TRANSFER PROCESSES
N TECHNICAL CHANGE

SIJTHOFF & NOORDHOFF

TRANSFER PROCESSES IN TECHNICAL CHANGE

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PREFACE

This book is about a group of activities usually referred to as "technology transfer" and much of the material it contains was first presented at a meeting held at the University of Stirling in July 1974 which brought people together to discuss "Technology Transfer – Research and Implementation". What happened at that meeting, and in subsequent discussions convinced the four authors that they needed to put a new label on the technology transfer bottle. The objective of the meeting, or more correctly the objective we ascribed to the meeting in the preliminary publicity, was stated thus:

To exchange ideas on concepts of technology transfer and the ways in which research and analysis can make an effective contribution to improving technology transfer performance. It is hoped to provide a forum for discussion for all those concerned with technology transfer, whether they be producers or receivers, policy makers or "catalysts", or researchers.

The composition of the audience attracted to the meeting is an indication of the interests and expectations that such a description aroused. Government, represented by Departments, Laboratories and other institutions, provided 11 people, industry and professional bodies 9, research associations and the National Research Development Corporation 4 and universities 19.

The occasion turned out to be one of more than usual significance because of timeliness of the discussions concerning the scope of the subject. The structure of the meeting was to group papers into sessions and for each session chairman to draw on these to emphasise the points he perceived to be important. The format afterwards adopted for extracting the learning that had occurred was the basis for this book. Some of the presented papers (but not all) are printed in Part II; Part I is an extended introduction and analysis of the papers and their discussion. We have not attempted to report the very lively exchanges of the meeting in verbatim terms.

Instead we have made free use of the medley of ideas and comments to form the basis of the opening six chapters. Whilst the authors take full responsibility for the views expressed they are grateful to all participants for their contribution. At the possible cost of distorting the views of speakers we have gained freedom to put together what was said in our own way alongside and interwoven with our own ideas; and, whilst we paid great attention to the transcripts of what was said, we avoided the interminable task of trimming, elaborating and updating the material to meet the current views of individual contributors.

How far the objectives stated above were achieved may be assessed by the readers. The authors feel that progress was enough to make an analysis of the main ideas and a presentation of a selection of the papers worthwhile. The book is the result of many months of drafting during which time ideas have developed and understanding increased.* The subject of transfer processes in technological change is and will remain in a very immature state in these early years. It is for this reason the proceedings and commentary are presented here with minimum of structuring. We hope that those interested may glean a useful idea or two to assimilate into their own thinking and understanding of what is indisputably a contemporary issue of major importance.

We wish especially to thank Dr. E.J.P. Clarke (Atomic Energy Research Establishment, Harwell) and Mr. Keith Pavitt (University of Sussex) for the valuable assistance they gave in chairing sessions.

Manchester, Oxford, Stirling
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* The authors are glad to observe that this is now clearly happening in the area of U.K. technology policy and industrial strategy, outdating some of our comments, especially in Chapter 3. However, the debate on technology transfer, its analytical, methodological and prescriptive problems, continues to grow so that what was written here becomes more, not less, significant with the passage of trial. (August 1975.)

FOREWORD

In the post-war world the overwhelming importance of technical change has been universally recognised. Whether in relation to military affairs, industrial production, consumer appliances, medical services or environmental protection scarcely anyone could fail to be affected by the new products and systems which have become available.

No single firm or small country could possibly hope to make more than a small proportion of the important advances in science and technology. Even large countries find it hard to keep abreast or achieve leadership in every branch simultaneously. Yet the pressure of international competition imposes severe penalties on those who do not keep close behind the leaders. In these circumstances it is scarcely surprising that the question of "technology transfer" has assumed much greater importance in recent years.

Transfer of technology has many different dimensions. It is obviously important between countries in every field of industrial technology. The successful industrialisation of may third world countries has been based to a very large extent on imported technology. The earlier industrialisation of Japan and the Soviet Union also depended to a very large extent on this process. But the transfer of technology is vital not only for countries who were once far behind and are catching up; it is no less important between countries and firms who are among the leaders, for example in relation to nuclear power, micro-electronics and telecommunications.

The available channels for the transfer of technology have greatly increased in range and capacity in the post-war world. The spread of multi-national enterprises around the globe is now a common place. The ease and speed of travel and communications have greatly facilitated the spread of information systems of all kinds. Payments for patents, licences and know-how have increased at an extraordinarily rapid rate for 30 years. International consultancy is a booming industry.

Yet despite this vast increase in technology transfer activities, very little was known until recently about the relative importance of the various different mechanisms, and still less about their relative efficiency. Cooper's study for the UN was one of the very few which attempted this elementary analysis and assessment.

This book is one indication of the increasing recognition by academics, industrialists and governments that the subject deserves a great deal more attention, discussion and research. The seminar was an extremely lively one, but the editors have resisted the temptation simply to produce a verbatim transcript of the proceedings. Although quick and easy to produce, such a report is always far more boring to the reader than to the actual participants in the seminar. There is an unbridgable gap between oral and written communication. The editors have done something far more useful: in presenting carefully selected excerpts from the various papers, they have produced a new analysis of the whole field which will be helpful to all students of this topic.

As both the analysis and the papers make clear, international technology transfer is only one dimension of a much more complex set of activities, which include internal transfers within laboratories, firms and industries, the web of relationships between scientists and technologists, and the complex interchange between government, universities and industries. We are still only at the beginning of undertaking this complex network, but Professor Bradbury and Stirling University are to be congratulated for organising this genuinely seminal meeting and still more for producing this carefully edited book as an invaluable starting point for much future work.

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INTRODUCTION

The Concept of Technology Transfer

1.1 The current interest in the concept of technology transfer reflects its perceived relevance to a range of different interests. In government, there is concern over the level of return on large investments of public money in research and development (hereafter R & D) and high technology, associated with the belief by some that there has been too much concentration on the production of knowledge and too little on its utilisation. Trade in technology is another important issue, both as an export because of its immediate contribution to the balance of payments and its possible long-term economic disbenefits, and as an import as an alternative strategy to R & D – led technological development. For nations of the Third World, the transfer of technology is seen as a vital aid to development and there is concern over the role of multinational enterprises in assisting or hindering the achievement of this goal. There are many signs of increasing public concern with the type of technological development that has occurred over the past two or three decades. It is now suspected that the type of technological novelty which has traditionally been sought may be inappropriate for the resolution of the pressing social issues of today, and consequently that mechanisms need to be devised to direct resources to a new range of problems such as those raised in the provision of adequate housing, transport and health care. This concern is demonstrated by the popularity of the writings of authors such as Schumacher [1] and Pirsig [2].

Definitions

1.2 In order to sharpen our understanding of the concepts associated with the movement of technology and its related science and engineering we must undertake some definitions.

Definitions, in so far as they attempt to describe a complex system in a sentence, are heroic things at best and utterly confusing at worst. No clearer exemplification of this could be found than in the literature and at meetings about technology transfer. One common definition is "the process by which a technology is applied to a purpose other than the one for which it was originally intended" or, in other words, "Technology transfer is putting technology into a different context". This view reflects the origins of the term "technology transfer" in the United States where since 1940 the federal government has been responsible for the direction of a steadily increasing share of national R & D resources, primarily for achieving military, space and atomic energy goals. This progressive concentration of R & D resources has raised warnings of consequent damage to the economy and to the achievement of broad social goals. The standard defence has been that this federal expenditure has created a vast technology that has been or could be transferred to the civilian economy, thereby maintaining economic growth as well as supplying funds to achieve other national goals. Hence evidence which suggests that "spin-offs" are both infrequent and suffer from long time-lags [3] [4] has induced a search for policies to ensure the maximum transfer of information and technology resulting from federally financed R & D. In this situation, "technology transfer" could be interpreted as a political response to maintain the hegemony of the defence, aerospace and atomic energy agencies over federally funded research.

1.3 Brooks has offered a wider definition of technology transfer [5]

> "Technology transfer is the process by which science and technology are diffused throughout human activity. Wherever systematic rational knowledge developed by one group or institution is embodied in a way of doing things by other institutions or groups we have technology transfer. This can be either transfer from more basic scientific knowledge into technology, or adaptation of an existing technology to a new use. Technology transfer differs from ordinary scientific information transfer in the fact that to be really transferred it must be embodied in an actual operation of some kind."

Brooks extends this discussion to recognise two types of transfer, which he designates as "vertical" and "horizontal". Vertical transfer is the process by which technology is transferred from the more general to the more specific, for instance by the incorporation of new scientific knowledge into technology and by the embodiment of a "state of the art" into a system. Horizontal transfer involves the adaptation of a technology from one application to another, as in the adaptation of a laboratory analytical instrument for on-line process control, and hence corresponds to the more restricted notion of technology transfer first introduced.

This suggests that it is not satisfactory merely to think of technology transfer as one single type of process, and the distinction that Brooks draws between technology transfer and scientific information transfer is a sharp reminder that no definition can be considered adequate unless it encompasses the thing that is being transferred, as well as its source and destination. We will return to the Brooks' definition later in the chapter.

1.4 A survey of research on the subject of technology transfer reveals that the term has been adopted over a wide range of fields, sometimes in order, one suspects, to give a new look to some well worn ideas. Areas to which the concept has been applied include the examples already given, transfer from industrialised nations to less developed countries, from the western industrialised countries to those in the Communist bloc, transfer between companies, and transfer problems that occur between departments or groups within a single organisation. It is also used to describe the professional activities of those engaged in licensing. The phrase "technology transfer" is applied so universally that in fact it becomes a featureless and all enveloping cloak which disguises the characteristics of those who wear it.

Resolving the problem of definition is important, because it identifies the problem to which the researcher or decision maker intends to address himself. Grouping phenomena ranging from invention, innovation and diffusion to international trade, licensing and the activities of international firms produces such a complex and variegated system that analysis becomes almost impossible; by selecting a definition we are defining for study a sub-set of the system of problems (a phrase coined by R.L. Ackoff [6]). We need to find a way of describing the diverse activities previously called Technology Transfer so that a clearer picture of the scope and boundaries of the area emerges. The definition must be flexible without being indiscriminate and selective without being over-narrow.

What is Technology?

1.5 As we recognised above, the definition of both "technology" and "transfer" must be agreed before technology transfer can be analysed. What then is technology? If we start with Donald Schon's wide definition of technology [7] as "any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capability is extended"

and if we ask what is this something which extends human capability we are likely to come to the view that technology is the body of practical knowledge techniques and equipment which people use to enlarge their work power, their ability to overcome constraints, their dominance over natural forces. The paper by Bell and Hill (Chapter 18) develops this view of technology in some detail.

1.6 If we move on to ask what is technology made of, the answer is simply technology. We have a nest of dolls situation; as you take apart any technology, you find many more technologies inside and many more inside each of these. Think of a process plant for making the weedkiller paraquat – a piece of innovation in which one of the authors was intimately concerned. Sodium is reacted with pyridine to make an intermediate which is further processed through a number of stages to produce the weedkiller. The paraquat manufacturing technology not only contains some important parts of sodium handling technology, it also depends completely on the existence and functioning of that technology for a vital material supply; likewise for pyridine and all other chemical materials used. Furthermore, every vessel, pipe and instrument on the process plants embodies other technologies. Of course, the paraquat plant is more than its component technologies just as any system is more than its parts.

Staying with this weedkiller it is easy to see how, in extending the capability of the farmer in matters of weeding and ploughing and seeding, the paraquat technology becomes embodied with, and in, a whole array of farming technologies. For example, it changes farming practice, maybe radically, by replacing the plough by a chemical, and it may demand parallel creation of enabling technologies such as special equipment for its application. Nonetheless, the net effect is simply to add one more piece of technology to an existing array; technology is absorbed into other technology, very probably displacing some existing technologies in the process.

But if we accept a definition as broad as Schon's, then almost anything which might be the subject of a transfer process could be called "technology". And if we allow this we run the risk of covering up differences once again. For instance many authors have found it necessary to distinguish "science" from "technology", and Brooks has postulated boundaries for technology and argued from this that many things lie outside the definition of technology

> "technology is essentially a specifiable and reproducable way of doing things ... the term technology does not span the whole domain of human action but only that part which can be specified in a replicable way. Thus it excludes many human skills and arts which, at least at the present time, cannot be codified, but must be learned from experience and by doing."

We do not accept the limitation that Brooks imposes on the concept of technology; much of human capability lies in the exercise of craft skills which can certainly not be codified but which nevertheless can be transferred. *Bricolage* is a term used by Levi-Strauss to denote a non-professional and instinctive craftsmanship. On this Sypher writes [8]. "A great deal of Leonardo da Vinci's work in both art and science was *bricolage*; the charge has been made again and again that Leonardo was a failed scientist because he never sustained his inventiveness by theories, which is only one way of saying he was not academic." *Bricoleur* Leonardo may have been but there is no denying his claim to being a technologist of the greatest eminence. The implication of these various views about the definition of technology is that there is no easy way of defining the word so that it will help us put boundaries around the phenomena we are seeking to understand. A broad definition encompasses everything, without illuminating it, while a narrow definition excludes many types of activity which people clearly feel the need to discuss at meetings on "technology transfer". If we have to argue that a person's experience or problems are not relevant because he is discussing not "technology" but "science" or "information" then, while we may take our own semantic problems easier, we serve very little purpose.

1.7 With so much variation between the various definitions of technology it is hardly surprising that a variety of different views have been advanced about the activity of transfer. For instance Price, [9] having distinguished between science and technology discussed at length the way that each develops and evolves, building on previous knowledge within its own field, with relatively little cross-fertilization between science and technology. Similarly Gibbons and Johnston [10] have shown that the ways organisations interact with and use sources of technological information differ from the way they interact with scientific sources, and we have seen above that Brooks differentiates sharply between technology transfer and scientific information transfer. If we return to our example of the development and adoption of paraquat technology and examine the process from the developers' viewpoint rather than the users' we can see differences in the various transfer processes involved. These are differences of degree rather than kind, but significant ones nevertheless. In the early stages of innovation, invention and development, technologies and science and engineering are deeply implicated, being absorbed in the emerging new system or innovation. The inventor is aware of existing weed control technologies, he is aware of existing chemical technologies, of chemistry, of physics, of engineering, all of which he draws upon to extend his capability as an inventor. The designer calls on the technologies of computing, of drawing, of testing and so on, and the plant constructor has access to an array of construction and fabrication skills and techniques. The whole operation of innovation viewed as the progress from "invention" to "technology in the hands of the user" is characterised by identification, selection and absorption of relevant technologies, science, know-hows and skills. It is not surprising, therefore, that delegates at technology transfer symposia will insist on discussing innovation processes at their meetings. Our discussion of paraquat technology suggests that conceptual models of innovation should be surrounded by arrows indicating the input of existing technologies (and science) into the process. This idea is shown at least in part, in one of the earliest and most widely quoted models of innovation, by Myers and Marquis, (Figure 2.1) [11] and perhaps more explicitly in a recent one by Jervis (Figure 1.1).

1.8 We accept that there is as yet no completely satisfactory way to codify and describe some parts of our broad category of technology, especially those components which are bricolage. Because of this their transfer can only be achieved, as Brooks' states, by experience and by action. We will return later to the technology transfer learning process but before leaving the Brooks' definition, we must observe that it is precisely the view that a technology can be specified in a replicable way that leads to an underestimation of the problems of transferring it to less developed countries, (LDCs) a case strongly argued in Bell & Hill's paper and discussed further in Chapter 2. But the major consequence of our discussion is that, however we operate on the words "technology" and "transfer" we make little progress towards a clearer view of the field of play.