowledge. Pavitt[5] has characterised this shift from:

> "the tactical problems of how firms and managers can ensure that specific projects are transformed into commercially successful innovations to strategic problems of how, on the basis of their existing technological skills, they can move successfully into new product/markets and technologies."

The development of the technology strategy perspective has led to an emphasis on the wide range of complementary mechanisms that can be used to acquire technology, ranging from the traditional R&D through licensing to joint ventures. The issue of interest is to determine the most appropriate mode of technology acquisition for a firm with particular capabilities, and needs, faced with particular opportunities and competition, in a specific industry. Guidelines have begun to emerge.[15]

A key aspect of technology strategy is the management of organisational innovation - to match and support the desired technological innovation, and in itself as a major source of competitive advantage. An increasingly important form of organisational innovation is the development of links with other firms, in the form of strategic alliances or partnerships, to acquire technology or to reduce the costs and risks of new technology developments.[16,17]

The design and implementation of coherent corporate technology strategies requires major managerial and organisational innovation. The growth of multiple modes for technology acquisition, and the emerging importance of inter-firm collaboration may mark the end of an era characterised by the centralised corporate R&D lab, and the vertically integrated multinational as the ideal model of international corporate operation.

Finally, the developing field of technology strategy analysis can provide frameworks to inform planning and assessment of industry and technology policy.

INTERNATIONALISATION

Globalisation, i.e. the increasing convergence and inter-dependence of economies and markets, is a new feature of the world economy. As a result, firms (and countries) are undergoing a process of internationalisation as they become more closely linked into global markets and relationships. These trends raise new issues for firms and governments.

Strong and often opposing currents are driving these processes. The characteristics of innovation in many industries in the 1980s, based on new generic technologies, facilitate global competition but also change the nature of that competition. The financial and technological resources required to maintain competitiveness are increasing in many industries. This has produced a situation of fierce global competition along with strong cooperative networks.[18,19]

Convergence in the characteristics of national markets and falling tariff levels is also increasing the scope for global production and marketing strategies. Governments are introducing more comprehensive and substantial innovation-related programs to support the competitive performance of their industries. "Technological nationalism" coexists with inter-governmental technology cooperation programs and further market deregulation.

Multinationals are developing global competitive strategies based on the coordination of dispersed plants and the location of value activities (e.g. R&D, manufacturing, marketing) where synergies and activity-specific comparative advantage is greatest. The recent surge in the formation of international inter-firm cooperative agreements is stimulated by these currents of change.

The dynamics of globalisation of trade and internationalisation of firms are so new that they are only poorly understood. At the same time the speed of their advance is such that firms and governments have to take urgent action.

These processes represent a considerable threat to the firms and economies of small industrialised nations. The speed, the cost, and the breadth of infrastructure associated with the new generic technologies may be beyond the resources of small countries. Competitive strengths based on niche positions in technology intensive industries also appear to be under increasing challenge. Hence the need for selectivity and concentration of resources is even greater.

On the other hand, strategic alliances with foreign firms, suitably selected

and managed, could provide a means for even relatively small Australian firms to operate internationally - indeed it may often be the only possible mechanism. The development of better understanding, and management experience, of international operations and negotiations and management of collaborative agreements, would appear an urgent priority.

STRUCTURAL COMPETITIVENESS

The significance for firm-level competitiveness of the national S&T infrastructure, the structure of the domestic industrial sector and the size and structure of local market demand, has been a perennial issue in policy-oriented innovation studies. Throughout their book, Rothwell and Zegveld emphasise the role of public policy with regard to the externalities and constraints that affect firm performance.

What is important in recent studies is that they draw on a deeper understanding of the systemic aspects of innovation dynamics and relate these to the characteristics of generic technologies. In the current phase of technological and related economic and social change the issue of structural competitiveness is a central concern for policy.

The starting point for recent important studies by Ergas[19] and Chesnais[20] is essentially the simple question:

Why do some countries innovate more than others?

The mastery of core generic technologies and rapid diffusion throughout industry of related technologies and skills is acknowledged as vital for international competitiveness. But in addition to the dynamism of domestic firms, structural factors such as the efficiency of the national economy, the flexibility of industrial structure, the rate and pattern of capital investment, and the level of technical infrastructure are important.

Three key structural factors have been identified: university-industry links, customer-supplier links, and the size and dynamism of domestic firms.

Chesnais[20] concludes:

"It is probably quite as erroneous and misleading for policy-makers to equate R&D with innovative capacity as it is to equate competitiveness of most industries in advanced industrial countries with wage costs. The finding that the technical competitiveness of firms and industries...are dependent on the structural attributes of firms' environment implies that...measures aimed at promoting innovation are unlikely to have a significant lasting effect in

isolation. Identifying the major points in firms' environment which impede or promote their capacity and readiness to innovate should be a key step in formulating national technology policy."

This discussion of the structural bases of competitiveness highlights implications which are complementary but at the same time potentially conflicting viz the need for adjustment, i.e. incremental adaptation and the need for transformation or discontinuous change.

A focus on adjustment leads to an emphasis on the issues raised above: new generic technologies, the importance of learning strategies, the significance of the rate of diffusion of new technologies and practices, the necessity of corporate technology strategies, and the challenges of internationalisation. The appropriate role of government is in the removal of barriers and the promotion of change.

The need for transformation arises from a recognition of the limited role of market forces in generating or signalling clearly requirements for major structural changes. This points to a much wider role for government, in integrating technology and industry policy with policies for education, employment, industrial relations, taxation, etc, and coordinating public and private planning and investment.

CONCLUSIONS

In the period since the publication of Rothwell and Zegveld's landmark book, innovation has become recognised as essential for a firm to establish and maintain a competitive position. Indeed, successful firms are marked by the central place of innovation within their strategies, their commitment to obtaining appropriate knowledge and "learning" by a wide variety of mechanisms, and by their emphasis on an international basis for the strategies and operations.

Likewise, successful internationally competitive nations are those that have developed a range of effective mechanisms which integrate innovation and technology policy with industrial and economic policy to encourage and support the industrial sector to establish long-term planning, to invest in knowledge acquisition and application, and to generate the structural features which underline an internationally competitive capacity.

The analysis and understanding of these dramatic changes inevitably lags behind the frontier of operations and decisions. Nevertheless, more comprehensive and robust conceptual frameworks have been developed that integrate previous fragmented studies, address issues that concern decision-makers in government and industry, and are clearly of value in analysing and interpreting technological and

economic change.

However, the speed of change in both the nature and importance of innovation, and of our knowledge about it, is not yet reflected in many decisions and policies. Indeed, drawing on our detailed knowledge of policy-making by governments and decisions in firms, we are able to claim that there is a legacy of assumptions drawn from previous experience and research, which are now inappropriate, misleading and out of date.

These are assumptions such as:

- innovation derives from scientific developments;
- close links between science/basic research and industry will promote innovation;
- publicly funded research organisations should focus on fundamental research whilst industry focuses on applied research;
- an ideal model of a research organisation-industry relationship would involve inventions being transferred to industry for commercialisation;
- firms generate innovations from R&D;
- innovation involves new technical products or processes;
- innovations are novel events producing new technologies that then diffuse to non-innovators;
- technology transfer is a substitute for in-house R&D;
- firms and industries invest and purchase or develop new technology through rational responses to market signals;
- multinational firms base location decisions on factor costs and tariff structures in different national markets;
- non-equity, non-market strategic cooperative relationships between firms (and particularly between competitors) are either a product of collusion or aberrations that either cannot or should not survive;
- mature industries will increasingly be located in industrialising economies which will have comparative advantages due to low labour costs;
- the competitive advantages derived from an innovation will be rapidly eroded due to imitation unless protected by property rights;
- in the early phase of an industry cycle process innovation is of little competitive significance;

- public innovation policy instruments are or should be applicable across industry;
- government innovation policy is concerned with the supply of innovation inputs and the maintenance of the macro-economy in order to sustain business confidence.

Each of these assumptions, as we have demonstrated in the earlier analysis, is no longer valid.

1. New Perspectives on Innovation Theory

The emerging new perspectives on innovation depart radically from many older views. The new approaches incorporate most of the previous elements, but rearrange and develop them to give a very different overall picture. Key aspects of this new picture include such perspectives as:

- the sources of innovation vary across industries and time - there is no general model;
- there is no ideal model of a science-technology or of research organisation-industry relationship;
- innovation is centrally an organisational and managerial issue and this is the context in which it should be understood;
- technology strategy involves the management of all forms of knowledge acquisition and the development of organisational structure and culture, and a variety of inter-organisational links;
- knowledge acquisition for innovation involves processes ranging from in-house R&D to learning-by-doing and relationships ranging from autarky to close collaboration with competitors;
- innovation is increasingly systemic due to inter-technology, inter-firm, inter-industry and international relationships;
- socio-cultural paradigms interact with all aspects of the innovation process and these links are vital for understanding the rate and direction of innovation;
- organisational and managerial innovations are as vital as technical innovation;
- major and incremental innovations are complementary processes in the evolution and diffusion of new technologies along trajectories and within paradigms;

- innovation, diffusion, investment and competition are closely related and cannot usefully be analysed or managed separately;
- there is no general pattern of technological development – the key characteristics of innovation vary more or less systematically among sectors;
- the process of adjustment by firms to major discontinuity in the external environment is often neither smooth, rational nor guided by market signals;
- the international competitiveness of firms arises less from the comparative advantage of economies than from firm-specific competitiveness and from the structural competitiveness of its host or home economy;
- a framework for innovation policy would encompass the bases of structural competitiveness, access to complementary assets required to capture the benefits of innovations and the organisational mechanisms required to design and implement policy instruments – intervention across this spectrum is increasingly the norm rather than the exception;
- the boundaries of firms, industries and national economies are blurring, creating new challenges for managers and policy-makers (and researchers and statisticians);
- the design of innovation policy will increasingly draw on a close familiarity with the global and local industrial context, insights from innovation theory and the assessment of past policy experiments - rather than rest on secure theoretical foundations;
- small countries are not 'little' big countries.

Interpreting and learning all these lessons will not be easy, or achieved overnight. But there is a need for policy-makers, indeed for all people who make decision about industrial development, to evaluate their assumptions, decision-making procedures and policies to see if they rely on inappropriate models, and where appropriate to develop quite new approaches which reflect the changed nature, importance and knowledge of innovation.

REFERENCES

1. Utterback, J.M. Innovation and Corporate Strategy. *Intern. J. Technol. Management,* 1986, **1** (1/2). 119 – 132.
2. Rothwell, R. and Zegveld, W. *Reindustrialisation and Technology.* Longman, Harlow, 1984.
3. Scott-Kemmis, D., Darling, T. and Johnston, R. *Innovation for the 1990s; New Challenges for Technology Policy and Strategy.* Australian Department

of Industry, Technology and Commerce, Canberra, 1988.

4. Dutton, J.M. and Thomas, A. Relating Technological Change and Learning by Doing. In Rosenbloom R.S., (ed.) (1983). *Res. Technological Innovation, Management and Policy, Vol. 1,* Jai Press Inc., Greenwich, Conn. 1985.

5. Pavitt, K. Technology, Innovation and Strategic Management. In McGhee, J. and H. Thomas (eds.) *Strategic Management Research,* Wile, New York, 1986.

7. Georghiou, L. Metcalfe, L.S. Gibbons, M., Ray, T. and Evans, J. *Post Innovation Performance ,* MacMillan, London, 1986.

7. Dosi, G. *Sources and Microeconomic Effects of Innovation: An Assessment of Recent Findings.* SPRU, Sussex, 1986. (mimeo)

8. Abernathy, W.J. *Industrial Renaissance: Producing a Competitive Future for America.* Basic Books, New York, 1983.

9. Abernathy, W.J. and Clark, K.B. Innovation: Mapping the Winds of Creative Destruction. *Res. Management. 1985,* **14**(1), 3 – 22.

10. Clark, P.A. *Sector-technology Life Cycle (STLC) Models and Innovation Capabilities; Rover SD1 and Volvo, Kalmar.* ESRC, Work Organisation Research Centre, Aston University, Aston, 1987.

11. Perez, C. Structural Change and the Assimilation of New Technologies in the Economic and Social Systems. *Futures, Oct. 1983. 357 – 375.*

12. Rosenbloom, R. (ed.) Research on Technological Innovation, Management and Policy, Vol. 1. Jai Press Inc., Greenwich, Conn., 1983.

13. Porter, M.E. *Competitive Advantage.* Free Press, New York, 1985.

14. Porter, M.E. (ed.). *Competition in Global Industries.* Harvard Business School Press, Boston, 1986.

15. Friar, J. and Horwitch, M. The Emergence of Technology Strategy: A New Dimension of Strategic Management. *Technol. Society,* 1985, **7**, 143 – 178.

16. McGhee, J. and Thomas, H. (eds.). *Strategic Management Research.* Wiley, New York, 1987.

17. Porter, M.E: The Technological Dimension of Competitive Strategy. In Rosenbloom, R.S. (ed.) *Research on Technological Innovation, Management and Policy, Vol. 1,* Jai Press Inc., Greenwich, Conn., 1983.

18. Fusfeld, H.I. and Haklisch, C.S. Collaborative Industrial Research in the US. *Technovation,* 1987, **5**, 305 – 315.

19. Ergas, H. *Why Do Some Countries Innovate More Than Others?* Centre for European Policy Studies, Brussels, 1984.

20. Chesnais, F. Science, Technology and Competitiveness. *STI Rev.* 1986, **1** 85 – 129.