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TIK WORKING PAPERS on Innovation Studies

No. 20110926

http://ideas.repec.org/s/tik/inowpp.html

Senter for teknologi, innovasjon og kultur
Universitetet i Oslo

Christopher Freeman: Social Science Entrepreneur

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Abstract

This paper focuses on Christopher Freeman's contributions to the field of innovation studies. First, we consider his role as the creator of various organisational and intellectual frameworks crucial for the field's development, including the main research activities he initiated. Next, we examine the publications by Freeman that these activities led to. A database of surveys of the innovation literature, assembled from articles in handbooks covering this area, is used to identify the most influential of his writings for this field. In addition, citations to these works in scholarly journals are analysed in order to examine the nature and extent of his influence on other scholars. The final section sums up the evidence regarding Freeman's influence on the field's development . A list of Freeman's scholarly works is included as an appendix.

Keywords: Freeman, innovation studies, SPRU, economics of innovation, innovation systems

1. Introduction

The emergence of innovation studies as a problem-oriented, cross-disciplinary field within the social sciences dates back to the early post-war period when researchers within economics, management and sociology started to be interested in the economic and social aspects of innovation and diffusion of technology. This interest was fuelled by the increasing attention given to science and technology by policy makers, especially in the USA but also elsewhere, during and after the Second World War.[1] How to get the most out of the resources devoted to science and technology emerged as an important policy problem, the solution of which seemed (at least to scholars) to depend on robust knowledge about the working of the science and technology system and its interactions with the economy and society. The view that a proper understanding of this problem required insights from several disciplines, not just one, caught on, and from the 1960s onwards several new cross-disciplinary research centers focusing on these topics were formed in the UK and elsewhere. Gradually, an infrastructure adapted to the needs of this type of research, consisting of conferences, journals and sources of relevant statistics, came into existence, and a common body of knowledge, often codified in the form of so-called 'handbooks', began to emerge.

The development a new scientific field is the result of activities of many devoted individuals within a variety of organisational contexts. However, some entrepreneurial individuals may have a disproportionally large influence on subsequent developments, for example by providing organisational frameworks or theoretical inspiration for future research activities. Freeman did both. He was the first Director of SPRU (1966), one of the very first cross-disciplinary research institutions in the field, which during his 15-year directorship developed into a global hub for research in this area. Freeman was also the founding editor of Research Policy (1971), one of the oldest and best known journals in the field, and he was the author of an early and highly influential synthesis of our knowledge about innovation and its role in society (Freeman, 1974). Hence Freeman clearly influenced the development of what today is a thriving cross-disciplinary field comprising several thousand researchers worldwide (Fagerberg and Verspagen, 2009).

This paper focuses on Freeman's contribution to the innovation studies field in some detail. In the next section we discuss his role as an entrepreneur, organizer and source of inspiration, and in particular as a provider of organisational and intellectual frameworks for the field's development. Then, in the third section, the publications by Freeman that these activities led to are examined. A

[1] For a discussion of pre Second World War attempts to approach this issue, particularly in the USA, see Godin (2006). These early attempts were, as Godin shows, to a large extent fueled by the perceived need for reliable statistics on the subject.

database of surveys of the innovation literature, assembled from articles in handbooks surveying this area, is used to identify the most influential of his writings for this field. Moreover, citations to these works in scholarly journals are analysed to illustrate the influence of his scholarship in the world of research more generally. The final section summarises the evidence regarding Freeman's influence on the field's development .

2. Freeman the entrepreneur

The importance of human agency for the emergence of new economic and social activities is a central theme in social science, and the notion 'entrepreneurship' is often used in connection with it. For the innovation theorist, Josef Schumpeter, an entrepreneur was somebody who had the willingness and ability to try new ideas out in practice in spite of the (often stiff) opposition from a resistant environment. An entrepreneur may also be seen as somebody who actively seeks and exploits opportunities as they emerge (Kirzner, 1973). Freeman was, as we shall see below, an entrepreneur in both senses of the word. In this, he was motivated by a vision of the role of science and technology for social and economic change that he formed early in life, and which gradually developed into an original and novel agenda for policy-related research on this issue. It took some time before he got the chance to transform this agenda into practice, but when the opportunity arose he was quick to grasp it.

The shaping of an agenda

As a young man Freeman had been exposed to Marx's evolutionary perspective on capitalist development, and this came to have a lasting impression on his understanding of social, economic and institutional change. Marx had analysed capitalism as a dynamic system characterized by continuous interaction between capital accumulation, technological progress and social and institutional conditions, and Freeman was strongly influenced by this perspective, as many others had been before him. Yet although Marx characterized capitalism as a historically progressive system, he also held that its social and institutional conditions needed to be radically changed (or revolutionized) if society was to reap the full benefits of potential technological progress, a view that many in the crisis-ridden Western societies of the 1930s came to sympathize with. However, like many of his generation, Freeman eventually became disillusioned with the attempts to engineer such

radical changes in the Soviet Union and elsewhere,[2] and decided to focus on how one might get the most out of technological progress here and now through appropriately shaped policy and management.

Around the time of the 2nd World War Freeman, studied at the London School of Economics (only interrupted by war service). He was, however, dissatisfied with the kind of economics that was taught there, which he saw as overly static in character (in contrast to Marx' dynamic approach) and totally deficient when it came to analysing technological progress and its relationship with science, an aspect that Freeman considered to be of increasing importance economically and politically. On the latter, he was influenced by the natural scientist and writer, J. D. Bernal, a devoted Marxist, who at the time gave extracurricular courses which Freeman attended. Bernal was a strong believer in the potential of scientific research, not only in universities but also in industry, to promote the welfare of mankind (Bernal, 1939). He argued that radically increasing the amount of research might benefit society enormously provided this was matched by appropriate policies and management. To support his argument, Bernal also provided an empirical estimate of the (rather modest) amount of resources devoted to this in the UK at the time. Freeman found this line of inquiry particularly inspiring. In a later[3] paper, he pointed out:

"Bernal went beyond Schumpeter and Marx in his perception of the extent to which the R&D function had become professionalised and internalised within both industry and government. (…) Bernal's principal contribution to economics and the other social sciences was his clear perception that the allocation of resources to the various branches of organised R&D and related scientific services and their efficient management had become crucial for the development and performance of nations and enterprises. " (Freeman, 1992 p. 5)

Despite his admiration for Bernal, Freeman realized that any analysis of the contribution from science and technology to economic progress would be deficient without a thorough understanding of what drives technological activities in firms, something that he felt was missing both in Bernal's work and in the kind of economics he was taught while attending university. There was, however,

[2] Freeman had joined the British Communist Party but broke with it after the invasion of Hungary in 1956. In a talk delivered at a conference organized in connection with his 80th birthday in September 2001, he strongly regretted that he had not fully realized the repressive nature of Stalinism at an earlier stage.

[3] Unlike the other papers in the collection of essays "The Economics of Hope" from 1992, this (first) chapter is not dated. On the manuscript that went to print, however, it indicates that it was revised in 1985.

another perspective, associated with the works of Marx and Schumpeter,[4] that he found more helpful in this regard. In *Capital*, Marx had put forward the theory that the driving force behind capitalist development was technological competition between firms and, as is well known, Schumpeter later made this the cornerstone of his theory (see, e.g. Andersen, 2009; Fagerberg, 2003; McCraw, 2007). Largely through the influence of Schumpeter's works, it also came to be adopted by other researchers looking at the relationships between technology, growth and trade (e.g. Posner, 1961; Hufbauer, 1966)[5] at about the time that Freeman was embarking on a research career. This so-called 'neotechnology' literature, focusing among other things on technological competition between firms and the resulting 'technology gaps' in the global economy (and the impact on trade), came to serve as an important source of inspiration for Freeman's work on these issues from the early 1960s onwards.

Freeman's vision was based on Marx's and Schumpeter's dynamic evolutionary outlook, with capitalist firms at the centre. However, he strongly felt that their analyses, largely for reasons to do with changes in the economy (and society) since their times, had failed to properly take into account the role of R&D at the level of the firm and in society more generally, as well as their interactions (Freeman, 1968b, 1974, 1992). This – and the policy issues arising from it – is what he set out to address. In so doing, he was particularly inspired by Bernal's pioneering work, which had not only highlighted the social and economic importance of these issues but also, crucially, indicated how they might be explored through empirical research.

Seizing the opportunity

It would take a decade from the completion of his studies at LSE before Freeman got the opportunity to pursue his research interests professionally, which happened when he was offered a job in 1959 as a researcher at the National Institute of Economic and Social Research in London. There he carried out pioneering work on R&D statistics, first for the Federation of British Industries (FBI) and then as a

[4] Rosenberg (1986) discusses the relationship between Marx's and Schumpeter's works (see also Fagerberg, 2003).

[5] Freeman repeatedly cited two early contributors to this literature, Michael Posner and Gary Hufbauer, and he frequently acknowledged them as important sources of inspiration (see e.g. Freeman, 1977a). Hufbauer has in private correspondence given the following evidence of Schumpeter's influence on his own work: "I was an undergraduate at Harvard College in the late 1950s, not quite a decade after his death in 1950. Schumpeter's ideas were a powerful influence on economists at Harvard in those days. Undergraduates all read Capitalism, Socialism and Democracy (…) for sure, Schumpeter was the one who inspired me to think about the interaction between technological change and international trade, and to turn these thoughts into a thesis when I went to Cambridge University for graduate work." (Email from Gary Hufbauer, October 23, 2010) Michael Posner also acknowledged Schumpeter's influence on his approach (Posner, 1961).

consultant to the OECD, resulting among other things in the first internationally agreed manual on how to collect such statistics (the so-called 'Frascati Manual' – OECD, 1962) and several comparative cross-country analyses based on this new source of information (Freeman, 1962; Freeman and Young, 1965). In an interview in 2003, Freeman described how he came to work on these issues:

"The FBI (…) came to NIESR and they said, "Have you got anyone who could work on research and development?", and the NIESR, which was quite a big organization – they had about 30 or 40 people – sent around a letter saying the FBI wants to have someone seconded to them for six months to work on definitions of R&D and measurement of R&D in British industry. I was the only one who volunteered; I said yes, I'd like to do that, so they said okay. So I went and did the measurement of R&D in British industry."

Hence, although Freeman did not create the opportunity, he was quick to grasp it when it finally occurred, which in many ways is the essence of an entrepreneurial attitude. This, in turn, created the springboard for further work along the same lines at an international scale, as Freeman explained:

"And because I had done that, the OECD hired me. (…) At that time there weren't many economists who worked on research and development, I was one of the few, so they sent me an urgent message to come to a meeting about definitions of research and development. So I went, and got dragged in to write a manual for the OECD, the so-called Frascati Manual. So that's how I got the connection with OECD… ." [6] [7]

While at NIESR, Freeman also embarked on a series of ambitious, in-depth studies of how technological gaps between countries in selected industries (plastics, electronic capital goods, chemical plants) might be explained, and what advice could possibly be made to policy-makers in the UK based on his findings (Freeman, 1965, 1968a; Freeman et al., 1963). However, at the time of publication of the first of these studies in 1963, new opportunities were about to arise that would come to influence the rest of his life.

[6] From an unpublished interview with Freeman conducted by Naubahar Sharif on 24 October 2003 (slightly edited and shortened by Jan Fagerberg).

[7] Alexendar King, the head of the new OECD Directorate of Scientific Affairs, notes in his autobiography : "One of the new directorate's first moves was therefore the formation of a unit for R&D measurement. I enlisted the leading pioneer in the field, Christopher Freeman, as consultant" (King 2006, p. 241).

"The coming of a new academic discipline"

This prediction - or perhaps more an expression of hope - comes not from Freeman but from the philosopher and historian of science, Stephen Toulmin, who in the journal *New Scientist* (7 November 1963) wrote about the need to set up a new research centre within the British university system on science policy. Toulmin had lobbied for this idea in various contexts for some time and had managed to attract the attention of the leadership of the newly established University of Sussex, which was relatively open to new initiatives and had a very positive attitude to cross-disciplinarity across the natural and social sciences, particularly in teaching (Blin-Stoyle, 1986). A conference with participants from the university and various other interested parties was held at the University of Sussex (on 9 November 1963) to discuss the idea and among those attending was Freeman (on Toulmin's invitation). Although the suggestion to set up a centre attracted broad support at the conference, strong "reservation about any idea that research in this area might be regarded as constituting 'a new discipline' – a 'science of science' " was also expressed.[8] So the issue was clearly a contentious one from the very start.

According to the recollection of Freeman and others,[9] the natural scientists at the university were "mostly sympathetic" to the suggestion of such a centre, while some social scientists were "more lukewarm" to the idea. In the event, the leadership of the University, despite initial expressions of interest, was reluctant to commit much of its own resources to the new venture, and made its support for Toulmin's plan conditional on the attraction of significant external finance. An ambitious research plan for the new centre was prepared, involving not only Toulmin but also Freeman, Geoff Oldham and others, focusing on science and science policy, the application of science to industrial innovation (Freeman's part) and the development of science and science policy in other parts of the world, and funding was sought from the British Government's Department of Scientific and Industrial Research (DSIR), a forerunner of the research councils.[10] However, the amount of economic support the DSIR was willing to give was far below Toulmin's and the University's expectations. When Toulmin by mid 1964 realized that he would not be able to raise the support, financially and otherwise, that he considered necessary for the new venture to succeed, he decided to abort the initiative and to accept a job-offer at a US university.

[8] Cited from Toulmin's report from the conference (University of Sussex archives).

[9] Jackie Fuller's notes from a conversation between Freeman, Oldham and Fuller, the three first employees of SPRU (26 June 2006).

[10] The DSIR was a government department with responsibilities for research from 1915 to 1965. It was formed during World War I with the aim of enhancing scientific and industrial research through government funding.

This was a major blow to the idea, but the university leadership, and especially the Pro-Vice Chancellor for Planning, the historian Asa Briggs, did not completely give up. After some time they contacted Freeman to find out if he was willing to come on more modest terms than those anticipated by Toulmin. In Freeman's own words:

"About six months later Asa Briggs rang me up and said, "Was I still interested in the idea, and if so, would I come?" (…) And I said yes, I would come more or less on any terms. And I was very interested in the idea, but I would like to have two colleagues coming with me, one of whom would be Jackie Fuller, who was working with me already in the National Institute of Economic and Social Research on various projects I was doing on technical change, and the other was a colleague I'd met at the OECD, Geoff Oldham, a physicist, who was extremely interested in Third World science and technology and in the development of science in China. So I said, if it were possible for the three of us to come, then I would very much like to come to Sussex. "[11]

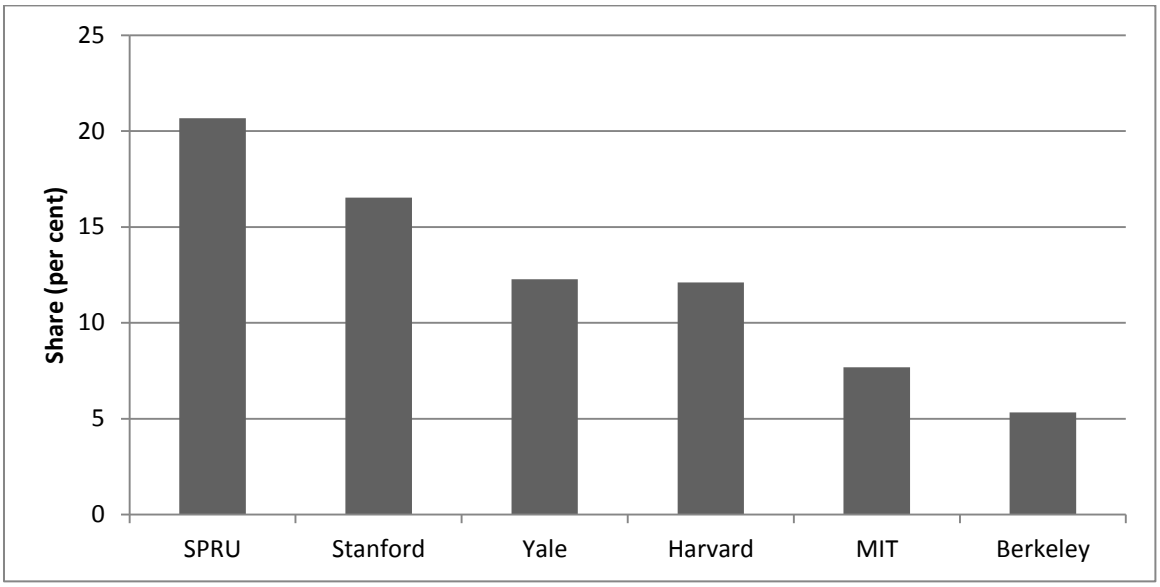
Putting ideas to work

The Unit for the Study of Science Policy, as it was initially called, was established in 1966 at the University of Sussex with Freeman as the Director. He was, however, unhappy with the name (not least because it did not lend itself easily to a good acronym), so he obtained the university's consent to change it to Science Policy Research Unit (with the acronym SPRU). After one year of operation the unit already had a research staff of nine and, when Freeman stepped down as Director fifteen years later, the number of research staff had increased to approximately fifty. Most of this expansion was externally financed, through grants from research councils and private foundations in particular, while the share of university finance was only fifteen percent on average during these years. Around forty per cent of the research staff had a background in natural sciences or engineering (some in combination with other subjects). Among the remainder, economics was the most common background (sometimes in combination with other subjects) among the SPRU staff, but a sprinkling of other social sciences and the humanities were also present, for example, history, psychology, political science, law, sociology and anthropology. Hence, under Freeman's directorship SPRU became a highly cross-disciplinary research environment and, as illustrated in Figure 1[12], an internationally leading institution within the emerging field of innovation studies.

[11] Excerpt (slightly shortened and edited by Jan Fagerberg) from an unpublished interview with Aldo Geuna in 1999.

[12] The figure illustrates the shares of the most productive research institutions in contributing to the core literature in innovation studies (as defined in Fagerberg et al., 2011) through studies published between 1970 and 1989. The source of the data is references in chapters in handbooks surveying the literature in this area

Figure 1. Innovation Studies: Share of leading research institutions (percent) in the production of core knowledge in the field, 1970-1989



Source: Fagerberg et al. (2011)

Text Box 1: Visitors to SPRU

Under Freeman's directorship SPRU rapidly became a global hub for the study of science, technology and innovation policy, attracting a large number of visiting fellows. Between 1971 and 1975 SPRU had more than twenty visiting fellows every year, many of whom came from countries in the process of development. They returned full of inspiration and ideas for how to do things differently at home.

Probably the first of these visiting fellows was Ergun Türkcan from TÜBİTAK, the Turkish research council, who came during the very first year of SPRU's existence (1966-1967). Türkcan remembers being warmly received by Freeman and the other members of the then small SPRU staff, stacked together in a few rooms in Lancaster House at the Sussex University campus. Freeman advised him to read Schumpeter and some of his own work on R&D published by the OECD, and invited him to take part in a conference organized by UNCTAD on the transfer of technology, which resulted in a joint paper with Freeman and Oldham. This, Türkcan notes, came to have a lasting influence on the direction of his life. He returned to Sussex several times after that, amongst other things to do work on his PhD. His most recent visit was in 2003 when he came to present to his mentor with the

(see section 3 of this paper). The share of an institution reflects the number of publications included in the core literature by authors affiliated with that institution (at the time of publication) and how often these publications are cited by the handbook chapters. In the case of multiple authorship (and different affiliations) the data are fractionalized.

recently published Turkish edition of the *Economics of Industrial Innovation*, of which he was the translator.

Source: http://www.freemanchris.org/ and email from Ergun Türkcan January 13, 2011.

What was Freeman's role in all this? It goes without saying that the director of a research institution that depends largely on external finance from a variety of sources has a crucial role in developing a research portfolio that both leads to first class research in its chosen field and attracts sufficient external financial support. This is a challenging task requiring intellectual leadership, entrepreneurial drive and the ability to work closely with a variety of actors. However, when strong research groups with well developed networks and relationships with external funders have become firmly established, the task may be easier to manage. Thus, Freeman's influence was probably most decisive in the early years, during which the profile of the organisation and the principles behind its operation was shaped, its networks and relationships to funders established, and the principal recruitments made.

In fact, Freeman had already contributed significantly to the developments of SPRU's profile well before the organisation was established, by persuading the original 'inventor' of the idea, Stephen Toulmin, to include elements not originally envisaged, such as a strong focus on R&D and innovation in industry, and interactions between industry, other knowledge providers and government. In its very first annual report, the Unit's purpose was described as contributing *"to a deeper understanding of the complex social process of research, invention, development and innovation. It aims to study this process in industry and in government, as well as in universities, and in the context of the environment in developing countries, as well as in industrial societies"* (SPRU, 1967 p. 5). Hence, the elements that Freeman had originally contributed as part of a broader programme now became the very foundations of SPRU's activities. Although the unit in some sense continued to be concerned with science and policy challenges arising in connection with that, Freeman's ideas clearly went much beyond what was commonly regarded as the typical issues of concern for research in this area. This is likely to have led to some confusion with regard to terminology because already in the annual report for 1971 Freeman found it necessary to emphasize that the unit used the term 'science policy' as a convenient shorthand for 'Science and Technology Policy'. This is followed by a mission statement, which states that:

"The Unit's central interest is in policy for the professional research and development network and the way in which this social subsystem interacts with society as a whole. This interest includes both technological innovation arising from R&D, and the narrower concept of 'science' as fundamental research. It extends to the diffusion process of innovations in social systems. From this it is clear that

the work of the unit is problem-oriented rather than discipline-oriented. Since the object of investigation is a social system, the Unit employs social scientists of various kinds in its research. But since the particular R&D sub-system consists largely of scientists and technologists, the Unit takes the view that direct collaboration with natural scientists and technologists is necessary for good work in the field. It also believes that collaboration between natural and social scientists can be fruitful in terms of method and cross-fertilisation of ideas. The Unit is therefore in principle a multidisciplinary group and wherever possible tries to deploy mixed teams on projects." [13]

This statement is noteworthy in several senses. First, it contains, albeit in a condensed form, a system perspective on R&D and innovation, an idea that Freeman would come to pursue in various ways during the decades that followed. The "professional R&D network" is seen as a system in its own right, characterized (as systems are) by actors and activities that are linked in various ways, but also as part of a broader social system (which uses its services) and which therefore also needs to be studied to adequately understand what is going on. Second, and related to this, it recognizes that the analysis cannot be limited to the creation of new ideas, products and so on but needs to include the use of these in the social and economic system, i.e. the diffusion process, something that Freeman increasingly would come to focus on in later work. Third, the need for cross-disciplinarity in researching these issues is strongly emphasized, something that was also followed up in practice, as the ratio of SPRU research staff across natural and social sciences during these years was close to fifty-fifty.

Arguably, the ambitions signalled in this programmatic statement not only characterise Freeman's own intentions, SPRU under his directorship or the research in which he himself took part; they also became characteristics of the cross-disciplinary field of 'innovation studies' as it evolved in the decades that followed. In many ways, SPRU as it was under Freeman's directorship became a role model for the many new centers and departments within this area that emerged over following decades. Freeman provided advice and actively supported many of these initiatives. After he stepped down as Director of SPRU and had more freedom for travelling and stays abroad, he visited several of them for shorter or longer periods, the most long-lasting affiliations being with the IKE group in Aalborg (led by Bengt Åke Lundvall) and MERIT in Maastricht (started in 1988 by Freeman's former co-worker at SPRU, Luc Soete).[14]

[13] SPRU (1971 p. 6).

[14] On Freeman's involvement in MERIT from 1988 onwards, see Soete and Verspagen (2010).

Projects

As director of an organization whose main source of income was externally financed research projects, Freeman was involved in numerous projects in one way or another, and it is beyond the scope of this paper to cover all aspects of this activity. There are, however, a few larger projects from his SPRU years that deserve mentioning here because Freeman played a central role in initiating them, carrying them out and writing up the results.[15] In fact, as the discussion will show, there is a very close relationship between these projects and what was to become his most influential published works. Although many people took part in these activities (as Freeman would have been the first to point out), our emphasis here is on his contributions.

One of SPRU's first large projects in which Freeman took an active part was 'Project SAPPHO', [16] which focused on the reasons for success and failure in innovation (Rothwell et al., 1974; SPRU, 1972). The project employed a highly multidisciplinary research team, including chemists, physicists, engineers, economists and historians. Initially expected to take three years, the project went through several phases, and in the end lasted almost a decade (from 1967 to 1976). Freeman, commenting on the project, pointed out that while there had been some previous research on successful innovation, failures had received little attention and attempts to compare success and failure were even rarer (SPRU, 1972). Hence, the purpose of the project was to bridge this knowledge gap through systematic comparisons of success and failure in (otherwise similar) innovation projects, initially in two selected industries, chemicals and scientific instruments, but later including engineering as well (specialized machinery for specific industries). The research showed that the most important factor discriminating between success and failure in innovation was the attention paid to user needs and marketing. It also highlighted the importance of effective use of outside technology and scientific advice, efficient management of innovation activities and the involvement of senior personnel as project leaders. Many other factors, such as the extent of resources devoted to R&D, were shown to be not significantly correlated with the outcome, though the later part of the project (conducted by Roy Rothwell) indicated that the role of R&D for innovation differed across industries. At the time the project attracted much attention, particularly in industry, and Freeman used it extensively in later work, particularly in his very successful 1974 book on the *Economics of Industrial Innovation* (see the next section). SAPPHO was a pioneering project and its main findings have been confirmed by a large

[15] The projects have been selected based on a study of SPRU's annual reports and on interviews with Freeman's co-workers, Jackie Fuller and Geoff Oldham.

[16] SAPPHO stands for Scientific Activity Predictor from Patterns of Heuristic Origins; perhaps in this case Freeman's preference for a catchy acronym was taken a bit too far!

amount of later research. The factors it pointed to as essential for innovation, such as the importance of users, the degree of interaction with external knowledge holders and the involvement of senior management, continue to be the main focus of much of the literature in this area.

Another major initiative during Freeman's time as Director of SPRU was the project on 'Social and Technological Alternatives for the Future' (STAFF). According to Freeman's recollection, the initial impetus came from Andrew Schonfield, then Chairman of the Social Science Research Council, who envisaged a need for research on social forecasting in Britain:

"The Social Science Research Council wanted to start an activity in forecasting; social forecasting. And so they went round various universities, and they publicised their interest in starting a programme of research on social forecasting, and various people responded to that. And Geoff Oldham and I responded to it with the firm proposition that we would like to work in this field, but only if it was support for scientific and technological forecasting as well as social forecasting. We were obsessed with a programme which we called Social and Technological Alternatives for the Future (STAFF). And so, in our debates with Andrew Schonfield and other people at the then SSRC, we insisted that we believed that you could not make good forecasts in the social area without taking account of technological change. And in the end this argument was accepted, a bit to our surprise actually!"[17]

STAFF (and related SPRU-activities) made it possible to make several important recruitments, most notably Keith Pavitt, who later succeeded Freeman as R.M. Phillips Professor of Science Policy (a chair Freeman had held since its creation) and as main editor of Research Policy. The programme employed a large number of researchers with a variety of disciplinary backgrounds from the early 1970s onwards. It included, amongst other things, computer-based modelling and simulations in areas such as energy and other resources, but it also extended to 'softer issues' such as changes in patterns of consumption and the organization of work and everyday life. At the time the dominant voice in the debate about the future came from the so-called 'Club of Rome', which in the book *Limits to Growth* (Meadows et al., 1972) predicted that the growth of the world economy would eventually collapse due to the cumulatively adverse consequences of resource depletion, environmental pollution and diminishing returns to agricultural investments. Although Freeman and SPRU colleagues agreed that these challenges, particularly pollution, were important, they objected to the predictions of Meadows et al., their main criticism being that these authors had not given sufficient attention to technical change in their simulations, leading to essentially flawed predictions and, in particular, unhelpful advice to policy-makers. This message, communicated through Freeman

[17] Excerpt from an unpublished interview with Aldo Geuna in 1999 (slightly shortened and edited by Jan Fagerberg).

et al. (1973) and other publications, received wide attention at the time.[18] Although the external funding to the STAFF programme on social and technological forecasting eventually came to an end, the argument that technological change and policies influencing it is essential for coping with social, economic and environmental challenges was here to stay. Moreover, some of the research activities associated with the programme, such as those related to energy, continued (under other headings) and have remained important for SPRU to the present day.

In the middle of the 1970s the world economy unexpectedly went into a major recession and, as a result, unemployment re-appeared as a major social and economic challenge. Economists were baffled but many, including an OECD expert group led by Paul MacCracken, tended to see it as being caused by a coincidence of unfortunate circumstances unlikely to be repeated on the same scale (McCracken et al., 1977). Freeman, however, was not convinced and at an OECD meeting in 1977 he argued that the problems might well be associated with long-run patterns of technical change, investment and growth, in the way foreseen many years earlier by Kondratiev and Schumpeter. He suggested that this possibility deserved thorough investigation and that, for this, a long-term historical perspective was needed (Freeman, 1977b). Freeman noted "that to substantiate or refute" this "would require a major research project or a whole series of such projects" (ibid., p.1), which is what he then set out to realize.[19]

The TEMPO project on technical change and employment opportunities, carried out at SPRU between 1979 and 1984, became the main vehicle for Freeman's ambitions in this area. Previously Schumpeter had put forward the idea that major new technologies tended to cluster for technical and economic reasons, and that such clusters for a while could have quite substantial effects on the economy, possibly leading to business cycles or 'waves' of economic activity of various durations. Freeman et al. (1982), in a book based on results from the TEMPO project, used the concept 'new technology systems' for such growth-inducing clusters of new radical technologies, and they applied the perspective to two selected industries that Freeman knew well from his early research at the NIESR, namely electronics and synthetic materials. However, it became apparent to Freeman and his co-authors that the growth and employment effects of new, radical technologies were less related to

[18] The book was also published in US, French and German editions and as a special issue of the journal *Futures*, and hence enjoyed a large circulation. According to Asa Briggs, Vice-Chancellor at the University of Sussex at the time and Chairman of SPRU's Advisory Board, this was the publication that "more than any single publication established the international reputation of the unit" (Briggs, 1986, p. xvi). However, it has not been as highly cited in academic journals (as covered in the ISI Web of Knowledge) as some of Freeman's other publications.

[19] See Soete (1986) for an overview of Freeman's work on 'long waves'.

innovations as such than to the diffusion of these innovations throughout the economy. Hence, as they point out, these effects *"depend not only on scientific or technological leadership but also on the capacity to initiate those social and organisational changes that facilitate the widespread adoption of the new families of innovations"* (ibid., p. xii) The insight emerging from this project, that social, institutional and organisational change may be crucial for exploiting technological opportunities, would become very central for Freeman in the years to come, not least through his cooperation with Carlota Perez (Freeman and Perez, 1984, 1986, 1988) and, much later, with Francisco Louçã (Freeman and Louçã, 2001).

Spreading the message

Freeman was an excellent communicator and network-builder. During his period as Director of SPRU and in the years that followed, he gave a large number of talks in a variety of contexts, domestic and international, spreading the message to a broad audience extending far beyond academia. He also maintained close contacts with the OECD and other international organizations, wrote papers, worked as a consultant and contributed to numerous policy reports. His engagement in this continued well beyond normal retirement age. For example, as his long-time co-worker Luc Soete explains, Freeman was during the 1990s involved in several European Union policy reports on technology diffusion and the development of an information society (Soete and Verspagen, 2010, p. 176).

After he turned sixty Freeman gradually reduced his commitments in SPRU, first stepping down as Director (he was succeeded by his long-time deputy, Geoff Oldham), then relinquishing his professorial chair (which went to Keith Pavitt) and finally formally retiring from the university in 1986. This gave him the opportunity to focus more strongly on his own research which, in addition to his engagement in the TEMPO project, also resulted in an analysis of the 'national innovation system' in Japan (Freeman, 1987), the first published work to use that concept. Freeman's last major book, focusing on how to understand and study long-run growth (Freeman and Louçã, 2001), appeared in 2001, the year he turned eighty.

However, it also gave him the freedom to strengthen his role as a network-builder, actively supporting the growth of a strong research community for innovation studies at a global scale. An especially important activity for Freeman during this period was an IFIAS project that brought together an international group of leading researchers with the aim of improving our understanding of the sources behind technical change and its implications for the growth of the global economy, while also pointing to unresolved issues and avenues for further research (Dosi et al., 1988). Freeman developed, as already mentioned, particularly close ties with the IKE group at the University of

Aalborg (Denmark) and MERIT at the University of Maastricht, with which he had formal affiliations, and he participated in a number of research projects in these and other contexts. For example, he took an active part in the IKE group's work on national innovation systems (Lundvall, 1992) and the comparative project led by Richard Nelson (Nelson, 1993) and others on the same topic.

Freeman was also a great teacher. He loved to interact with research students, contributing decisively to the development of their perspectives and skills, but also (as he was quick to stress) learning from them. The SPRU library at University of Sussex is packed with theses acknowledging Freeman's contribution, many of which were not formally supervised by him. Nevertheless, between the start of SPRU and the graduation of his last research student there (in 1988), Freeman was the sole or joint supervisor of more than twenty DPhil and MPhil theses, a remarkable achievement of someone who was the Director of a large and busy research institute. A list of those theses is included as Appendix 1. A striking feature is the broad range of sectors and topics covered, from information technology via chemicals to tourism, along with research on technological change, skills and employment, technology and the environment, inter-organisational linkages in innovation, and broader aspects of national policy and strategy in a historical or contemporary perspective.

Text Box 2. Freeman's first DPhil students

Within a year of SPRU's start-up in January 1966, it provided a home for two doctoral research students, both supervised by Freeman. The research projects of those two students spanned topics that were central to Freeman's own work. The first, a forward-looking analysis of radically novel areas of innovation at the frontiers of technological progress, was the subject of research by Tony Golding, who examined innovation, growth and the diffusion of technology in the then infant semi-conductor industry. The second, a retrospective analysis of historical experience, was the focus applied by Kay Andrews to politics and the organisation of UK scientists in the early twentieth century. Both these doctoral graduates went on to embody the connection between research and practice that Freeman advocated. Tony Golding took his understanding of the nascent semiconductor industry to an initial career in the international electronics business, moving later to investment banking in the city of London. Then, some 40 years after placing his thesis on the library shelves at Sussex, he took up his pen again to write a best-selling book about the financial workings of 'The City'. Kay Andrews, armed with her research-based understanding of politics and science, was later centrally involved at the heart of public policy-making in Britain, not least as Baroness Andrews, the Labour Government spokesperson for Education and Skills in the House of Lords.

3. Freeman's writings

Freeman was a prolific writer. His list of publications contains nearly three hundred entries of which twenty-five are books written or edited by Freeman. In addition he published more than two hundred articles in books and journals. To do justice to all of these all is clearly impossible within the scope of a single paper. Therefore, what will be attempted here is to focus on his most important contributions to innovation studies, the field he did so much to develop.

To help identify the most important contributions, this paper makes use of a database of references in chapters in handbooks on (various aspects of) innovation; this database has been developed by Fagerberg and colleagues as part of an attempt to identify the most important contributions to innovation studies more generally (Fagerberg et al., 2011). The assumption is that authors in such handbooks, who have been asked to survey a body of literature of relevance for innovation studies, will include the most important references for their subject. Although the subjects and orientations of the authors will differ, which results in some variation, some of these references may be cited many times by different authors and handbooks simply because they are considered to be of crucial importance for the field more generally.

The data come from 277 chapters in eleven different handbooks published between 1993 and 2010. Together these contain 21,313 references, of which 14,857 are different. Since the purpose was to identify references of high general relevance, not only for a specific topic but for the field in general, only literature cited by chapters in at least three different handbooks were selected for further study. This reduced the sample to 572 different references. Of these, ten were to works by Freeman (see Table 1). In the table, these are ranked in terms of how often they are cited by the handbook authors, i.e. the J-score.[20]

[20] The J-score is the number of times a publication is cited, as a percentage of the total number of times it theoretically could have been cited, given its date of publication. Hence the score adjusts for the fact that more recent publications have a smaller chance to be cited (simply because some of the handbooks are older).

Table 1. Central works by Christopher Freeman

Rank	Author(s)	Title	Year	Type	J-Score	ISI citations
7	Freeman, C.	The Economics of Industrial Innovation	1974	Book	12.64	1033
12	Freeman, C.	Technology Policy and Economic Performance: Lessons from Japan	1987	Book	9.75	423
54	Freeman, C. & Louçã F.	As Time Goes By: From the Industrial Revolution to the Information Revolution	2001	Book	5.00	74
57	Rothwell, R., Freeman, C., Jervis, P., Robertson, A. and Townsend, J.	SAPPHO Updated - Project SAPPHO Phase II	1974	Journal Article	4.69	299
89	Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L.	Technical Change and Economic Theory	1988	Book	3.97	568
90	Freeman, C. and Perez C.	Structural Crises of Adjustment: Business Cycles and Investment Behaviour	1988	Book Chapter	3.97	145
99	Freeman, C.	The 'National Innovation System' in Historical Perspective	1995	Journal Article	3.64	118
128	Freeman, C.	Networks of Innovators: A Synthesis of Research Issues	1991	Journal Article	3.25	198
176	Freeman, C., Clark, J. and Soete, L.	Unemployment and Technical Innovation: A Study of Long Waves and Economic Development	1982	Book	2.53	283
471	Freeman, C.	The Economics of Technical Change	1994	Journal Article	2.15	127

Note: Citations to Freeman (1974) include citations to the two subsequent editions of the same book.

Freeman's most influential works (at least as judged by the authors of chapters in innovation handbooks) may be subsumed under three headings:

(i) innovation;

(ii) long-run capitalist development; and

(iii) national innovation systems and policy.

In addition there are, towards the bottom of the list, a few survey articles with a more general focus.

His clearly most influential work, *The Economics of Industrial Innovation* from 1974, belongs to the first category, as does the article from 1974 with Rothwell and others on Project SAPPHO (Rothwell et al., 1974). The book is a veritable tour de force on the role of innovation in modern society, drawing extensively on results from SPRU research, but also giving due credit to contributions by others on that topic. The first section of the book is historical in nature, focusing particularly on evidence from the chemical and electronics industries, two sectors Freeman knew well from his own research at NIESR and later. Then, in the second section, Freeman focuses on what we know about innovation in firms, drawing to a large extent on results from Project SAPPHO, but also addressing other issues such as the roles of uncertainty and firm strategy in innovation. Freeman's discussion of firm strategies is especially perceptive, emphasizing their heterogeneous character, and foreshadowing a lot of work on this topic in the decades that followed.[21] After a relatively brief discussion of policy issues, the book then ventures into how scientific and technological activities can be measured, drawing to a large extent on his own work for the OECD and the UN. The book was published in three editions (1974, 1982 and 1997), the last being co-authored with Luc Soete, his long-time collaborator at SPRU and MERIT.[22] It should be noted, however, that about three-quarters of the citations are to the two first editions, so its influence was probably largest in the early phase when it had a virtual monopoly in giving a synthetic overview of the knowledge in the field.

A second theme in his research is long-run capitalist development and in particular the interaction between technological, economic, social and institutional change in this process. A book that falls squarely within this theme (and which at the time was quite influential but is less so today) is that by Freeman, Clark and Soete (1982), based on research undertaken in the TEMPO project (see section 2). His joint contribution with Carlota Perez to the book that emerged from the IFIAS project (Perez and Freeman 1988), of which Freeman was also one of the editors, develops and extends the earlier analysis. This also applies to the most recent entry to the list of influential work, his joint book with Franscisco Louçã (Freeman and Louçã, 2001). Freeman's approach in these studies, characterized by

[21] Freeman takes as his point of departure that firms are different and that multiple strategies are therefore likely to coexist. This differs from the perspective of an earlier UK study on the subject, that by Carter and Williams (1957), which with its notion of 'the progressive firm', seemed to suggest that there is a single best strategy.

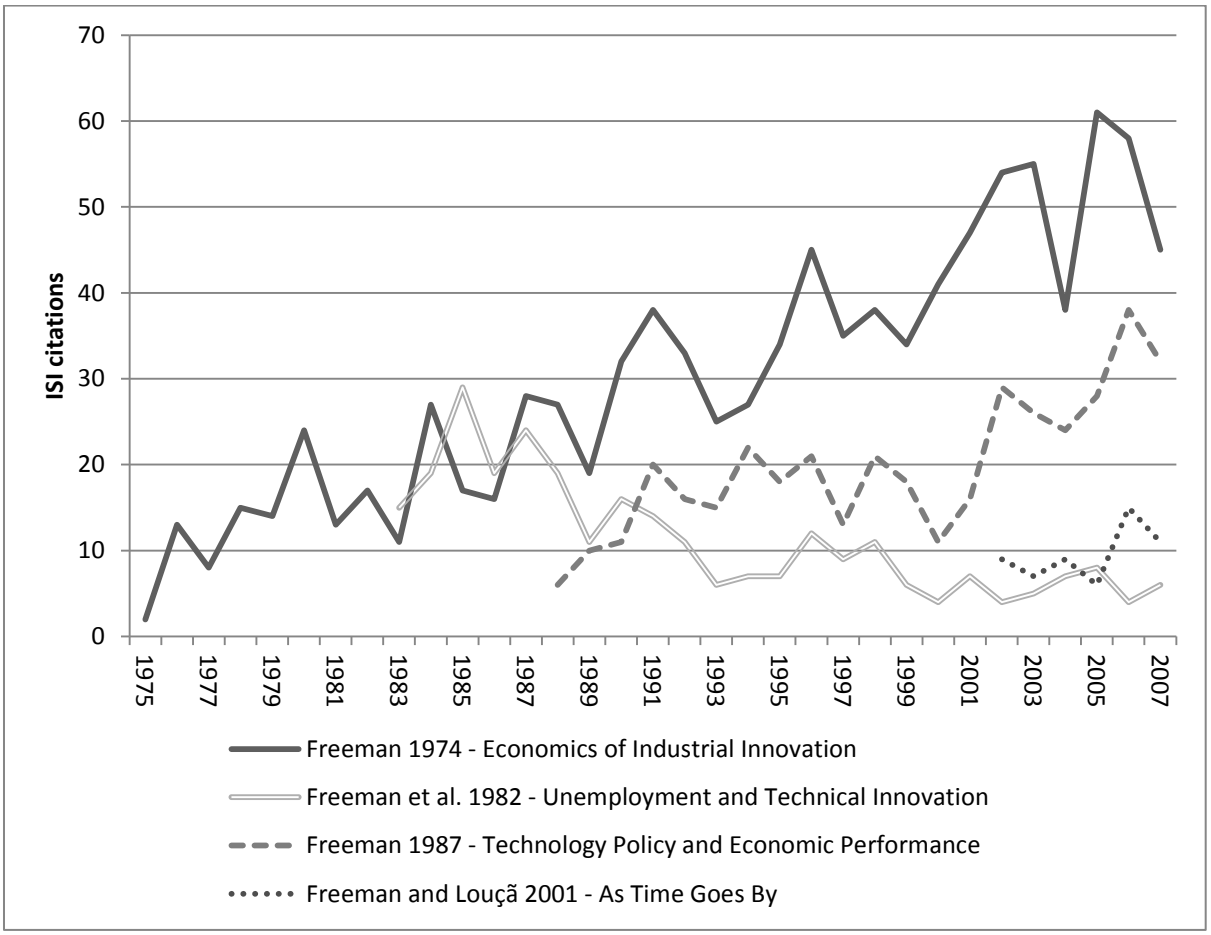
[22] The second edition, appearing after eight years was a relatively minor revision, consisting of some updating of references and the inclusion of a new chapter drawing on research in the TEMPO project. The third edition, appearing fifteen years after the second edition, involved major revisions, adding an entirely new section on the "macro-economics of innovation", covering issues such as national systems of innovation, growth, trade and development, and also expanding the policy discussion to include topics such as the information society and environmental challenges.

him (Freeman et al., 1982 p. ix) as “reasoned history” (a term adapted from Schumpeter), consists of a relatively detailed analysis of the emergence and diffusion of new technological systems in historical time, focusing in particular on the role that economic, social, institutional and cultural factors play in these processes and, through this, the implications for policy.

The third major theme of Freeman’s research is associated with the concept of “national systems of innovation” that emerges for the first time in print in his book on *Technology Policy and Economic Performance: Lessons from Japan* (Freeman, 1987). He discusses the implications and origins of this approach in more detail in a later survey article (Freeman, 1995) that is also included in the list of influential works list. In the 1987 book Freeman returns to some of the issues he started out with when he embarked on his research career, namely the emergence of technology gaps in the global economy, their subsequent evolution and how these may be affected by policy. A central part of the analysis consists of a case study of technology policy in Japan, focusing partly on policies aimed at speeding up ICT diffusion in traditional industries, which Freeman endorses, and partly on the Japanese system for technology forecasting, which Freeman sees as an important asset.

Figure 2 contains information on citations per year for four of Freeman‘s most important books. For the three most important publications, as assessed by the handbooks, the annual rate of citations increases over time. In particular it is striking that, in the case of *The Economics of Industrial Innovation* (1974), the citations continued to rise during the third decade after the publication of the first edition. In the case of *Technology and Economic Performance* (1987), the annual citation rate increased sharply during the second decade after publication, while the most recent book (Freeman and Louçã, 2001) also shows a rising rate of citation, though over a much shorter period. In contrast, the fourth book included in the comparison (Freeman, Clark and Soete, (1982), was very highly cited in the years immediately following its publication, after which the number of citations started to decline towards a very low level. From this, we may tentatively conclude not only that some of Freeman’s work seems to have continued to attract interest over a long period of time, but also that his most important contribution to innovation studies, as assessed by the users (i.e. those that cite his work), consists of the general perspective on innovation and its role in social and economic developments that he outlined in his very first book and his later work on policy. In contrast his work on ‘long waves’ and related topics, although highly popular when it first emerged in the early 1980s, is not seen as so relevant today.

Figure 2. Citations (ISI Web of Science) to Freeman's books



Note: Citations to Freeman (1974) include citations to the two subsequent editions of the same book.

Freeman's most influential works are cited in more than five hundred different journals spanning a variety of disciplines and scientific fields. Table 2 lists the ten most important of these journals (based on the number of citations to Freeman's most important works) together with the descriptions in the ISI Web of Science of the scientific fields (or 'subject-areas') of these journals. As one can see, the most important journal is *Research Policy*, the journal Freeman created in 1971, and described by researchers in innovation studies as the most important publishing outlet for their work today (Fagerberg and Verspagen, 2009). Among the subject-areas of these journals, management, engineering and business are the most frequent, followed by 'planning and development', economics, geography and environmental studies. Hence, the use of Freeman's work clearly spans a broad range of scientific disciplines and fields. Two of the ten journals also include 'multidisciplinary' as part of the ISI description (and several others probably could as well).

Table 2. Journals citing Freeman

Rank	Journal	Counts	Percent	Journal subject area
1	RESEARCH POLICY	358	13 %	Management; Planning & Development
2	TECHNOVATION	121	4 %	Engineering, Industrial; Management; Operations Research & Management Science
3	INTERNATIONAL JOURNAL OF TECHNOLOGY MANAGEMENT	99	4 %	Engineering, Multidisciplinary; Management; Operations Research & Management Science
4	R & D MANAGEMENT	84	3 %	Business; Management
5	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	73	3 %	Management; Multidisciplinary Sciences
6	REGIONAL STUDIES	72	3 %	Environmental Studies; Geography
7	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	70	3 %	Business; Planning & Development
8	CAMBRIDGE JOURNAL OF ECONOMICS	62	2 %	Economics
9	JOURNAL OF PRODUCT INNOVATION MANAGEMENT	56	2 %	Business; Engineering, Industrial; Management
10	INDUSTRIAL AND CORPORATE CHANGE	48	2 %	Business; Economics; Management

The ten journals account for only 39% of the scholarly citations to Freeman's work. To obtain a more precise description of the orientations of all academic users of his work, we have in Figure 3 included an overview of the 'disciplinary' orientation of these users, based on the subject areas of the journals in which these citations occurred. For the purpose of illustration, we found it useful to aggregate the several hundred subject areas into a smaller number of categories using an aggregation scheme proposed by Fagerberg et al. (2011).

Figure 3. Disciplinary orientation of 'users' of Freeman's work

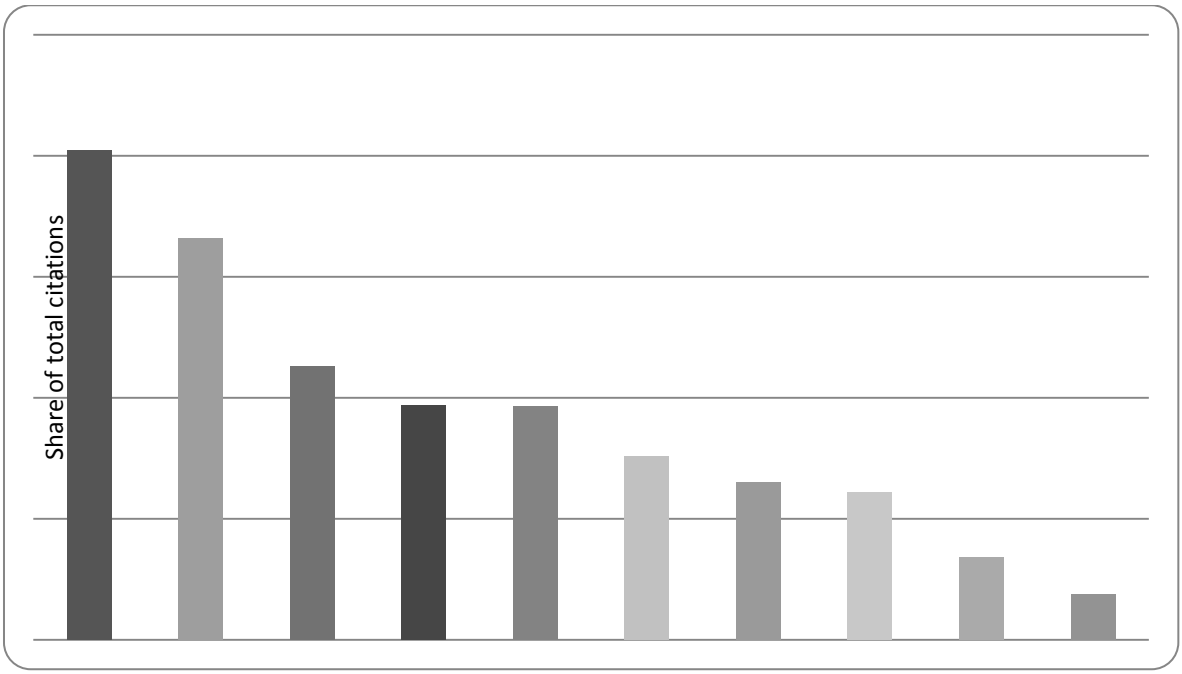
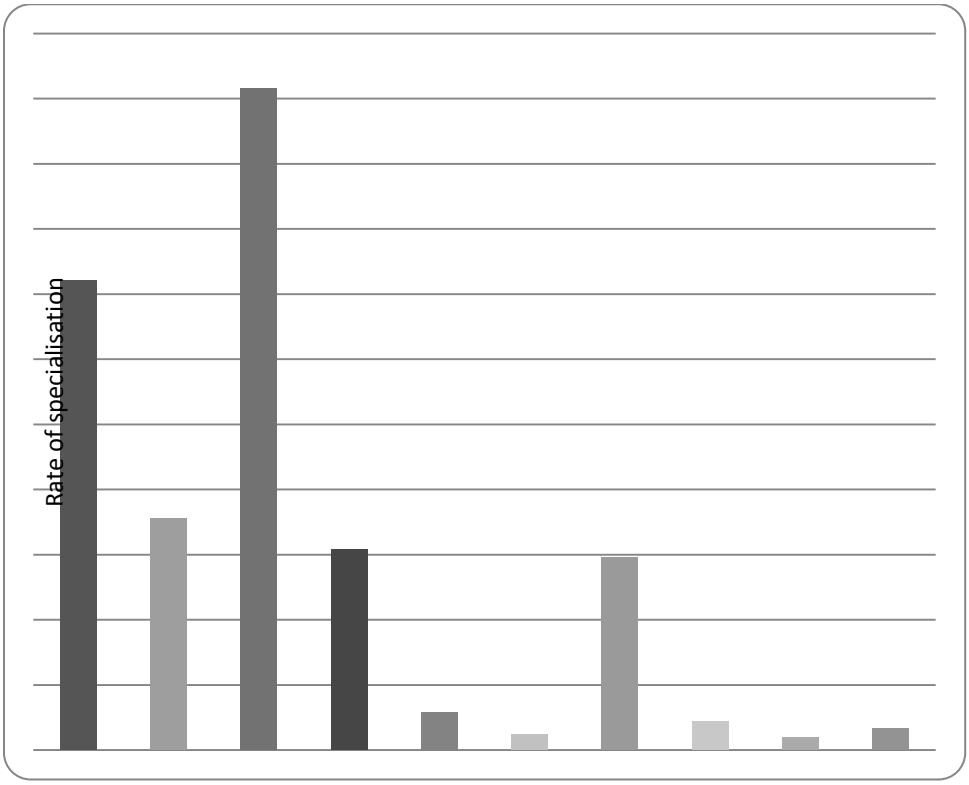


Figure 3 confirms that Freeman's works are used in a large number of fields and disciplines, among which Management, Economics, Planning and Development, and Business are the most important. However, there are also many users in other parts of the social sciences and the humanities (aggregated into the broad 'Social Sciences and Humanities' category). Engineering, and Computer and Information Science are also common user backgrounds, indicating that interest in Freeman's work clearly extends well beyond the Social Sciences.

The composition of users reported in Figure 3 is, of course, influenced by the size of the various disciplines/fields, as large fields - everything else being equal - will tend to have more users. In Figure 4, we have instead calculated how eager the users in the various categories are when it comes to the use of Freeman's work. This was done by dividing the shares reported in Figure 3 by the share of the same subject areas/fields in relation to the total number of citations in the Web of Science. If the resulting index is unity, it means that the users on average are just as likely to cite Freeman's work as everything else. The results in Figure 4 indicate that there are two user groups that hold Freeman in especially high regard, namely Planning and Development and Management. These are followed by Economics, Business and Geography.

Figure 4. Especially eager users of Freeman's work



4. Conclusion: Freeman's contribution to innovation studies

Christopher Freeman's contributions to innovation studies are many and varied. What most of his students and colleagues probably would emphasize first is the example he created for others by being so inclusive, helpful and supportive in his attitude towards them. This was particularly so for younger scholars. In fact, it would be easy to fill up the entire paper with such stories, so we will let one of his early collaborators, Stuart Blume, speak for them all:

I first met Chris before the Unit (the name SPRU wasn't yet in use) was established, and when he was still based at the NIESR. I guess it must have been sometime in 1966. I was working (with little enthusiasm) on a PhD in chemistry at Oxford. I'd discovered the emerging field of science policy studies, read about the Sussex Unit soon to be established in the newspaper. It mentioned Chris so I wrote to ask to come and talk to him. He offered me a place as research assistant - on the strength of no more than intuition. I had nothing more than enthusiasm to offer. My feeling about him at the time, that never changed, was that he was a caring, committed and remarkably open-minded man: a man who always had time for people, whether they were fellow-professors or merely students. It is

Chris who made my career possible and has always been a role model for me as teacher and as professor. (Email from Stuart Blume, 23 January 2011)

As is well known among his collaborators, Freeman would famously downplay his own contributions, and emphasize those of others, [23] especially when that scholar happened to be younger than himself, which of course was increasingly the case. Unusual as this may be among academics, it contributed to the creation of a culture within the innovation studies field that was open, inclusive and friendly, providing an attractive environment for younger scholars to join.

However, Freeman not only offered an exemplar of good scholarly practice, he also provided others with a framework for how to carry out research on innovation's relationship with society, including its scientific underpinnings. This was based on an original and broad understanding of the subject that transcended narrow disciplinary boundaries[24] and that became highly influential. Freeman had the rare ability to talk to scientists about something inherently economic in ways they immediately understood. And to economists he managed to convey the message that to understand innovation a narrow disciplinary perspective somehow would not suffice. As one SPRU PhD student, Luigi Orsenigo, wrote in his thesis: "Christopher Freeman reminded me that economics is a social science" (Orsenigo, 1989). From early on, Freeman was an ardent supporter of cross-disciplinarity in innovation research, and this was more than mere lip service. As shown in section 2 of this paper, SPRU from the very start deployed cross-disciplinary teams on projects, and close to one half of its researchers had a background in the natural sciences or engineering. This strong emphasis on the need for cross-disciplinarity would come to influence many of the new centers, institutes and departments in Europe and elsewhere that emerged later, often modelled on the basis of the experiences of SPRU.

There is much more to Freeman's work than his emphasis on cross-disciplinarity, though. The influence of his early synthesis of our knowledge about innovation and its role in society in *The Economics of Industrial Innovation* (1974) was enormous. Rereading it leaves one with the impression that much of what is on the research agenda today actually consists of relatively modest elaborations on the themes taken up there. The fact that that Freeman, according to a survey of more than one thousand researchers world-wide (Fagerberg and Verspagen 2009), [25] ranks among

[23] As McCraw (2007) emphasizes, Schumpeter was also well known for being generous in acknowledging the contributions of others, most notably in his lectures.

[24] This is another characteristic that Freeman shared with Schumpeter (see McCraw, 2007).

[25] The three most important sources of scholarly inspiration (according to the respondents in the survey) were Schumpeter, Nelson and Freeman (see Fagerberg and Verspagen, 2009, for further details). The study by

the top three sources of scholarly inspiration for researchers in this area, probably owes much to the influence of this book, which by far is the most cited of his works.

Arguably, Freeman's most original and influential contribution was his strong advocacy of a holistic and systemic approach to the understanding of innovation, including its underpinning and social and economic consequences. The 'mission-statement' from SPRU's 1971 annual report mentioned earlier is telling in this regard:

"The Unit's central interest is in policy for the professional research and development network and the way in which this social subsystem interacts with society as a whole. This interest includes both technological innovation arising from R&D, and the narrower concept of 'science' as fundamental research. It extends to the diffusion process of innovations in social systems."

As Freeman came to emphasize repeatedly in his later work (e.g. Freeman, 1987; Freeman et al., 1982), it is not sufficient to study one particular aspect of the innovation process, say invention; what is needed is to understand the process in its entirety, including its diffusion throughout society, and the feedback from the diffusion process to the earlier stages (including science). What this implies is that at any time there will be a broad range of economic activities, and policies influencing them, that affect innovation and – perhaps more indirectly but no less importantly – decisions regarding investments in R&D and priority-setting in science. Freeman (1987) used the concept of 'national system of innovation' to account for such interdependencies, which are, of course, crucial to be aware of when designing science, technology and innovation policies.

Freeman is best known for his advocacy of cross-disciplinarity, his strong emphasis on the need to integrate historical and economic perspectives, and his broad, systemic approach to the study of innovation, its underpinnings and social and economic consequences. This does not mean, however, that he shied away from what within economics (or more precisely macroeconomics) is perhaps seen as the most central issue, namely the relationship between innovation and economic growth. On the contrary, this was the issue to which he devoted most of his energy after retirement and which resulted in his last major work (Freeman and Louçã, 2001). Moreover, he strongly advised others to take the same path. This is what he had to say about the subject a few years later, at the age of 82:

"Sectoral systems, regional systems are all very constructive and helpful. But I think the main area that needs to be strengthened is the main core of economic theory, macro-economic theory, and I

Fagerberg et al. (2011), based on an analysis of references in handbooks covering the field, also points to Freeman as one of the three most influential scholars in this area.

think you can't shift the main central core of neoclassical economic theory simply with microeconomic studies. (…) You can point to the success of Pakistan in medical instruments or Brazil in boots or shoes or whatever, or the United States with the internet, and if you point out the role of innovation in all those micro level studies, that's very useful. And if you point out certain regions of countries are more innovative, and the north of Italy has contributed more to the growth of the country than Sicily, that's all very useful. But I don't think you'll change the main paradigm of neoclassical economics, I think you have to attack it head on in the centre (…) Most of the people working on innovation systems prefer to work at the micro-level. They are a bit frightened still of the strength of the neoclassical paradigm at the macroeconomic level. But I think that's where they have to work. You have to have an attack on the central core of macroeconomic theory. It is happening but not happening enough." [26]

Freeman was not the first to recognise the importance of innovation and to subject it to systematic study – Schumpeter is conventionally credited with that.[27] Nevertheless Freeman's contributions , and particularly his broad, systemic approach to the role of innovation in the economy and the society, surely place him, along with Richard Nelson and Nathan Rosenberg, among the most important intellectual contributors to the field over the last 50 years. However, for a research field to prosper, a common body of knowledge, data, methods etc. is not enough, one also needs a range of organizations and institutions. Freeman made a fundamental contributions on both these fronts. He set up one of the first research units dedicated to the study of innovation, which quickly developed into a global hub, and started one of the first journals in the field, *Research Policy,* today widely regarded as the leading journal in innovation studies (Fagerberg and Verspagen 2009). Freeman also helped establish fruitful interaction between policy researchers and policy makers through organisations like OECD. Lastly, he was crucial in shaping the 'culture' of the field of innovation studies, characterized by a strong emphasis on interdisciplinarity, an empirically oriented, fact-finding approach and a recognition of the necessity of inspiring the young, and learning from them, if the field is to remain vital. In all these respects, Chris Freeman was truly a social science 'entrepreneur'.

[26] From an unpublished interview with Freeman conducted by Naubahar Sharif on 24 October 2003, and slightly edited and abbreviated by Jan Fagerberg.

[27] Godin (2008) has also identified a number of other individuals such as Maclaurin, who studied technological innovation in the 1940s and 1950s.

Acknowledgements

The authors wish to thank Aldo Geuna and Naubahar Sharif for sharing transcripts from previous interviews with Freeman, and allowing us to use these here. Assistance from the SPRU Pavitt Library in identifying Freeman's many writings is gratefully acknowledged. Thanks must also be given to Stuart Blume, Alan Freeman, Gary Hufbauer, Carlota Perez, Luc Soete, Ed Steinmueller, Ergun Türckan, Gunnar Westholm, Alison Young and others who have contributed to the progress of the work through email-correspondence or in other ways. Finally, a sincere note of gratitude to Jackie Fuller, Ron Gass, Norman MacKenzie, Richard Nelson and Geoff Oldham for participating in (long) conversations about Freeman's various achievements and giving helpful advice. Any remaining errors and omissions are, however, our own responsibility.

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Orsenigo, L., 1989. Market and Institutions in the Dynamics of Industrial Innovation. The Theory and the Case of Biotechnology, SPRU. University of Sussex, Brighton.

Posner, M.V., 1961. International Trade and Technical Change. Oxford Economic Papers 13, 323-341.

Rosenberg, N., 1986. Schumpeter and Marx: How common a Vision?, in: MacLeod, R.M. (Ed.), Technology and the Human Prospect. Frances Pinter, London.

Rothwell, R., Freeman, C., Horsley, A., Jervis, P., Robertson, A., Townsend, J., 1974. SAPPHO Updated - Project SAPPHO Phase II reprinted. Research Policy 3, 258-291.

Soete, L., 1986. Technological Innovation and Long Waves: an inquiry into the nature and wealth of Christopher Freeman's thinking, in: MacLeod, R.M. (Ed.), Technology and the Human Prospect: essays in honour of Christopher Freeman. Pinter, London.

Soete, L., Verspagen, B., 2010. Remembering Christopher Freeman's Work at MERIT. African Journal of Science, Technology and Development, 175-183.

SPRU, 1967. Annual Report, University of Sussex.

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Appendix 1

Chris Freeman – Research Student Supervision at the Science Policy Research Unit (SPRU), University of Sussex

Name	Date (Completed)	Degree	Thesis Title
Golding, A. M.	1971	DPhil	The semiconductor industry in Britain and the United States: a case study in innovation, growth and the diffusion of technology.
Achilladelis, B. G.	1973	DPhil	Process innovation in the chemical industry.
Sinclair T. C.	1974	DPhil	Human life and safety in relation to technical change.
MacLeod (Andrews), E. K.	1976	DPhil	Politics, professionalisation and the organisation of scientists: the Association of Scientific Workers, 1917-1942.
Luke, J. A.	1977	MPhil	The UK oil refining industry and the Environment
Lever, B. G.	1978	DPhil	Planning technological change: A case-study of the Agricultural chemicals industry
Cooray, N.	1980	DPhil	The technological factor and its relevance to the competition between synthetic and natural rubber in international trade.
McCutcheon, R	1980	DPhil	Modern construction technology in low-income housing policy: the case of industrialised building.
Haywood, B. W.	1985	DPhil	Technical change and employment in the British printing industry.
Issidoridis, G.	1986	DPhil	Optimal diffusion: a theoretical and empirical analysis of the diffusion of innovations
Faulkner, W. R.	1986	DPhil	Linkage between industrial and academic research: the case of biotechnological research in the pharmaceutical industry.
Muchie, M.	1987	DPhil	Capitalist technology and socialist development
Fukasaku, Y	1988	DPhil	Technology imports and the development of technological capability in the industrialization of Japan: training and research at Mitsubishi Nagasaki shipyard 1884-1934.

Poon, A	1988	DPhil	Information technology and innovation in international tourism: implications for the Caribbean tourist industry.
Lastres, H. M. M.	1992	DPhil	Advanced materials and the Japanese national system of innovation.
Assis, J. A. B.	1998	DPhil	External linkages, innovation and the small and medium sized enterprise: the role and effectiveness of public technology policy in Portugal.

Notes. (i) This list includes a few students who were jointly supervised by Christopher Freeman and others. It does not include a number of students, perhaps 5 or 6, whom he supervised for only a short part of their research, or who were unable to complete their research – usually because of practical constraints such as employment pressures or political change in their home country.

(ii) Not all these students were formally registered as SPRU students. Especially in the earlier years before SPRU was formally recognised as a teaching department of the University, students supervised by Christopher Freeman were registered in other academic units such as Economics or History and Social Studies of Science

Appendix 2

Christopher Freeman – Publications List

The following list was compiled from three main sources: (i) Freeman's personal publication list,[28] which was maintained as part of his CV and updated by various secretaries over the years; (ii) the Pavitt Library in SPRU, where Freeman deposited copies of most of his papers as they were prepared; and (iii) the 'List of publications by Freeman whilst at MERIT' compiled by Luc Soete and colleagues at MERIT.[29] The combined list was then checked against other sources including boxes of Freeman's papers deposited in the Pavitt Library at SPRU and the ISI *Web of Knowledge*. Those checks would suggest that the list reproduced here is reasonably complete, at least with regard to major publications. However, it may be missing a few reports and working or background papers as well as details of some of the various foreign translations of the main books. Book reviews have not been included here, nor have unpublished conference or seminar presentations.

Books

1. *The Economics of Industrial Innovation,* Penguin Modern Economic Texts, Harmondsworth, 1974. (Spanish edition: *La Teoria Economica de la Innovacion Industrial,* Penguin Alianza, Madrid, 1975.)
2. (With U. Colombo, R. Nelson, K. Pavitt and N. Rosenberg) *Technical Change and Economic Policy: Science and Technology in the New Economic and Social Context,* OECD, Paris, 1980.
3. *The Economics of Industrial Innovation* (2nd edition), Frances Pinter, London, 1982.
4. (With J.A. Clark and L.L.G. Soete) *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*, Frances Pinter, London, 1982. (Spanish edition: *Desempleo e Innovacion Tecnologica: un estudio de las ondas largas y el desarrollo economico,* Ministerio de Trabajo y Seguridad Social, Madrid, 1985.)
5. (With L.L.G. Soete) *Technical Change and Full Employment*, Basil Blackwell, Oxford, 1987.
6. *Technology Policy and Economic Performance: Lessons from Japan*, Pinter, London, 1987.
7. *The Economics of Hope: Essays on Technical Change and Economic Growth*, Pinter, London, 1992.
8. (with L Soete) *Work for All or Mass Unemployment? Computerised technical change into the 21st century*, Pinter, London, 1994. (Italian edition: *Lavoro per Tutti o Disoccupazione di Massa*, Etaslibri, Rome, 1994; Spanish edition, *Cambio Tecnológico y Empleo: una Estrategia de Empleo para el Siglo XXI*, Coleccion Forum Universidad-Empresa, Fundacion Universidad-Empresa, Madrid, 1996.)
9. (With L. Soete) *The Economics of Industrial Innovation* (3rd edition), Pinter, London, 1997.
10. (With F. Louca) *As Time Goes By: From the Industrial Revolutions to the Information Revolution*, Oxford University Press, Oxford, 2001.
11. *Systems of Innovation: Selected Essays in Evolutionary Economics*, Edward Elgar, Cheltenham, 2008.

[28] A version of this can be found at http://www.freemanchris.org/publications (accessed on 17 March 2011), where it has been sorted by research theme.

[29] This can be found at http://www.merit.unu.edu/archive/docs/hl/201009_201008_ChrisFreeman_final.pdf (accessed on 17 March 2011).

Edited books

1. (Ed. with H.S.D. Cole, M. Jahoda, K.L.R. Pavitt) *Thinking about the Future: A Critique of 'The Limits to Growth'*, Chatto and Windus/Sussex University Press, London and Brighton, May 1973. (US edition: *Models of Doom: a Critique of 'The Limits to Growth'*, Universe Books, New York , 1973; German edition: *Zukunft aus dem Computer? Eine Antwort auf 'Die Grenzen des Wachstums'* , Luchterhand, 1973; French edition: *L'Anti-Malthus: une Critique de 'Halte à la Croissance'*, Seuil, Paris, 1974.)
2. (Ed. with B.V.A. Roling, A.M. Weinberg and H.F. York) *Technological Innovation: A Socio-political Problem*, Proceedings of the Symposium on the Control of Technological Development, organised on the occasion of the 15th Anniversary of the Twente University of Technology, 29-30 November, 1976, Boerderijcahier 7701, Twente, 1977.
3. (Ed. with M. Jahoda) *World Futures: The Great Debate*, Martin Robertson, 1978.
4. (Ed.) *Long Waves in the World Economy* (enlarged edition of two special issues of *Futures* (August and October 1981) containing additional papers by European economists), Butterworth, London, 1983; 2nd edition, Frances Pinter, London, 1984.
5. (Ed.) *Design, Innovation and Long Cycles in Economic Development*, Design Research Publications No. 1, Royal College of Art, London, 1984; 2nd edition, Frances Pinter, London, 1986.
6. (Ed.) *Technological Trends and Employment: 4. Engineering and Vehicles*, Gower, London, 1985.
7. (Ed. with B-A Lundvall) *Small Countries Facing the Technological Revolution*, Pinter, London, 1988.
8. (Ed. with G. Dosi, R.R. Nelson, G. Silverberg and L.L.G. Soete) *Technical Change and Economic Theory*, Pinter, London, 1988.
9. (Ed.) *The Economics of Innovation*, in the Series International Library of Critical Writings in Economics, Edward Elgar, Aldershot, 1990.
10. (Ed. with L. Soete) *New Explorations in the Economics of Technical Change*, Pinter, London, 1990.
11. (Ed. with M.L. Sharp, W.B. Walker) *Technology and the Future of Europe: Global Competition and the Environment in the 1990s*, Pinter, London, 1991.
12. (Ed. with D. Foray) *Technology and the Wealth of Nations: the Dynamics of Constructed Advantage*, Pinter, London, 1993; (French edition: *Technologie et Richesse des Nations*, Economica, Paris, 1992.)
13. (Ed. with H. Mendras), *Le paradigme informatique: technologie et évolutions sociales*, Descartes & Cie, Paris, 1995.
14. (Ed.) *Long Wave Theory*, International Library of Critical Writings in Economics, Edward Elgar, Aldershot, 1996.

Book chapters[30]

1. Research, Technical Change and Manpower Forecasting, in B.C. Roberts and H.H. Smith (eds), *Manpower Policy and Employment Trends*, Bell, London, 1966.
2. 'Foreword', in *Innovation and the Balance of Payments: The Experience in the Pharmaceutical Industry*, Office of Health Economics, London, 1967, vii-xvii.
3. Science and Economy at the National Level, *Problems of Science Policy*, OECD, Paris, 1968, 55-71.

[30] Unfortunately, in some cases the page numbers for these chapters were not recorded in Freeman's CV nor could they be retrieved for books that are not readily available in libraries.

4. (With G. Oldham and E. Türkcan) The Transfer of Technology to Developing Countries with Special Reference to Licensing and Know-How Agreements, *Proceedings of UNCTAD Second World Conference*, New Delhi, 1968.
5. Size of Firm, R&D and Innovation (and supplementary paper on Innovation and Size of Firm), *Proceedings of Conference on Monopolies, Mergers and Restrictive Practices*, King's College, Cambridge, 1969.
6. A Commentary on the Papers and Discussion, in *Policies and Means of Promoting Technical Progress*, Papers presented to the Fifth Meeting of the Senior Economic Advisers to ECE Governments, UN Economic Commission for Europe, United Nations, New York, 1968, 1-16.
7. Innovation and Coupling Systems in Research and Development, in Maurice Goldsmith (ed.) *Technological Innovation and the Economy*, John Wiley, New York, 1970, 177-187.
8. (With C.M. Cooper, O. Gish, C.H.G. Oldham, S.C. Hill, H. Singer and R.C. Desai) Draft Introductory Statement for the World Plan of Action for the Application of Science and Technology to Development, Annex II of *Science and Technology for Development: Proposals for the Second UN Development Decade*, UN Department of Economic and Social Affairs, UN, New York, 1970.
9. A Study of Success and Failure in Industrial Innovation, in B.R. Williams (ed.) *Science and Technology in Economic Growth*, Proceedings of Conference held by the International Economic Association, St. Anton, Austria, Macmillan, London (1973), 227-245.
10. The International Science Race, in D.O. Edge and J.N. Wolfe (eds), *Meaning and Control: Essays in Social Aspects of Science and Technology*, Tavistock Publications, London, 1973, 231-238
11. Author of Chapter 1, Introduction: Malthus with a Computer, and co-author of Chapter 6, The Capital and Industrial Output Subsystem, in H.S.D. Cole, C. Freeman, M. Jahoda and K.L.R. Pavitt (eds), *Thinking about the Future*, Chatto and Windus/Sussex University Press, London and Brighton, 1973.
12. Inter-Governmental Cooperation and the Future, in *Europe Now: Cooperation in Research and Technology*, Proceedings of 1973 Symposium of the R&D Society, 1973, 24-38.
13. Economics of Research and Development, in E. Spiegel-Rosing and D. de Solla Price (eds), *Science Policy Studies in Perspective*, Sage Publications, London, 1977, 223-275.
14. Technical Change and Unemployment, in *Proceedings of the Conference on Science, Technology and Public Policy: An International Perspective*, University of New South Wales, 1977.
15. Preface, in *Policies for the Stimulation of Industrial Innovation: Vol. 1, Analytical Report*, OECD, Paris, 1978, 5-14.
16. The Kondratiev Long Waves, Technical Change and Unemployment, in *Structural Determinants of Employment and Unemployment, Vol. II*, OECD, Paris, 1979, 181-196.
17. Technical Change and Unemployment, in S. Encel and J. Ronayne (eds), *Science, Technology and Public Policy: an International Perspective*, Pergamon Press, Oxford, 1979, 53-76.
18. Technical Innovation and British Trade Performance, in F. Blackaby (ed.), *Deindustrialisation*, Heinemann/NIESR (Economic Policy Papers 2), 1979, 56-77.
19. Microelectronics and Unemployment, in *Automation and Unemployment*, papers presented at ANZAAS Symposium, The Law Book Co. Ltd., Sydney, 1979, 99-113.
20. Social and Economic Impact of Microelectronics, *Proceedings of the Workshop on Technology Assessment: its Role in National and Corporate Planning*, Australian Government Publishing Service, Canberra, 1979, 13-24.

21. Die Mikroelektronik: Wettbewerb und Arbeitsmarkt ('Microelectronics, Competition and Employment'), in *ISI Jahreskolloquiums zum Thema 'Mikroelektronik, Wettbewerb und Beschaftigung - eine Bilanz'*, FhG ISI, Karlsruhe, 1980.

22. Unemployment and Government, in T. Forester (ed.), *The Microelectronics Revolution: the Complete Guide to the New Technology and its Impact on Society*, Basil Blackwell, Oxford, 1980, 308-317.

23. Government Policy, in K.L.R. Pavitt (ed.), *Technical Innovation and British Economic Performance*, Macmillan, London, 1980, 310-325.

24. British Trade Performance and Technical Innovation, in *Technical Innovation and National Economic Performance*, Proceedings of a Workshop held at Institute of Production, Aalborg University Centre, 8 December 1980, Aalborg University Centre, Denmark, 1981, 1-25.

25. Some Economic Implications of Microelectronics, in *Technology and Employment: the Impact of Microelectronics*, papers from the Workshop held at Institute of Production, Aalborg University Center, Denmark , 1981, 7-54.

26. (With J.A. Clark and L.L.G. Soete) Long Waves and Technological Developments in the 20th Century, in D. Petzina and G. van Roon (eds), *Konjunktur, Krise, Gesellschaft: Wirtschaftliche Wechsellagen und Soziale Entwicklung im 19 und 20 Jahrhundert*, Klett-Cotta, Stuttgart, 1981, 132-169.

27. Policies for Technical Innovation in the New Economic Context, and Concluding Comments, in P.H. Kristensen and R. Stankiewicz (eds), *Technology Policy and Industrial Development in Scandanavia*, Proceedings of a Workshop held in May 1981, Research Policy Institute, Lund University, Sweden, and Institute of Economics and Planning, Roskilde University Center, Denmark, 1981, 21-44 and 209-217.

28. Introduction to the New Technology, in *Managing Technology in the '80s: Part 2 - Complete Proceedings*, LAMSAC, London, 1981, 12-22.

29. Technology and Employment: Long Waves in Technical Change and Economic Development, in H.S.D. Cole et al., (eds), *Methods for Development Planning: Scenarios, Models and Micro Studies,* UNESCO, Paris, 1981, 121-134.

30. Innovation as an Engine of Economic Growth: Retrospect and Prospects, in H. Giersch (ed.), *Emerging Technologies: Consequences of Economic Growth, Structural Change and Employment*, Proceedings of Kiel Symposium, 1981, J.C.B. Mohr (Paul Siebeck), Tübingen, 1982, 1-32.

31. The Economic Implications of Microelectronics, in C.D. Cohen (ed.), *Agenda for Britain 1: Micro Policy Choices for the '80s*, Phillip Allan, Oxford, 1982, 53-88.

32. (With J.F. Townsend and V.M. Walsh) The Determinants of Technical Change in the Chemical Industry: Demand-Pull or Technology-Push?, in S.F. Frowen (ed.), *Controlling Industrial Economies*, Vienna Institute for Comparative Studies (VICES), Macmillan, London, 1983, 83-108.

33. Technological Change and the New Economic Context, in S. Hill and R. Johnston (eds), *Future Tense: Technology in Australia*, University of Queensland Press, 1983, 47-67.

34. (With L.L.G. Soete) Cambio Tecnologico y Politicas de Ajuste, *Papeles de Economia Espanola* special edition on Politicas para una Recuperacion Prolongada, Raycar, S.A. Matilde Hernandez, Madrid, 1983, 386-395.

35. Long Waves and Technical Innovation, in *Proceedings of the TNO Conference on Technology and Economic Development*, TNO, Netherlands (1983).

36. Keynes or Kondratiev: How Can We Get Back to Full Employment, in P.K. Marstrand (ed.), *New Technology and the Future of Work and Skills*, Pinter, London, 1984, 103-123.

37. Long Waves of Economic Development, in T. Forrester (ed.), *The Information Technology Revolution*, Basil Blackwell, London, 1985, 602-616.

38. Innovation, in A. Kuper and J. Kuper (eds), *The Social Science Encyclopedia*, Routledge & Kegan Paul, London, 1985, 394-395.

39. (With L.L.G. Soete) Theories of the Long Wave, in G. Bianchi et al. (eds.), *Long Waves, Depression and Innovation: Implications for National and Regional Economic Policy*, IIASA, Laxenburg, 1985, 211-4.

40. (With L.L.G. Soete) New Technologies, Investment and Employment Growth, in *Employment Growth and Structural Change*, OECD, Paris, 1985, 52-83.

41. Technical Change and Unemployment, in *Executives Organizing Committee Report on the International Symposium on Microelectronics and Labour*, Tokyo, 1985.

42. The Role of Technical Change in National Economic Development, in A. Amin and J.B. Goddard (eds), *Technological Change, Industrial Restructuring and Regional Development*, Allen and Unwin, 1986, 100-115.

43. Information Technology as a Change of the Techno-Economic Paradigm, in *Neue Dimensionen der Information Perspektiven Für die Praxis*, Stuttgart, 1986, 48-62.

44. Policy Research for Science and Technology, in R.J. Blin-Stoyle (ed.), *The Sussex Opportunity*, Harvester Press, 1986, 190-205.

45. Innovation, Long Swings in Economic Growth, and Structural Unemployment, Contributions to *The New Palgrave*, Macmillan, London, 1986.

46. The Depression of the 1930s and its Relevance for the Contemporary World, in M Korner (ed.), *Wozu Geschichte und Wirtschaftsgeschichte? Einleitende Vortrage zum Kongress und zu den Arbeitsgruppen "Debates und Controversies"*, Neuvieme Congres International D'Histoire Economique, Berne, 1986, 69-94.

47. Technical Innovation, Diffusion and Long Cycles of Economic Development, in T. Vasko (ed.), *The Long Wave Debate*, Springer-Verlag, Berlin & Heidelberg,1987, 295-309 (adapted version in *The Bridge*, Summer 1986).

48. Technical Innovation, Long Cycles and Regional Policy, in K Chapman and G Humphreys (eds), *Technical Change, and Industrial Policy*, Blackwell, 1987, 10-25.

49. Western Europe's Research in Perspective, Introduction to Section 3: New Partnerships: Patterns of Science and Technology in Europe, in N. Calder (ed.), *Scientific Europe: Research and Technology in Twenty Countries*, Nature and Technology, Netherlands, 1987.

50. The Case for Technological Determinism, in R. Finnegan et al. (eds), *Information Technology: Social Issues: A Reader*, Hodder and Stoughton, 1987, 5-18.

51. The Challenge of New Technologies, in *Interdependence and Co-operation in Tomorrow's World*, Proceedings of a symposium marking the twenty-fifth anniversary of the OECD, OECD, Paris, 1987, 123-156.

52. Diffusion: The Spread of New Technology to Firms, Sectors and Nations, in A. Heertje (ed.), *Innovation, Technology and Finance*, Basil Blackwell, 1988, 38-70.

53. Quantitative and Qualitative Factors in National Policies for Science and Technology, in J. Annerstedt and A. Jamison (eds), *From Research Policy to Social Intelligence: Essays in Honour of Stevan Dedijer*, Macmillan, 1988, 114-128.

54. Innovazione Tecnologica, Cicli Lunghi e Politiche Regionali, in F.Belussi (ed.), *Innovazione Tecnologica ed Economie Locali: il Caso del Veneto*, Milan, Franco Angeli, 1988, 41-56.

55. Japan: A New National System of Innovation, in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory*, Pinter, 1988, 330-348.

56. Introduction, in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory*, Pinter, 1988, 1-8.

57. Preface to Part II: Evolution, Technology and Institutions: a Wider Framework for Economic Analysis, in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds), *Technical Change and Economic Theory*, Pinter, 1988, 9-13.

58. (With C. Perez) Structural Crises of Adjustment: Business Cycles and Investment Behaviour, in G. Dosi, C. Freeman, R.R. Nelson, G. Silverburg and L.L.G. Soete (eds), *Technical Change and Economic Theory*, Pinter, 1988, 38-66.

59. Induced Innovation, Diffusion of Innovations and Business Cycles, in B Elliott (ed.), *Technology and Social Process*, Edinburgh University Press, 1988, 84-110.

60. Information Technology and the New Economic Paradigm, in H. Schutte (ed.), *Strategic Issues in Information Technology: International Implications for Decision Makers*, Pergamon Infotech Ltd, 1988, 159-176.

61. Technology Gaps, International Trade and the Problems of Smaller and Less Developed Economies, in C. Freeman and B-A. Lundvall (eds), *Small Countries Facing the Technological Revolution*, Pinter, 1988, 67-84.

62. Technische Innovationen, Ihre Verbreitung und Lange Zyklen der Wirtschaftsentwicklung, in W. Sydow (ed.), *Technologien im Umbruch*, Berlin, 1988, 128-147.

63. (With C Perez) Long Waves and Changes in Employment Patterns, *Proceedings of ALC Conference on Structural Change and Labour Market Policy*, Stockholm, 1988.

64. Preface, in J. Perrin, *Comment Naissent les Techniques*, Editions Publisud, Paris, 1988, 11-13.

65. Introduction: Measuring the Japanese Challenge, *Scientific Europe: Research and Technology in 20 Countries*, Scientific Publishers Ltd, 1989.

66. International Trends in Science and Technology: A View from UK, in B. Abu-Laban (ed.), *University Research and the Future of Canada*, University of Ottawa Press, Edmonton, 1989, 435-457.

67. Preface, in M. Dodgson (ed.), *Technology Strategy and the Firm: Management and Public Policy*, Longman, 1989, v-vi.

68. R&D, Technical Change and Investment in the UK, Chapter 11 in F. Green and S. Aaronowitch (eds), *The Restructuring of the UK Economy*, Harvester, Brighton, 1989.

69. The Third Kondratieff Wave: Age of Steel, Electrification and Imperialism, in J. Bohlin et al. (eds), *Samhällsvetenskap, ekonomi och historia: Festskrift till Lars Herlitz*, Daidalos, Gothenburg, 1989, 281-318.

70. Comments, in Joseph Stiglitz et al. (eds), *The Economic Role of the State* Bank Insinger de Beaufort NV, Amsterdam, 1989, 135-143.

71. The Diffusion of Biotechnology through the Economy: The Time Scale, in *Bio-Technology: Economics and Wider Impacts*, OECD, Paris, 1989, 45-55.

72. Technical Change and Depression in the 1930s and 1980s, in M. di Matteo, R. Goodwin and A. Vercelli (eds), *Social and Technological Factors in Long-Term Fluctuation*, Lectures in Economics No.321, Springer Verlag, Berlin & Heidelberg, 1989.

73. (With L. Soete) Information Technology and the Global Economy, in J. Berleur, T.R.H. Sizer, D. Whitehouse and A. Clement (eds), The Information Society: Evolving Landscapes, Springer Verlag, Berlin and Heidelberg, 1990, 278-294.

74. Measuring the Japanese Challenge, in N. Calder (ed.), *Scientific Europe: Research and Technology in 20 Countries*, Maastricht: Foundation Scientific Europe, 1990, 80-83.

75. Schumpeter's 'Business Cycles' Revisited, in A. Heertje and M. Perlman (eds), *Evolving Technology and Market Structure: Studies in Schumpeterian Economics*, University of Michigan, Ann Arbor, 1990, 17-38.

76. Preface, in J. de la Mothe and L.M. Ducharme (eds), *Science, Technology and Free Trade*, Pinter, London, 1990, xi-xiii.

77. Technical Innovation in the World Chemical Industry and Changes of Techno-economic Paradigm, in C. Freeman and L. Soete (eds), *New Explorations in the Economics of Technical Change: Global Competition and the Environment in the 1990s*, Pinter, London, 1991, 74-91.

78. (With G. Oldham) Introduction: Beyond the Single Market, Chapter 1 in C. Freeman, M. Sharp and W. Walker (eds), *Technology and the Future of Europe*, Pinter Publishers, London, 1991, 3-17.

79. The Nature of Innovation and the Evolution of the Productive System, in *Technology and Productivity: The Challenge for Economic Policy*, OECD, Paris (1991), 303-314.

80. Developing Technological Capability in a Competitive World, in *Proceedings of the Technology and Reconstruction Colloquium*, University of Cape Town, 1991, 126-142.

81. Die Zukunft der ökonomischen Wissenschaft (The Future of Economics), in H. Hanusch and H.C. Recktenwald (eds), *Ökonomische Wissenschaft in der Zukunft*, Verlag Wirtschaft und Finanzen, Dusseldorf, 1992, 147-153.

82. Formal Scientific and Technical Institutions, in B-Å Lundvall (ed.), *National Systems of Innovation*, Pinter, London, 1992, 167-187.

83. Foreword, in R. Bentley, *Research and Technology in the Former GDR*, Westview Press, Boulder and Oxford, 1992, xiii-xiv.

84. Catching up in World Growth and World Trade, in M. Nissante and A. Hewitt (eds), *Economic Crisis in Developing Countries: New Perspectives on Commodities, Trade and Finance (essays in honor of Alfred Maizels)*, Oxford University Press, Oxford, 1992.

85. Foreword, in C. Antonelli, P. Petit and G. Takar (eds), *The Economics of Industrial Modernization*, Academic Press, London, 1992, vii-viii.

86. (With L. Soete) Conclusions, in D. Foray and C. Freeman (eds), *Technology and the Wealth of Nations: the Dynamics of Constructed Advantage*, Pinter, London, 1992, 389-400.

87. Introduction to Part I, in D. Foray and C. Freeman (eds), *Technology and the Wealth of Nations: the Dynamics of Constructed Advantage*, Pinter, London, 1993,25-28; (French version, Introduction de la partie I, in D. Foray and C. Freeman (eds), *Technologie et Richesse des Nations*, Verlag Bild-Kunst, Bonn, 1992, 41-46).

88. (With J. Hagedoorn) Global Perspective 2010: Tasks for Science and Technology, in *Global Perspective 2010*, Vol. 3-4, CEC, Brussels, 1992, 1-79.

89. Interdependence of technological change with growth of trade and GNP, in M. Nissanke and A. Hewitt (eds), *Economic Crisis in Developing Countries*, 1993, Pinter, London, 157-177.

90. Science Policy, in W. Outhwaite and T. Bottomore (eds), *The Blackwell Dictionary of Twentieth-Century Social Thought*, Blackwell, Oxford, 1993, 567-568.

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