Government policy for technology transfer: an instrument for industrial progress

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Abstract. Noting the growing interest in technology policy as an instrument for improving industrial performance, this paper examines the role of technology transfer in technology policy. The concentration on the transfer of the results of R & D carried out in government organizations is criticized and a case made for a broader view. The vital role of the technological infrastructure in promoting transfer processes is explored and a 'transfer' model for radical innovations proposed. Policy implications are drawn from these research findings.

The concern in the industrialized nations with the problems of maintaining an effective industrial base for economic growth is reflected in the emergence of the concept of technology policy alongside the more traditional groupings of economic instruments. The goal of technology policy of promoting industrial growth and efficiency is necessarily pluralistic requiring the incorporation of a number of diverse policy fields, such as fiscal, manpower and science and technology, and the involvement of a variety of distinct governmental, and other, institutions. Thus, as noted in a recent report (OECD, 1975), technology policy should be envisaged less as the establishment of mechanisms for the rational determination of priorities than as a focus of attention on a set of objectives related to industrial activity and development.

Further emphasis is added by the publication in the past twelve months of three major reports examining various aspects of the state of technology policy in the U.K. (Pavitt and Walker, 1976), the U.S.A. (Gilpin, 1975) and the nations who are members of the OECD (OECD, 1975). In each one considerable stress is placed on the need for the more effective formulation and evaluation of policies in this area. The primary issues in need of detailed examination, in the U.K. context, are asserted to be:

'(a) the history and effectiveness of U.K. Government support for the high technologies;
(b) the economic effects of government funding of commercial development activities in industry;
(c) the factors influencing the usefulness to industry of government-financed scientific research and related activities;
(d) the factors influencing the propensity and competence to innovate in U.K. industry, particularly outside the high technology industries.'

(Pavitt and Walker, 1976)

THE NEED FOR TECHNOLOGY POLICY

Before proceeding to an analysis of the place of technology transfer in technology policy, we need to have an understanding of why governments should concern themselves with technological advance and seek to formulate policies with respect to it.

The often unspoken assumption underlying government intervention in the private sector is that market forces cannot be allowed to operate unchecked in a modern world mixed economy. Thus Young argues:

> 'From the standpoint of industrial efficiency market forces cannot be relied on to solve the basic economic problems by ensuring through a process of spontaneous adaptation that maximum use is made of resources in both declining and expanding sectors. Governments resort to intervention as a means of prodding strategic parts of the economy. They try to iron out deficiencies such as under-utilization of assets and the laying-off of skilled men at one stage of the economic cycle, and labour and materials shortages when factories are approaching full capacity at the other end of the cycle.'
>
> (Young, 1974)

In other words, because the disbenefits of the economic cycle can no longer be accepted, whether for economic or social reasons, government is forced to intervene.

Pavitt and Walker (1976) offer a more detailed classification of 'imperfections'[1] of the market system which may justify government intervention.

'(i) Management imperfections resulting from lack of technical competence within industrial firms or from lack of knowledge about the essential organizational ingredients for successful innovation;
(ii) Knowledge imperfections amongst potential buyers of innovations, especially in consumer goods and in government service markets;
(iii) External social costs of innovations in terms of safety, health, amenity and job satisfaction;
(iv) Inadequate or inappropriate economic incentives and rewards for desirable innovations, resulting from the general industrial climate or from the degree of competition or monopoly, or from the workings of the patent or the tax system;
(v) Inadequate investment, from a national point of view, by industrial firms in longer-term, more radical innovations, because of short-term time horizons and risk aversion, or cost.'

(Pavitt and Walker, 1976)

Thus with the emergence of the mixed economy and the notion of planning, the role for government in promoting eco-

[1] It should be apparent that imperfections are social rather than natural categories, i.e. what is perceived to be an inadequacy depends itself on international trade, economic competitiveness, social milieu, etc.

nomic growth and limiting the social disbenefits thereof, has become a central plank of modern industrial society. More latterly, with technological entrepreneurship being seen as the chief dynamic in economic growth, attention has particularly focused on policy for technology, *per se.* However, the importance of technology transfer for technology policy has yet to be realized.

THE CONTEMPORARY VIEW OF TECHNOLOGY TRANSFER

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 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 utilization. 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 multi-national enterprises in assisting or hindering the achievement of this goal. Within the public there is concern that the sort of technological novelty stimulated by the patent system is inappropriate for the resolution of the pressing social issues of today and consequently 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.

The term 'technology transfer' originates 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 (Etzioni, 1964; Solo, 1962; Bloomfield, 1962). 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, not only maintaining economic growth but supplying funds to achieve other national goals. Hence evidence which suggests that 'spin-offs' are both infrequent and suffer from long time-lags (Doctors, 1969) 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.

Technology transfer is currently used as a blanket term to cover a wide range of activities. These include information flow from the laboratory through the various appropriate departments of a firm to production, marketing and diffusion of innovation, shift of knowledge from 'production'-oriented to application-oriented institutions, application of a technology to a purpose other than the one for which it was developed, licence or sale of technology produced in the industrialized nations to companies in the communist bloc or in developing countries, and at the most general the process by which science and technology are diffused throughout human activity. Indeed, the fashionability of the term is so pronounced that it was recently noted that technology transfer has become a 'featureless and all enveloping cloak which only succeeds in disguising the characteristics of those who wear it' (Bradbury *et al.*, 1976).

The one element common to all these activities is the shift of knowledge, embodied in one form or another, across an interface between two environments which differ in some respects from one another. To reduce confusion, the more general term 'technology processes in technical change' has been coined (Bradbury *et al.*, 1976). 'Technology transfer' is restricted to its original sense of the application of technology to some purpose different from that for which it was first developed. This more general concept is to be preferred as it leads to a focus on the aspect which is common to all the interests previously mentioned, yet at the same time distinguishes those features which are specific to a particular environment, interface, type or embodied form of knowledge. This shift in definition can be coupled with a shift in emphasis from promoting bonus spin-off benefits from existing R & D programmes to transfer processes aimed more directly at meeting social needs whereby the contributions technologies can make to extending human capability in chosen areas are identified and appropriate transfer processes facilitated.

The major studies of the role of governments in the transfer of technology have focused on the dissemination of information produced or stored within particular departments or agencies. Thus Doscher (1974) has noted the efforts to transfer technology in the U.S. by the Departments of Agriculture and Defence and NASA, the Atomic Energy Commission, and the Small Business Administration and concluded that 'technology transfer programs are generally created and implemented by mission agencies having significant research and development support programs'.

Doctors (1969), in a more extensive study of the horizontal transfer of technology from mission agencies in the U.S. has argued that technology originating in government agencies is predominantly sophisticated quality – rather than cost-oriented. As a result successful transfer is likely only to those organizations in those industries capable of handling high-cost, science based technology.

Within the U.K., the corresponding goal of policies for technology transfer has been 'the encouragement of Government research establishments to act on a commercial basis as agencies for private manufacturing industry not only in the R & D phase, but also in the later stages of the innovative chain' (Zuckerman, 1968).

The most notably successful has been the Harwell laboratory of the Atomic Energy Authority, such that it is now held up world-wide as a shining example of what can be achieved (Clark, 1974; Fishlock, 1973).

It should be apparent from this review that policies for technology transfer have been restricted, by and large, to the transfer of information produced within government agencies. In practice, the application of the customer-contractor principle at Harwell, for example, has resulted in the generation of knowledge specifically attuned to a particular user's needs. Still, the focus is almost exclusively upon the R & D process.

Why such a concentration on this one aspect? I would argue that it is a result of a widespread confusion which conflates technology with R & D. Its origin can perhaps be traced to what has been called the 'Scientific Opportunity Syndrome' (Mencher, 1975), which is based on the belief that all national requirements can be met by using available, or by developing new, technology and that the identification and development of the appropriate technological solution is a task for scientists and technologists alone. Despite the demonstration of the frequently minor role of R & D in the innovation process, the assumption of a linear process of technological innovation from research, or science, to application, still appears. This is particularly evident in studies purporting to be of the relationship between technology and economic growth, which are concerned only with the levels and performance of R & D, in particular, that sponsored by government. This criticism is not intended to suggest that evaluation of government supported R & D is not important. However, in the context of technology policy it needs to be viewed as just one interacting element of a more complex system.

Once it is fully accepted that technology has no necessary and inevitable connection with research, the scope for technology policy in general and for policies to promote technology transfer in particular, are considerably widened. A range of regulatory and non-regulatory measures can be envisaged with such goals as promoting an industrial structure appropriate for optimum transfer, concentrating resources in key industries and assisting in the establishment of appropriate supportive institutions designed to promote transfer between industries and from industrial to public sector, and vice versa.

In the following sections the research base will be examined for guidance to the formulation of policies to promote the transfer of technology appropriate to the achievement of national goals, such as economic growth, or improvement in the 'quality of life'.

THE TECHNOLOGICAL INFRASTRUCTURE

In any country a wide variety of institutions is involved in the production, storage and adaptation of knowledge necessary for the development of technological capabilities. Rather than deal with each of these separately, the term 'scientific infrastructure' has been coined to denote 'the network of public and semi-public institutions whose interests focus on R & D, higher education in science and technology, information gathering and distribution and technological extension services to industry' (Clark, 1971). I wish to develop this concept under an alternative heading of technological infrastructure, to avoid the bias to R & D previously noted, and to include not only the traditional knowledge-oriented institutions such as university departments, government research establishments, research associations and professional societies, but also those which collect and transfer information in the pursuit of other tasks, such as professional consultancies, trade associations and technical service and sales agents.

The importance of this infrastructure in the economic, and in particular, the innovative performance of industry has been demonstrated in a number of cases. Shimshoni (1966) has shown that ready access to a well developed research network can have the effect of reducing the costs of acquiring market knowledge, providing the level of communication necessary for the technical exchange between buyer and seller necessary in sales of technologically intensive products, allowing access both to specific research results and informally to the general state-of-the-art of an appropriate field, attracting a pool of highly skilled manpower and making available risk capital from a financial community with understanding of the problems and risks of scientific entrepreneurship.

In a different context, it has been shown that universities can make significant contributions to industrial innovation not only through the performance of general research to provide an adequate knowledge base and contract research to resolve specific problems, but also in the provision of a pool of suitably qualified manpower, of a body of independent advice and expertise, and of a range of both general and specialist facilities (Johnston, 1974). Other studies have been made of the role of the research associations (Johnson, 1973). However, rather than examining the value of each individual element, I want to emphasize it is the performance of the overall infrastructure, the elements of which can have a relationship ranging from symbiotic through neutral, and parasitic to antagonistic, which is critical in the innovative performance of an industry.

Thus the technological infrastructure operates by providing a supportive service to industry. This consists not only of the general provision of basic knowledge which may create the technological opportunity for innovation and the provision of a range of adequately trained manpower, but a much more specific contribution to the resolution of particular problems, advice about possible innovations, information about competitors' new products and developments, availability of new components and raw materials, and advice concerning new markets. As well as promoting and assisting the innovation process, the infrastructure, perhaps even more importantly, assists considerably in the diffusion of 'best-practice' throughout an industry. From the discussion of the previous section, it should be apparent that the establishment and maintenance of an effective technological infrastructure is also of vital importance in all transfer processes.

The mere existence of a well-established and organized technological infrastructure within an industry does not automatically mean that all firms can gain access to it. There is a price to pay in terms of the need for the individual company to develop and maintain the capability to draw on, and contribute to, the infrastructure. The means by which organizations wishing to disseminate information can reduce institutional barriers and promote transfer are by now well known (Bradbury *et al.*, 1976), but it has been shown that both capability and interest are needed by the receiver. Though the transmitter can arouse interest, ultimately it is only receiver-led transfer processes which have proved effective.

The importance of this infrastructure in the provision of both supporting information and appropriately trained manpower, ranging from the managerial section through the R & D, marketing and production divisions, has been demonstrated (Bell and

Hill, 1976) in another context. In any process involving technical change there are large numbers of secondary perturbations throughout the various systems of the firm. For example, production may have to cope with tighter quality control standards and the necessary monitoring systems will have to be instigated or adapted. Marketing may require a new approach or even a new type of outlet for a different product. Changes in factor prices may require management action. All of these adaptations will require technical skill and know-how. Thus for a technologically innovatory industry, one of the important factors determining their rate of advance is the existence of a fully developed and efficient technological infrastructure into which the majority of companies are firmly coupled. Insufficient is known about its establishment and the conditions under which this coupling is developed, though examples described below do suggest some possible implications for technology policy.

The operation of the technological infrastructure has so far been considered at the level of both the industry and the firm and it is clear that it is only by assessments at these two levels that some insight into its operation can be gained. However, at a more general level there is evidence to suggest that the infrastructure in the U.K. is rather more fragmented than in many of its competitors, i.e. that the separation between the major sectors of the universities, government research establishments and industrial firms is considerable. As an example to support this assertion, the level of inter-sectorally funded research, i.e. research funded in one sector and performed in another was higher in countries such as the U.S.A., Germany and Japan when compared with the U.K. (OECD, 1975b). While such data can only be indirect indicators, and there is an undoubted need for further examination of this question, it does appear that the traditional policy of self-sufficiency in each of these sectors has had the effect of placing major barriers in the technological infrastructure and seriously reduced the flow of knowledge on paper, by personal contact, embodied in manpower and various forms of technology, from one sector to another.

The research associations represent a fairly unique element of the technological infrastructure in the U.K. Until 1970 these government-supported institutions were charged with the provision of advice and services to their relevant industry. With the Conservative government's attempt to implement disengagement there arose a shift in considerations from a basis of cost benefit to one of cost effectiveness, and the RAs were required to become, at least to a large extent, self-supporting (Bessborough, 1973). The principle, now widely established (Rothschild, 1971) that the customer should determine the nature of the research he needs appears an effective form for establishing accountability, but the impact on the flow of information through the infrastructure is in need of careful examination. Preliminary studies of a selected number of RAs suggest that the predominant strategy they have adopted may not be in the long-term interests of British industry. This is to use their considerable expertise to assist in the transfer of established U.K. production processes to the developing countries. There can be no doubt that a great deal of adaptory innovation is necessary to effect such transfers and that in the short term they may make a considerable contribution to the balance of payments, but such a strategy contributes relatively little to the rejuvenation of an industry. Closer examination may, of course, reveal that in certain declining industries, such a response is indeed the only viable one.

Thus there is a need for the policy-maker to be aware of the impact of any changes on the operation of the technological infrastructure and in a more positive sense, to be aware that in the absence of an effective infrastructure, fiscal and exhortatory incentives are liable to have relatively little effect on technical progressiveness in the long term. For it provides a vital enabling mechanism for the wide range of transfer processes shown to be of key importance in industrial development.

A 'TRANSFER' MODEL OF TECHNOLOGICAL DEVELOPMENT

The transfer processes examined so far have been shown to facilitate the process of incremental innovation. There is another major role, however, in the 'transfer' of radical innovations and major technological capabilities from one industry to another. There follows a necessarily brief description of one such major technological advance, *viz.* the introduction of man-made fibres into the textile industry in the U.K. which is used to examine the role of transfer, and the technological infrastructure, in such developments (Anderson, 1976; Anderson and Johnston, 1976).

Throughout this century the traditional British textile industry has been in steady decline. Output, exports, machines in place, and the work-force have steadily decreased, as Tables 1–3 demonstrate for the cotton section of the industry. The weakness of the industry has been attributed to its highly fragmented structure, with many companies having a workforce of less than 200, the high proportion of family-owned companies, and low levels of investment, of innovation, and of R & D. A variety of government reports have been made and incentives offered to reduce the over-capacity, replace outdated machinery and promote restructuring to form industrial units of larger size. However, the various measures have had little effect and the industry has

Table 1. Production from the U.K. cotton industry 1910–1970

Year	Production of yarn	Production of tissues
	(million lbs)	(million linear yards)
1910	1963	8050*
1924	1395	6046*
1937	1234	4122
1949	811	2591
1959	651	1925
1970	440	1235

* Square yards

Table 2. Exports from the U.K. cotton industry 1910–1970

Year	Yarn	Tissues
	(million lbs)	
1910/13	217·3	6672
1920	147·4	4790
1937	173·1	2000
1949	103·6	1075
1959	68·1	411·2
1970	31·9	256·5

Table 3. Machines in place in U.K. cotton spinning industry 1900–1970

Year	Mule spindles	Ring spindles	Total
	(millions)	(millions)	(millions)
1900	42·6	0	42·6
1913	42·5	10·4	52·9
1927	43·8	13·5	57·3
1937	28·1	10·7	38·8
1949	19·1	10·1	29·2
1959	8·7	9·5	18·2
1970	0·3	3·3	3·6

continued to decline, losing the majority of its export market and being driven to seek tariff protection for its shrinking home market.

In the late 1930s and 1940s the chemical industry, seeking new outlets for its vital new feedstock, petroleum, engaged on a programme of research which led, among other things, to the discovery and subsequent production of 'man-made fibres'. After various teething troubles, textiles based on these new synthetic fibres rapidly established a considerable market for themselves. By and large, in this country, the chemical industry concerned itself predominantly with the production of the raw material and the development of a new industry based on the specific properties of the synthetics, i.e. to a large extent they bypassed the traditional textile industry (Table 4). The consequence has been that the traditional industry has continued to decline but a new industry has emerged alongside competing for the same markets.

Table 4. Adoption of man-made fibres by the textile manufacturing industries

Sector	Yarn types	Fibre consumption % 1937	Average 1951–55	Average 1961–65	1968
Cotton Spinning	Cotton	99	88	81	75
	Rayon	1	12	17	19
	Synthetics	–	–	2	7
Worsted Spinning	Wool/Hair	–	95	86	74
	Rayon	–	5	1	1
	Synthetics	–	–	12	25
Wool Spinning	Wool/Hair	–	99	81	76
	Rayon/Synthetics	–	1	19	24
Hosiery & Knitwear	Wool	40	44	28	16
	Cotton	44	33	27	16
	Spun Rayon	–	2	1	1
	Rayon Filament	13	17	6	5
	Spun Synthetic	–	1	11	12
	Synthetic Filament	–	5	27	49

This new textile industry has been highly innovative, exploiting the properties of the synthetic materials to develop radically new processing techniques, as in the non-woven fabrics, new chemically-based dyes and new printing techniques, and has experienced major growth.

What has happened here is that the traditional markets of an ailing craft industry with a poor innovatory performance and a weakly developed technological infrastructure have been taken over by new technologies developed in a highly innovative industry with a strong technological infrastructure. In effect, the general technology (or technologies) of the chemical industry, not only with regard to the synthetic raw material but also with regard to material handling, and processing techniques, have been transferred into a completely new product and market area.

I want to suggest that this represents a fairly general 'transfer model' of technological development. Other examples include the invasion of the material industry by plastics and of various sectors of the mechanical engineering industry by the electronics industry. The complete replacement of one industry by another is not the only way that this 'transfer' can occur, though because of the self-contained nature of the process it may be a very effective one. The current battle within the intensely craft-based watch-making industry against the intrusion of electronics may represent a case in which the new technology is transferred into, rather than replacing, the traditional industry and its methods. In each case what is transferred is not just a technology, if such were indeed possible, but a complete package of technologies, background experience, the advantages of and access to a highly developed technological infrastructure, management skills and an innovatory orientation. Of course this can only be successful if there is an adequate coupling of such technological capability with a recognized or potential market demand. The well-known failure of the chemical industry in its attempts to produce synthetic materials for shoe-making, such as the DuPont 'Corfam' should offer a suitable caution that demand factors are always critical in such developments.

POLICY IMPLICATIONS OF TRANSFER MODELS

Many of the proposals of support for industry have viewed the government role as one of 'assisting the weaker'. Thus Nelson *et al.* (1967) in the context of support for industrial R & D have proposed three criteria: firstly the industry must have a low level of R & D activity and a low rate of technical progress; secondly, the industry must have institutional barriers that are deterring R & D by private firms and thirdly, the industry should be one where the value of more rapid progress is high.

In contrast, if any credence is given to the transfer model of technological development, and the vital role of the technological infrastructure, then a policy of 'backing losers' i.e. attempting to augment the low level of research in an industry, or offering incentives for rationalization, may not offer very great prospects, at least in the short term, for improved economic performance. With regard to research, industries without an adequate technological infrastructure will lack the capability to take advantage of the knowledge produced and it may only aid the better-placed foreign competitors. It may be that a more effective policy to offer specific support for 'winners' i.e. industries with a record of effective technological growth, to diversify their capabilities where possible into traditional and ailing market areas.

Such policies may have the particular advantage of having some effect in a relatively short period, whereas the alternative of promoting the development of an adequate infrastructure and the coupling of firms into it, relying to a large extent as it does on changing attitudes, such as to the employment of QSEs, can only take effect over a considerable period. It is recognized that they also carry with them potential hazards, particularly in terms of concentration effects.

CONCLUSIONS

The process of technology transfer has been shown to be of very great importance to industrial progress at a number of levels and the importance of the inclusion of measures which take it into full account in the formation of technology policy demonstrated. In particular, there is a need for such policy to be viewed in much broader terms than the support of research. The value of specific government action is to maintain and develop appropriate technological infrastructures and to promote innovative industries to transfer their technological capability into market areas which have a considerable potential for exploitation and which are served by ailing traditional industries.

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