STATE INTERVENTION IN TECHNOLOGY IN THE POST WAR YEARS : CASE STUDIES IN TECHNOLOGY POLICY

BARRY WHITE

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SUMMARY

This thesis is concerned with the means by which the state in Britain has attempted to influence the technological development of private industry in the period 1945-1979. Particular emphasis is laid on assessing the abilities of technology policy measures to promote innovation. With that objective, the innovation literature is selectively reviewed to draw up an analytical framework to evaluate the innovation content of policy (Chapter 2).

Technology policy is taken to consist of the specific measures utilised by government and its agents that affect the technological behaviour of firms. The broad sweep of policy during the period under consideration is described in Chapter 3 which concentrates on elucidating its institutional structure and the activities of the bodies involved. The empirical core of the thesis consists of three parallel case studies of policy toward the computer, machine tool and textile machinery industries (Chapters 4-6). The studies provide detailed historical accounts of the development and composition of policy, relating it to its specific institutional and industrial contexts. Each reveals a different pattern and level of state intervention.

The thesis concludes with a comparative review of the findings of the case studies within a discussion centred on the arguments presented in Chapter 2. Topics arising include the state's differential support for the range of activities involved in innovation, the location of state-funded R & D, the encouragement of supplier-user contact, and the difficulties raised in adoption and diffusion.

Index Terms : technology policy; innovation; computers; machine tools; textile machinery.

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Dickens obviously knew a thing or two about thesis writing when he decided that "it was the best of times, it was the worst of times ... it was the spring of hope, it was the writer of despair". Every thesis is the result of a degree of collaborative effort and one of the best times, perhaps the best time, comes with the most pleasant task of finally thanking all those people who have contributed to its production.

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CHAPTER 1 INTRODUCTION

State interest in science and technology for economic ends has a long but fragmented history: the patent system is, for instance, centuries old. Interest though has gathered momentum in Britain during this century, partly because of the two World Wars but more recently because of the identification of technical progress as a key agent in economic growth[1] and the consequent explanation of Britain's post-war industrial decline in terms of its failure to adequately generate and assimilate technical change.[2]

Explicit policies to encourage technological development are now accepted as a proper function for government, but although agreement exists as to their need there is much less agreement as to their extent and form. Lately, both the Advisory Council on Applied Research and Development and the National Economic Development Council have prescribed a more active and wide-ranging role for the state in promoting industrial innovation than the present Government has been willing to accept.[3]

Ideally assessment of the efficacy of past policy would help decide the case for and against particular technology policy measures, but the methodological problems are severe.[4] Whilst this thesis does not attempt to assess efficacy it does aim at another discernable gap in the literature, that of historical studies of technology policy. Implicit within this thesis is the belief that only on the basis of such studies relating the development of policy to its historical and industrial context can its ramifications and effects begin to be understood.

This thesis then is concerned with how the state in Britain has attempted to influence technical developments in industry in the period 1945-1979. It is based on three case studies of policy toward the computer, machine tool and textile machinery industries. At one level it can be regarded as an examination of one particular strand of the relationship between state and industry, but more concretely it is an investigation of how technology policy has evolved in the post-war period, what its characteristics and emphases have been, its institutional structure, and what strategies have been adopted.

The advantages and disadvantages of a case study approach are well known. A case study allows for the detailed exploration of a specific situation or process which may or may not be generally representative. However, by including case studies of three industries that have been subject to very different forms and levels of state attention this thesis tries to avoid the limitations of a single study but preserve its advantages. Moreover, in order to locate these three industry studies (Chapters 4-6) within the mainstream of technology policy, Chapter 3 traces its development in the post-war period.

In the absence of existing accounts empirical studies have a value of their own but they nonetheless need to be situated within an appropriate theoretical context. The production of technology is rarely perceived to be a goal in itself, instead technology policies are a means by which objectives in other functional areas such as medicine, health and safety, defence, etc. are pursued. The focus here is upon the use of technology policies to induce technical change in industry for economic ends. It is appropriate therefore that the case studies are located in a discussion of how technical change occurs through the process of innovation. Although the search for a 'useful' theory of innovation continues,[5] Pavitt and Walker[6] and Rothwell and Zegveld[7] have, among others, constructed guidelines for government innovation policies on the basis of available empirical evidence and partial theory. While their intentions were prescriptive rather than analytical in the sense of using the literature as here to draw conclusions about the content of policy, they nonetheless show that the lack of coherent general theory does not stop its effective use in the discussion of policy matters. In particular, Pavitt and Walker's review of the literature serves as a rough model for Chapter 2 which although differently organised covers and updates many of the same topics.

Before going on to discuss the wider literature it is first necessary to define more precisely what is meant by the term technology policy. Technology policy is closely related to policies for the stimulation of innovation (PSI) which "represents that area of decision-making where science policy, technology policy and industrial policy converge and become almost undistinguishable",[8] but the essence of PSI is that their explicit aim is to stimulate innovation.[9] As Braun defines it, technology policy consists of "the totality of measures taken by government and its agents which directly control the creation, application and use of technology."[10] It therfore includes a diverse range of measures for the stimualtion and diffusion of innovations as well as those more usually thought to belong to the areas of science and industrial policies. (Table 1.1).

An important aspect of this definition is that technology policy is enacted through the state - the government and its agents - rather than the government alone. The government's agents in this context are bodies like

Table 1.1 Technology policy measures

TYPE OF MEASURE	EXAMPLES
Financial	Grants, loans, conditional grants, subsidies, financial sharing arrangments, loans and gifts of equipment, provision of free services, provision of buildings.
Taxation	Company-, personal-, indirect-, payroll-, taxation, tax allowances.
Legal & regulatory	Patents, environmental regulations, health regulations, inspectorates, protection of designs, arbitration services, monopoly regulations.
Educational	General education, universities, technical education, apprenticeship schemes, continuing and further education.
Procurement	Defence purchases, central government purchases and contracts, local government, public corporation, R & D contracts, prototype purchases.
Information	Information networks and centres, libraries, radio and television, freedom of information, advisory services, statistical services, government publications, data bases, museums, exhibitions, liaison services.

Public enterprise	Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, correction of imbalances by public enterprise, participation in private enterprise.
Public services	Purchases, maintenance, supervision and innovation in health service, public building, construction, transport, consumer protection, telecommunications.
Political	"Atmosphere", honours system, planning, regional policies, innovation by decree.
Scientific & Technical	Technical standards, research laboratories, testing stations, support for research associations, learned societies, professional associations, research grants.
Commercial	Trade agreements, tariffs, currency regulations.

Source Braun, E. Government policies for the stimulation of technological innovation. Laxenburg, IIASA, 1979.

the National Research Development Corporation or Science and Engineering Research Council which are answerable to their responsible Minister and thereby ultimately to Parliament but nevertheless have a substantial degree of administrative autonomy concerning their activities. Obviously public agencies have to operate within the broad boundaries of Government policy, but while there is occasional provision for them to act directly on behalf of Government, they are left in the main largely free to determine their own policies subject to their briefs and the constraints of their budgets. Given the number of governmental agencies that appear in the pages of this thesis and the leeway they are allowed, technology policy as practised in Britain is best regarded therefore not as a coherent entity but rather as the sum of their different activities and policies.

Notwithstanding the definition that thas been built up here, the identification of policy measures still poses some difficulties. As one author suggested earlier where they converge industrial, science and technology policies are virtually undistinguishable: so what at this point characterises technology policy? Rather than attempt to draw a fine but thus debateable line around the boundary of technology policy an essentially pragmative answer is adopted. Technology policy, as used here, refers to the specific - as against climate or macro - measures that influence the technological behaviour of firms. All specific or micro-policy measures impinging on the case study industries are therefore considered in order to tease out their technological implications.

Underlying the specific concerns of this thesis is the debate about the need for and effectiveness of state support for not only technology but industry in general. The economic case for public assistance is usually couched either in terms of a divergence between social and private benefits or in terms of market imperfections preventing an optimal allocation of resources. It has been pointed out, for instance, that private industry is likely to underinvest in long-term fundamental R & D and be wary of investing in risky or long-term projects. On the basis of such arguments it is usually to argue the case for state support for a scientific and technological infrastructure to provide 'free' information and trained personnel the private sector, for emergent technologies where uncertainties are high, and for mechanisms to offset any capital market inadequacies.

On the other hand, it is contended that no matter what its imperfections the market is still a more efficient system of resource allocation than the state. According to this viewpoint, the best projects are financed through the market leaving the state to pick up those of the second rank. Immersed from the hard world of commercial realities civil servants and politicians are neither in the best position nor have the experience to assess or decide between competing projects. Once committed to providing assistance to a project or company it becomes difficult for the state to withdraw from making further finance available. On the other side, featherbedding by public funds is said to result in bad and sycophantic management practices aimed at collecting ever more state support. Projects such as Concorde tend to bear this view out, but while very expensive Concorde can hardly be claimed to be representative of the state's support for industry in general. In case such prestigous projects are not supported for purely industrial or technological reasons but involve a web of interacting factors.

As Grant observes, economic justifications hide the true nature of the debate which, instead, is founded on differing political conceptions of the respective primacies of the state and market. In Britain these views are polarised on broady party political lines with the Conservative Party supporting less state influence in general and the Labour Party in favour of higher levels of state intevention. Thus, the case of selective intervention is also based on the belief that the state has a positive right and duty to engage in private industry to ensure that its otherwise short-term parochial interests coincide with longer-term national objectives.[11]

However, there is also a more pragmatic side to the politics of industrial and technological support. From his experience as a junior Minister at the Ministry of Technology in the 1960's Dell shows that the practice of policy is constrained by the need to respond to immediate industrial difficulties. When "government is presented with specific problems it will have to attempt to deal with them"[12]: faced with a crisis it is better to act and be seen to act than to do nothing. In these circumstances assistance may have to be quickly arranged and, with time at a premium, ex ante calculations of the benefits and costs of support and its long term implications may be foregone. Although Dell is referring to the general area of industrial policy, and whilst it might be assumed that the case for technological support could be considered in more leisurely fashion, questions of industrial and technology policy overlap and as indicated earlier are often inseparable.

Despite the continuing controversy over the form that it should take, technology policy as an area remains under-researched, and although its literature is growing in size it is as yet relatively unstructured. It is perhaps indicative of its present state that no major review of the field has been published. However, one discernable theme among the existing literature concerns schemes for the classification of innovation policy measures. Braun, for example, offers two complementary typologies. The first distinguishes between the four levels at which policy measures may act: the general environment, which is the economic, social and political atmosphere in which innovation takes place; industry in general, including measures to strengthen industrial performance; innovation in general; and specific innovations. Measures falling into the definition of technology policy belong to the last three categories.[13] Braun's second classification involves categorising policy measures according to the phase of the innovation process they are intended to affect. The zeroth phase represents the general climate for innovation (equivalent to the first category of the previous classification); the first phase, the emergence of an idea for innovation; the second, the development of innovations; and the third, the implementation phase, their manufacture and marketing.[14]

In spite of the analytical content of such schemes[15], only Abernathy and Chakravarthy have shown how one might work in practice. Their classification consists of three broad categories: technology creation actions, which involve direct governmental support for techological development; product characteristic interventions, which attempt directly or indirectly to share product innovations; and market modification actions that induce innovation by acting on market structures, direct purchasing, etc.[16] But restricted to considering the effectiveness of government support for single projects where intervention was defined simply in terms of its intensity, the applicatability of this classification to complex structures of assistance has yet to be proved.

Although this thesis does not use a classificatory system as such to assess policy content, the analytical framework derived in Chapter 2 incorporates a variant of Braun's 'phase of innovation' typology. However, the potential of classifications like these to wider ranging discussions is well demonstrated by Young and Lowe's use of a similar scheme in considering aspects of UK industrial policy in the period 1964-1972.[17]

More generally, the industrial policy literature helps elucidate the context in which technology policy has operated since the War. Often implicitly incorporating technology policy as a component of industrial policy, several studies emphasise the incoherence of policy, that it is composed of policies rather than a single policy, its reactive nature, and the growth, particularly between 1964 and 1979, of selective intervention as a means of influencing the investment decisions of firms.[18]

A second theme apparent within the technology policy literature itself is made up of various types of evaluative studies, usually concentrating on single measures or projects. Examples of ex post cost benefit analyses include examinations of two separate projects funded by the National Research Development Corporation[19] and Gardner's analysis of the use of launching aid to support the British aerospace industry.[20] Despite the obvious value of such studies their findings are ultimately specific to the project under investigation. Even if the results are apparently clear they need careful interpretation because, as Gardner points out, projects may be undertaken with multiple, possibly conflicting goals.

As means to better industrial performance, the effectiveness of technolgy policies has ultimately to be gauged in these terms rather than by the success or failure of single projects or measures. But while industrial performance can be described easily enough in terms of production or export levels for instance, the effects of policy are not so easily determined. Technology policy consists of a number of schemes and agencies functioning at the same time and quite possibly affecting each others effectiveness. Firms too operate within and respond to a dynamic environment in which factor prices, competition from other companies, etc. are constantly changing, and of which state policies only comprise a part. Technology policies moreover may be in competition with other policies. Employment subsidies, for instance, pull in the opposite direction to policies which are aimed at encouraging greater capital investment.

This same set of difficulties also beset a second group of formal evaluative studies concerned with the econometric analysis of more general measures.[21] As such they do not fall into the ambit of technology policy as defined here, but the tentativeness of their conclusions reveals the methodological problems associated with applying even well substantiated areas of economic theory to policy matters. In addition, Howe and McFetridge's investigation of the determinants of Canadian industrial R & D expenditure, indicating that the effects of policy can vary not only between industries but also between firms within one industry, suggests that policy needs to be considered in relation to specific industrial circumstances.[22]

A similar lack of context can be levelled as a criticism against an international comparative study by Rubenstein et al of managerial attitudes toward innovation policies.[23] Although the question of why international and interindustry difference were observed was not addressed, they are a likely sign that such attitudes are partly dependent at least on the specific policy experiences and economic conditions pertaining in different industries and countries.

More specifically, if it is not to be simplistic an assessment of the success or failure of policy needs to be imbedded in a discussion of changing institutional structure, industrial circumstances, the relationship of policy to the perceived industrial problems it seeks to rectify, and the appropriateness of the content of policy to those problems, discussed in this thesis in terms of its ability to positively affect the innovative capabilities of firms. That said, it is perhaps surprising that there has been a shortage of empirical histories of technology policy of the type now becoming more common in the contiguous area of industrial policy.[24] Although industrial R & D support does not comprise the whole of technology policy it is nonetheless an important component and a few years ago Nelson was able to state with some authority that "no good history of governmental industry R & D assistance exits."[25] Since making that statement, Nelson has gone someway to rectifying the situation by editing a collection of studies of American technology policy.[26]

With regard to Britain, the examinations of technology policy toward the machine tool and motor industry by Daly[27] and Stubbs[28] respectively are at present the only two examples of substance. Stubbs argues that the government's more interventionist attitude in the 1970s was associated with the specific conditions of the industry which had resulted in ever increasing levels of imports in relation to income elasticities of demand, but that the state's technological role remained muted in comparison with its rescues of BL and Chrysler. Noting the policy difficulties posed by the dominance of multinational firms in the industry, he suggested that a better defined technology policy incorporated within an explicit industrial strategy would pay dividends as long as it was guided by some notion of commercial realities.

After outlining state policy toward the machine tool industry in the period 1964-1978 Daly contended that the provision of more skilled personnel would do more to help the industry in the long run than would short term measures. Given the industry's central position within the manufacturing sector, however, its fate was also dependent upon general programmes to enhance industrial competitiveness.

Both studies therefore give due regard to the wider industrial and historical context of technology policies, as does this thesis. In fact Daly covers some of the same territory as Chapter 5, but the approach here is somewhat different in that the emphases are upon tracing in some detail how policy has developed and upon investigating its innovation content.

The structure of this thesis is reasonably straightforward. Chapters 2 and 3 provide the background for the following case studies. Chapter 2 defines and describes the process of innovation and selectively reviews the literature with special reference to five points: innovation and industrial structure; costs in innovation; knowledge and information; the supplier-user nexus; and adoption and diffusion. The Chapter ends with the construction of a loose analytical framework derived from the preceeding discussion. The broad sweep of British technology policy in the period 1945-1979 is presented in Chapter 3, which thereby acts as a backdrop to the following case studies. The Chapter is essentially descriptive and relies heavily on secondary sources but where possible attempts have been made to utilise primary source materials.

Chapters 4-6 form the core of the thesis and consist of detailed chronological accounts of technology policy toward the computer, machine tool and textile machinery industries. All three chapters are similarly organised. Each begins with a brief introduction to the products and technology of the industry and of the industry itself, and ends with a discussion guided by the conclusions of Chapter 2, although other points arising are also discussed as appropriate. Sandwiched in between, the empirical accounts are divided into three time periods, 1945-1964, 1964-1970 and 1970-1979, each coinciding with a particular phase of UK technology policy marked respectively by the Department of Scientific and Industrial Research, the Ministry of Technology and the Departments of Trade and Industry, and Industry. This division was similarly used in Chapter 3.

The case studies are constructed from a variety of mainly primary sources. Official publications and statistics, the annual reports of important organisations, trade and national presses have all been utilised. In addition, interviews with representative figures were conducted both to collect additional information and to discuss the contents of the case studies.

The purpose of Chapter 7, the Conclusion, is to summarise and compare the findings of the preceding case studies. Finally, it discusses some wider issues and the implications of this thesis for future research.

CHAPTER 2 THE PROCESS OF INNOVATION

The purpose of this chapter is to review the innovation literature so as to provide a framework to guide the discussion of technology policy in Chapters 4-7. Since innovation was identified as a key practice in economic growth it has attracted an increasing amount of research on various of its aspects and from a variety of disciplines. The result is an extensive but fragmented literature which, although it has yet to produce an agreed 'theory', shows that innovation is a complex social process enacted in diverse environments of multiple and often conflicting pressures and influences.

Given the size and varied nature of the literature this review is necessarily selective. After some definitions and a description of the activities that comprise innovation, it is constructed around five themes: industrial structure and innovation; cost distributions in the process of innovation; knowledge and information; the supplier-user nexus; and the adoption and diffusion of innovations. Inevitably this chapter covers some of the territory previously surveyed in a seminal paper by Pavitt and Walker.[1]

2.1 Definitions

The OECD defines technological innovation as "those technical, industrial, commercial or other steps which lead to the successful marketing of new manufactured products and/or the commercial use of technically new processes or equipment."[2] But according to Parker successful marketing is not integral to the definition of innovation which instead "covers all of the activities in bringing a new product or process to the market."[3] A successful innovation is therefore one which is a commercial success not one which successfully reaches the market place. Innovations which are commercial failures, that is those which do not recover the investment made in them, can nonethless be technically successful. In common with Freeman this thesis also prefers the use of 'technical' to 'technological' innovation, as technological refers to advances in technical knowledge rather than advances in technique.[4]

While the term innovation therefore describes the process by which new products, etc. arrive at the market it is also often used to describe the artefact itself. Thus the computer was an innovation resulting from a process of innovation. As the OECD definition suggests the term innovation is additionally used to denote a customer's first use - or adoption - of an innovation: hence "one firm's innovation may be anothers firm's sales."[5]

Following the Schumpeterian distinction it is also useful at this stage to distinguish between invention and innovation. "An investion is an idea, a sketch, or a model for a new or improved device, product, process or system."[6] Inventions can therefore be bases for innovations but not all inventions are necessarily commercialised to become innovations.

Innovations are usually categorised as being either product or process. A product innovation is a new or improved good or artefact, while a process innovation is a new or improved production technique. While these are the two main general classes of innovations two specific sub-categories have also been identified in the literature. A new alloy or fibre, for instance, constitutes a materials innovation, but "a new way of producing an essentially established product by an essentially established process", for example the use of microelectronic control systems in otherwise standard production equipment, has been defined as a manufacturing innovation.[7] Disregarding manufacturing innovations, the product category comprises the most usual form of innovation among British firms according to a recent study. Product innovations accounted for 77-79% of more than 2000 significant post-war innovations, while process and materials innovations comprises 16-17% and 3-4% respectively of the total.[8]

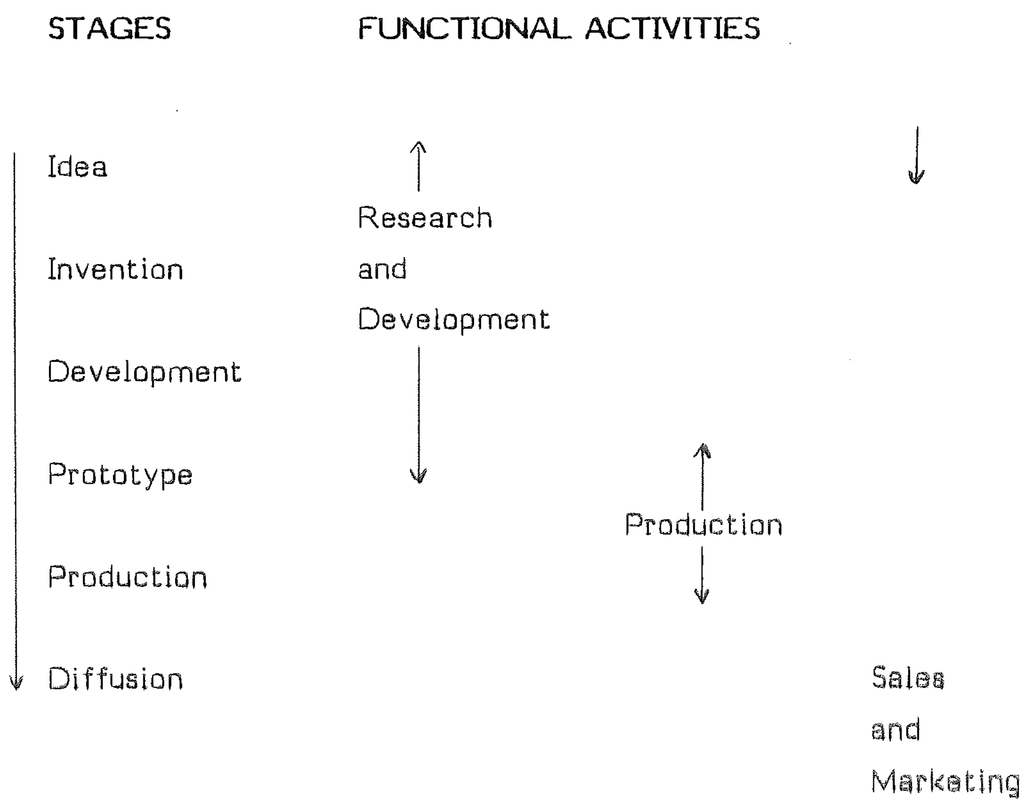
The last distinction to make here is between radical and incremental innovation. Generally an innovation is classed as radical if it makes a substantial break from previous practice. An incremental innovation on the other hand is one which improves upon without significantly altering existing products or techniques. Of course the distinction is not always sharp, innovations represent a degree of technical advance along a spectrum with very radical at one end and minor incremental at the other. Moreover, radical innovations may depend upon substantial subsequent refinement through incremental change to make them successful.[9]

2.2 The nature of innovation

Innovation is often depicted as a series of linked activities leading from invention to the diffusion of the finished product (Fig. 2.1). Although this linear model presents a simplistic and perhaps erroneous view of how innovation proceeds, it will nonetheless serve as an adequate starting point for the ensuing description of the functional activities that are normally involved in innovation.

It needs to be stressed, however, that the stages shown in Figure 2.1 are neither necessarily temporally nor conceptually separated within the firm. Large firms are often functionally organised as shown into research and development, production, and sales and marketing, but the smaller the company the less organisationally distinct from one another these functions become so that in the smallest firms there will be considerable overlap with staff performing a variety of tasks. For the sake of clarity the description below concentrates on product innovation in large, functionally organised companies. Following sections explore particular facets of the innovation process in more detail and with greater recourse to the literature.

Figure 2.1 Linear model of product innovation



The first part of the innovation process then is concerned with the generation of an idea for a product, either in recognition of a market opportunity as a result of feedback from potential or existing customers' or in response to opportunities presented by the technology itself. On occasions an appropriate line of technical advance may be clearly identifiable within the technology.[10] In either case projects are likely to go through some form of selection process matching the risk involved with potential market demand. If the firm decides to go ahead with development it enters a phase of lesser or greater technical and commercial uncertainty depending in part on the degree of technical advance engendered. There is no guarantee that the idea can be translated into practice, or if it is, whether it will be accepted by the market. Consequently, many ideas and investions are shelved during development because of technical problems or changed market circumstances.

Innovation involves an opportunity cost and requires the firm to risk resources on the chances of success. A firm's corporate ethos imbues its strategy toward innovation: some, for instance, attempt to gain competitive advantage through a deliberate aggressive policy of being in the fore-front of technical progress, while others may decide on more defensive competitive approaches.[11] Despite any use of articulated project selection procedures, innovation is also ultimately bound-up with intra-firm politics[12], and success can depend upon the appointment or emergence of a 'product champion' with enough authority to promote and elicit sufficient support within the firm and ensure coordination between departments.[13]

The construction of one or more prototypes marks the beginning of the next stage in the linear model. It is then that machine trials can start in earnest and when manufacturing departments can begin to sort out production details. Development work nonetheless carries on: improvement of technical/economic characteristics, product design and debugging can all require considerable further effort and may in reality blur the distinction between development and prototype construction. Poor performance etc. at this stage may again mean that the project is discontinued.

What organisational and equipment requirements the production stage entails depends on the innovative extent of the product, its nature, and the expected size of market. Incremental product changes are likely to require less change in the manufacturing set-up than more major ones which might necessitate considerable retooling and reorganisation. Entirely new products might mean the construction of new production facilities. Alternatively where production systems are flexible little equipment change may be needed. If markets are expected to be small production beyond a few initial models is likely to be in response to orders received. Similarly, the less standardised the product and the more tailoring it needs for customer use the more production will also be tied to orders.

The problems of production are not to be under-estimated - post-launch production difficulties have been shown to be an inhibiting factor in successful innovation. To reduce such problems production staff might be involved in development to ensure that design difficulties are identified and dealt with at an early enough stage. Further problems may also be presented by the commissioning of new production equipment.

Once it has been decided to go into production, the sales and/or marketing department will start to arrange the market launch. Publicity and sales material has to be written and designed. For maximum exposure the product may be unveiled at a major exhibition. Sales and servicing staff have to be trained, pricing policies finalised, and where appropriate agents and dealers acquainted with the innovation.

Although its market launch marks the point at which the product at last becomes an innovation it does not mark the end of the process of innovation. Adoption and diffusion are considered separately in section 2.7 but suffice to say here that they constitute an integral part of the process. Development work often continues and may in the end make for the difference between initial commercial failure and eventual success. But just as many ideas are not acted upon and many development projects aborted, many innovations still fail once they reach the market.

2.3 Industrial structure and innovation

For many years Governments have accepted the principle that industrial structures can be altered for economic and political ends, for instance by nationalisation or privatisation. Even though recent attention has been focused upon the roles of new-technology-based industries and small firms in innovation, controversy remains as to which industries or technologies should be targetted, as well as to what firm size or industrial structure is the most conducive to innovation.

Table 2.1 R & D performed within, or financed by, industry and net output, 1975

	R & D		NET OUTPUT	
	£m	%	£m	%
Food, drink + tobacco	50.3	3.9	4772.1	15.3
Chemicals	251.0	19.3	3343.4	10.7
Iron + Steel	27.7	2.1		
			2352.3	7.5
Non ferrous metals	8.7	0.7		
Mechanical engineering	104.0	8.0	4746.4	15.2
Scientific instruments	26.1	2.0	631.8	2.0
Electronics + telecommunications	279.3	21.4	1741.2	5.6
Other electrical engineering	73.1	5.6	1597.0	5.1
Shipbuilding	16.2	1.2	630.0	2.0
Motor vehicles	88.5	6.8	2519.0	8.1
Aerospace	291.9	22.4	954.0	3.0
Other	85.6	6.6	8002.8	25.6
TOTALS	1302.4	100.0	31290.0	100.1

Sources Arrumdale, R. Research and development: expenditure and employment. Economic Trends, 309, 100-124, July 1979; Census of Production, 1975. London, HMSO, 1977.

Table 2.1 shows that R & D is heavily concentrated within just a few sectors of British industry. In 1975 more than 60% of all UK expenditures were in the chemicals, electronics and aerospace industries whose continued net output amounted to less than 20% of the total. Conversely, the food, drink and tabacco, mechanical engineering, and 'other' sectors accounted for some 56% of total net output but less than 20% of R & D expenditures.

Why R & D expenditures should be so concentrated is partly explained by military expenditures in aerospace and electronics, but a more fundamental explanation is offered by Rosenberg in terms of underlying stocks of scientific and technical knowledge that individual industries are able to draw upon. At any one time the level and asymmetry of scientific and technical understanding limits the potential return of research and thus the inventive and innovative activity in any sector. Industries with strong and articulated scientific bases or with clear lines of achievable advance (technological trajectories) are more amenable to organised R & D activities than those without such bases.[14]

'Learning-by-doing' is an important component of, complement to, or even substitute for formal R & D in those other industries where 'knowhow' is largely carried by individuals rather than by textbooks, and professional inculcation is by apprenticeship type training rather than by conventional education. This does not mean that there will be necessarily little or no technical advance or that organised R & D will not exert a powerful influence at times upon the direction of technical change in these industries. In the case of NC machine tools, for instance, radical innovation resulted from the incorporation of a technology (electronic control systems) originating outside what was otherwise a mainly craft-based industry.

As this example shows product innovations from one sector may be primarily for use in another. Such flows of technology have recently been investigated in the UK by a direct examination of the origin and use of innovations[15], and in the USA through the construction of an inter-industry technology flow matrix based on patent and R & D data from 443 large U.S. corporations.[16] By identifying patterns of interdependence these studies could be used to pinpoint strategically important sectors and potential areas of fruitful inter-industry collaboration.

Turning to the structure of individual industries, the debate over the relationship of market structure to the propensity to innovate has given rise to two opposed views.[17] The first, stemming from economists of the 19th century, is that free competition in an atomistic market is the best way of encouraging innovation. According to this argument the desire to exploit monopoly power to gain maximum profits inevitably retards rates of innovation. The second view point, most notably propounded by Schumpter[18] and Galbraith[19], is that by dispersing much uncertainty the returns to market dominance allows for large scale investments in R & D and innovation. The available empirical evidence, however, does not clearly favour either hypothesis. McLaurin, for instance, found no relationship between the introduction of new products and processes and concentration over thirteen US industries,[20] while Mansfield found a positive relationship for the American coal and petroleum refining industries but not for the steel industry.[21]

A related question concerns the relationship between firm size and innovation. Recent direct innovation counts show that very small firms (<200 employees) have regularly accounted for just over 10% of the significant innovations introduced in the UK since the Second World War in the sectors studied. Over the same period large firms (>10000 employees) have steadily replaced medium-sized firms (1000-9999 employees) as sources of significant innovation. At the same time, however, the most frequent size of innovating unit has been in the medium size range, so that while the average size of innovating firm has increased over the period the average size of innovating unit has decreased.[22]

Other studies have used R & D expenditure data and patent counts as indicators of innovative activity to explore the question of firm size and innovation. In general, they have found that industrial R & D is heavily concentrated within companies with the largest R & D programmes.[23] It has also been shown that the bulk of research is also carried out by large firms, although the degree of concentration is not nearly so great as many large firms - those belonging to low R & D sectors - conduct very little research.[24] It is thus the large firms in R & D intensive industries which account for the great proportion of total R & D.

Despite the predominance of large companies in formal R & D many studies have emphasised the importance of small firms and individuals in the generation of innovations. Jewkes et al, in perhaps the best known, found that the majority of their sample of 71 important inventions originated outside the laboratories of large firms.[25] Single firms and industry studies have come to similar conclusions.[26] But with their focus on invention rathern than innovation, these studies do not do justice to the role that large companies can play in the development of inventions into commercially useful products and processes. As noted earlier, the route from invention to innovation can involve considerable uncertaincy and greater time, effort and resources than many small firms are able to afford. If small companies and individuals have a higher potential for invention it can be argued that large firms have the organisational and financial clout to convert technically feasible ideas into marketable innovations.

Much of the recent attention given to small firms has concentrated on their role in the emergence of new technology-based industries.[27] According to one model of industrial development it is during the early stages of an industry's life that small entrepreneurial firms are able to exploit technological or market opportunities disregarded or unrecognised by large organisations.[28] Competition is based on performance rather than cost and technical expertise is at a premium. Some entrants are forced out of business, but new firms take their place. As technology and markets mature and firms become larger, R & D becomes formalised and competition increasingly price-based. Entrance costs once relatively low increasingly limit the ability of new firms to join the industry. But as Rothwell has argued[29], and the history of the robotics industry displays[30], large and small firms complement one another during the first phases of the industry cycle: new firms spin off from existing ones, and designs and sales licenses are bought and sold. Just as important large firms, perhaps from adjoining technological areas, acquire small firms and their expertise to gain footholds in the new industry.

Although some industries are dominated by a few large firms other, even well established ones, remain apparently unconcentrated. the five largest enterprises in the UK machine tool industry, for instance, accounted for just 24% of its net output in 1976. But as it is made up of a number of non-competing sub-sectors supplying lathes, drilling machines, etc. of various sizes and sophistications and very different technical characteristics, the scope for economies of scale either in production or expertise is restricted and as markets are relatively small so are suppliers. Nonetheless, within specific product markets the degree of concentration may be much higher than for the industry as a whole (Chapter 5.1, 5.2).

2.4 Cost distributions

The results of four surveys of the costs of innovation, focussing on how they are distributed across the spectrum of activities involved, are presented in Table 2.2. The US Department of Commerce study is based on the subjective evaluations of 20 experts[31]; Mansfield's on 38 innovations in the US chemicals, electronics and machinery industries[32]; Stead's on 83 innovations in the Canadian chemical, electrical, and machinery and transport equipment industries[33]; and Kamin's on 33 innovations in the Israeli chemical and electronics industries.[34]

As different classification schemes were used in the collection of data the results presented in the Table are only broadly comparable, but even from such a comparison it is clear that the evaluations of the US panel of experts are at variance with the empirical studies which agree that roughly a half of all innovation costs are accounted for by R & D. Kamin et al suggest that Israeli firm's much higher proportional marketing costs reflect their relative lack of established export marketing infrastructures.

Table 2.3 reanalyses the data to show the distribution of costs in individual industries. Greatest variation appears in the Canadian study which may be explained by the inclusion of all capital costs presumably greater in capital intensive process industries, such as chemicals.

Kamin et al also investigated the relationships between size of firm, complexity of innovation and cost distributions. Bearing in mind that their sample was skewed toward low complexity projects in large firms and high complexity ones in small companies, they found that R & D accounted for proportionally more of total innovation costs in small firms (54%) than in their larger brethren (41%). Not surprisingly, low complexity projects involved lower proportional outlays on R & D (37%) than high complexity ones (64%). The further finding that small firms spent proportionally more on marketing and less on tooling up, was due, the authors argued, to a greater pressure on small firms to commercialise their products as quickly as possible. But an alternative hypothesis might involve the argument that these firms' manufacturing operations might have been more flexible or less capital intensive than those of larger companies, thus requiring less new investment.

In some respects this argument parallels Utterback and Abernathy's theory of the relationship between product and process innovation in the innovation cycle, which suggests that product innovation is facilitated during the early stages of an industry's life because production systems, often manual, are flexible enough to quickly accommodate new designs or products.[35] At a later stage there is evidence that the amount of new fixed investment required can influence the type and rate of innovation pursued. In the UK tractor industry, for instance, "retooling costs constituted a significant barrier to radical product innovation (while) the costs imposed by the limited flexibility of the mass production technology are the main constraint on ..... incremental innovation."[36]

Table 2.2 Distribution of costs in the innovation process (%)

	U.S. Dept. of Commerce	Mansfield (U.S.A.)	Stead (Canada)	Kamin (Israel)
R & D	15-30	46	59	47
Prototype	40-60	37	31	18
Manufacturing Start-up	5-15	9	6	15
Marketing	10-25	8	2	20

Sources See text : references 31-34.

Table 2.3 Cross industry cost distributions (%)

		R & D	MANUFACTURING START-UP	MARKETING
Chemicals	Mansfield	43	50	7
	Stead	22	70	8
	Kamin	55	34	13
Electronics	Mansfield	51	43	6
	Stead (Electrical)	77	21	2
	Kamin	43	32	25
Machinery	Mansfield	47	42	11
	Stead	43	51	6

Sources: As for Table 2.2.

A drawback of the three empirical studies presented in Tables 2.2 and 2.3 is that because they do not distinguish between success and failure at innovation they are unable to suggest an appropriate balance of costs, if one exists that is, across the range of innovation activities. An implication of Project SAPPHO, for instance, is that a greater proportional marketing effort might enhance an innovations chances of success.[37] Nonetheless, the value of these studies is that they emphasise that the later stages of the innovation process - manufacture and marketing - incur costs as large as those absorbed by research and development, and should not in consequence be neglected as a source of financial difficulty.

2.5 Knowledge and information

While Figure 2.1 presented innovations as a sequence of linked activities it can also be modelled in terms of flows of information and thus as a learning process. Units of scientific, technical and marketing information are all utilised in conceptualisation, design and construction. Within the firm, information flows between the various departments concerned. During adoption knowledge, as technology, is not only transferred to the customer embodied in the innovation itself but also as documentation, training, etc. The focus in this section is upon the use and generation of information by the innovating firm: the two way flow between supplier and customer is dealt with in the next two sections.

A number of studies have attempted to determine the source of ideas or units of information critical to the production of innovations. Some have been intent upon distinguishing between the respective contributions of science and technology to provide a basis for the assessment of the economic benefits of research. Project Hindsight concluded that science played only a minor part in innovations[38], while the TRACES project came to the opposite conclusion, that about 70% of all knowledge-providing events came from science. In another study Gibbons and Johnston found that about 20% of all information obtained during the process of innovation "had its origins in basic scientific research."[40]

Other studies have concentrated on disentangling the institutional source of such inputs distinguishing in particular between sources internal and external to the firm (Table 2.4). Once again their results cannot be strictly compared because they were collected using different methodologies and classifications. This is especially so in the case of the Gibbons and Johnston study in which detailed classification was largely by type of provision, such as trade literature, handbooks, etc. which cannot be easily reanalysed to fit the Table. But in general, all the studies agree that sources of knowledge and information are various and multiple, and that in-house sources are of especial importance.

Gibbons and Johnston also distinguished between 'personal' and 'internal' sources of information, that is between whether the information was actually possessed by the problem-solver, or whether it came from elsewhere in the firm. Personal sources accounted for more than one third of all technical information units in their sample, and for more than two thirds of all units originating within the firm, whereas in-house research and development was responsible for about 20% of all information inputs. Personal contributions are therefore important in technical development. A further analysis of the educational background of problem solvers revealed the interesting finding that graduates, in comparison with non-graduates, tended to rely more upon external sources of information, especially the scientific literature and university scientists. University educated personnel it was thus argued were better able "to extend their resources."[41]

Table 2.4 Sources of knowledge inputs to innovations (%)

<table>
<tr><th></th><th></th><th>Langrish <u>et al</u> 158 ideas, 57 innovations</th><th>Gibbons & Johnston 887 units, 30 innovations</th><th>Townsend <u>et al</u> major inputs 2293 innovations</th></tr>
<tr><td>In-house</td><td></td><td rowspan="2">35</td><td>30</td><td rowspan="2">47</td></tr>
<tr><td>Personal</td><td></td><td>36</td></tr>
<tr><td>Parent Company</td><td></td><td></td><td></td><td>7</td></tr>
<tr><td>Other industry</td><td></td><td>15</td><td>7</td><td>14</td></tr>
<tr><td>Government:</td><td>defence</td><td rowspan="3">15</td><td rowspan="2">1</td><td>1</td></tr>
<tr><td></td><td>civil</td><td>3</td></tr>
<tr><td></td><td>research assocs.</td><td>3</td><td>2</td></tr>
<tr><td>Universities</td><td></td><td></td><td>3</td><td>1</td></tr>
<tr><td>Individuals</td><td></td><td>1</td><td></td><td>1</td></tr>
<tr><td>Foreign</td><td></td><td>34</td><td></td><td>24</td></tr>
<tr><td>TOTAL</td><td></td><td>100</td><td>80</td><td>100</td></tr>
</table>

Sources Langrish, J. et al. Wealth from knowledge. London, Macmillan, 1972; Gibbons, M. & Johnston, R. The role of science in technological innovation. Research Policy, 3, 220-242, 1974; Townsend, J. et al. Science and technology indicators for the U.K. (SPRU Occasional Paper Series, 16). Brighton, 1981.

This communication with the outside scientific community has been associated with success at innovation elsewhere,[42] while Project SAPPHO found that coupling with that specialised part of the community working in directly related areas was a significant factor in success.[43]

Information and ideas therefore are not the free good that they were once often portrayed to be. Much requisite information is literally embodied in key personnel. These too are the people that recognise, gather and assimilate information from outside the firm, frequently through personal contacts. Moreover, as argued in section 2.3, tacit knowledge, as opposed to information contained in books, etc., is particularly important for some technologies, again emphasising the critical role of individuals. Even information presented as blueprints, patents, etc. may require considerable effort by a firm's technical staff before it can be utilised. R & D departments therefore not only generate new information, they also act as repositories of information and knowledge, and as a means for the incorporation of information from external sources. Technology transfer is thus frequently and possibly best accomplished through the movement of key individuals, a well recognised route to the formation of small new technology-based enterprises.[44]

Manpower costs appear to be the reason why small firms, which employed qualified scientists and engineers at half the concentration of large firms in 1968[45], on average use external sources of information - research and technical associations, consultants, and universities - less than large ones.[46] Another survey with a similar implication reported that 75% of its sample of firms with less than 200 employees had no contact at all with universities, while the equivalent figure for companies with more than 5000 employees was 9%.[47] Their relative insularity may help explain why small firms appear to generate a relatively high percentage of important knowledge inputs for innovation internally.[48]

2.6 The suppler - user nexus

Previous sections have remarked upon some of the links that exist between innovators and their customers. In this section two particular strands of this supplier-user nexus, the understanding of user needs and the provision of product-related services, are explored in more detail.

Project SAPPHO, a comparative analysis of 29 pairs of matched successful and unsuccessful innovations from the chemical process and scientific instrument industries, found that the understanding of user needs was the clearest discriminating factor between success and failure. The related findings that innovations needing less adaption by users, or suffering fewer after sales problems, were more likely to be successful were also regarded as functional indicators of a greater sensitivity to user requirements.[49] Phase II of the Project, which examined a further 43 pairs of innovations from the same two industries, confirmed the results of the earlier study.[50] In providing further supporting evidence for the importance of understanding user needs, Teubal et al introduced the concept of market determinateness. High market determinatesness, defined as a high degree of specificity of market signals received by the innovating firm, was correlated with successful innovation, while low signal specificity, leaving the innovator uncertain as to user requirements, was associated with failure.[51] Other less formalised studies have also stressed the value of understanding user needs to innovation.[52]

But user needs are not as Mowery and Rosenberg have trenchantly observed the same as market demands as is often assumed. Market demands concern the relationship between the price and supply of goods which is mediated through the market place. User needs are not, however, transmitted in this way but rather through the formal or informal interchange of ideas, requests and information between customers and their suppliers.[53] This is not to say that all user needs are communicated, or that all transmitted needs are acted upon, or even that all innovations arise in response to them.

Whilst none of the studies referred to above report how user needs are, or might be, transmitted to the innovator, lines of communication appear to differ according to type of market. When markets are large and dispersed and involve a relatively standardised product, user-supplier contacts are consequently mainly indirect. In the case of the UK tractor industry, for instance, marketing departments typically process ideas for innovation originating from a variety of sources, including dealer reports, analysis of warranty claims, and most influentially the assessment of technical parameters developed in the community of dealers, sales departments, experienced customers, trade journals, test reports and so on.[54] Direct supplier-customer contacts might be expected to be easier to establish in smaller or more specialised markets as, for example, for defence equipment, often developed under contract.

Perhaps the extreme example of 'close' contact occurs when innovations are developed for in-house use. Von Hippel has observed that user-based innovation is particularly prevalent in some US industries such as scientific instruments and electronic sub-assembly equipment. Alternatively, users may also develop their own versions of existing innovations. In either case users may go on to manufacture their innovations for wider commercial sale or allow existing suppliers to take over during the later stages of the innovation process.[56]

According to Von Hippel, the pattern of user produced innovations can be explained in terms of the appropriability of the benefits of innovation. Very simply, if the ususal supplier of process machinery can reasonably expect to sell 'many more' units than a single user can itself utilise, the supplier is more likely to be the locus of innovation than when markets are small which, in turn, encourage in-house development of specialised equipment. Von Hippels's locus of innovation hypothesis though is unable to explain the way that the way that some enterprises, for instance a number of Japanese robotics suppliers, have deliberately utilised their internal production requirements and knowledge as a platform, in this case, for the development of robots and associated applications expertise, from which to enter the wider robot market.[58]

Whilst it is reasonable to expect that the closer the relationship between supplier and customer, the better the supplier understands the requirements of users and the more successful he will be at innovation, substantiating evidence is largely missing from the literature. However, such a relationship has been shown to have been important to the success of one textile machinery manufacturer,[59] while its absence has been associated with the poor innovative record of the UK machine tool industry.[60]

The second strand of the supplier-user nexus concerns the provision of product related services during and following adoption. Adoption, the next section argues, is a period of uncertainty for the customer. Supplier support during this phase helps transfer knowledge and skills and lessens this uncertainty.

Product-related services include experimental trials, technical advice, the design and installation of systems, servicing contracts, training provision and so on. Evidence of their importance comes from Project SAPPHO which found that successful innovators paid more attention to educating users,[61] and Bessant who found the whole range of services to be of major value.[62] Case studies have also emphasised the role of product-related services to the successful strategies of individual firms from IBM downwards.[63]

The provision of such services is not cost free: significant resources may have to be set aside by the supplier to recruit and train staff, and establish an appropriate service infrastructure, which might be particularly costly in foreign markets. But the more complete the range of services offered and the better the working relationship with customers, the higher a supplier's standing becomes.[64] A good reputation has been shown to be one of the considerations among the 'non-perceptible' differences dominant in the purchasing decisions regarding medical products in the USA,[65] and a positive factor in the diffusion of textile chemicals and dyestuffs in the UK,[66] and robots in Sweden[67]. Of course a good reputation is made up of more than just product-related services, but such services are in the first instance a means of allaying customer doubts about adopting innovations and constructing a reputation.

2.7 Adoption and diffusion

Diffusion is the cumulative effect of instances of adoption, which in turn represent the investment decisions of individual organisation. Various researchers have argued that the overall rate of diffusion among a pool of potential adopters is a function of the relative advantage that the product or technique offers over its competitors, but a decreasing function of the size of investment required.[68] This has led to the suggestion that as larger firms are better able to carry the financial risks involved they should be more common among samples of early adopters.[69] While it has also been suggested that small firms face more difficulties in acquiring external investment finance,[70] various empirical studies have conversely found no correlation between size of firm and the date of introduction of innovations.[71] Yet other researchers have demonstrated that high relative economic advantage - low investment costs and risk, and the prospect of high rates of return - do not guarantee fast diffusion.[72]

Before diffusion can begin potential adopters have to be aware of both the innovation and the possibilities it presents. It has thus been argued that the rate at which awareness itself diffuses is a determinant of rates of diffusion, thus accounting for some observed local concentrations of early adopters.[73] Awareness of course is a twin-edged process involving the supply infrastructure and potential customers. On the one hand suppliers have to promote their innovations, and indeed marketing effort has been associated with successful innovation,[74] while the role of national promotional efforts has been used as an explanatory variable in accounting for international differences in robot diffusion rates.[75] On the other hand potential adopters have to be able to recognise the utility of an innovation to them, which has been described as a function of their 'technical progressiveness'. As with the generation of innovations, this is likely to be contingent on the technical skills a firm possesses, and upon the extent of its contact with the outside technical and industrial community, including existing users.[76] Personal contacts made through trade and professional associations have been pinpointed as one fruitful source of information about textile chemicals innovations.[77]

Rates and levels of diffusion are also affected by industrial structures. Ultimately the size and composition of a nation's industrial sector places an upper limit upon the number of potential adoptions, although this limit will change as the innovation evolves. Moreover, certain industries have been shown to be pre-eminent in the early stages of diffusion of some innovations, for example, the aircraft and motor vehicle industries with regard to NC machine tools[78] and robots[79] respectively.

The car industry's role in robot diffusion also demonstrates the influence of investment cycles upon diffusion of capital innovations. In this case the widescale introduction of spot welding robots in the main awaited major investments tied to the introduction of new ranges of cars.[80] More generally, high volumes of capital investment are believed to contribute to the rates of diffusion of new processes.[81]

So far, diffusion has been treated as though it is a self contained code to the rest of the innovation process with finished innovations being presented to a static market. But innovations and their markets are neither static nor independent, both evolve and interact in a complex manner. The continued post-launch development of innovations resulting in improved performance, greater reliability, easier use, etc. together with the associated extension of applications and the development of user skills all alter the environment for diffusion, and mean that diffusion curves are often in reality several smaller curves pertaining to different 'ages' of an innovation superimposed upon one another.[82] Computers and their progression through successive technical generations offer a case in point. (Chapter 4.1, 4.2). While improved cost/performance ratios reduced the financial investment involved in adoption, the development of faster input-output devices, larger memories, more reliable machines, and programming languages specifically designed for commercial applications made computers useful to a new class of technically unsophisticated users with large data handling needs, such as banks and insurance companies.

Diffusion as stated is the aggregate effect of adoption. Put another way adoption is diffusion at the micro-level: it is where the problems attending diffusion are enacted in practice. As diffusion studies do not operate at this level they consequently usually assume that adoption is instantaneous and unproblematic, but studies of adoption show that it can be a complicated social process often taking long periods of time. They also show that adoption decisions are not necessarily simple and clearcut, and neither do they always turn upon purely economic calculations. Rather, considerations affecting adoption involve a host of non-economic factors specific to the firm. When performed ex ante economic evaluations of new processes are fraught with all kinds of difficulties and can in any case be tailored to produce particular results.[83]

With many innovations, adoption requires considerable managerial and technical effort and learning.[84] The more radical and complex the innovation, the greater the risk assumed by the adopter and the greater the inputs necessary to successfully effect the adoption. The fewer the technical problems encountered at this stage the more likely the innovation is to be a success.[85] Adoption, too, frequently has to be accompanied by new organisational procedures, working practices and the acquisition of new skills.[86]

The shortage of appropriate skills, often at a premium during the early stages of diffusion, poses an especial problem for without them users are totally dependent upon their suppliers for the kinds of technical support services recounted in the last section. Conversely, the accumulation of technical and managerial experience of adoption, that is by being already advanced on a general adoption learning curve, may account for the findings that the same Swedish companies have consistently been in the vanguard of adoption of new processes,[87] and that those companies with previous experience of introducing automation are more successful at adopting robots.[88]

More generally, widespread diffusion of innovations can take many years to achieve.[89] It is not always the case that even with ultimately very successful innovations that firms involved early on are able to carry the costs of their initial development programmes, the need to continue development, and the requirements of a marketing and service infrastructure. Nonetheless, during the early phases of diffusion innovators are able, in contact with customers, to cultivate their own expertise and establish their reputations. Diffusion, as cumulative adoption, is an active process in which the innovator must properly engage and be committed to if he is to succeed.

2.8 Conclusions

The purpose of this chapter has been to selectively review the innovation literature in order to provide a framework for the discussions of technology policies that appear in Chapters 4-7. Although a variety of sometimes conflicting evidence has been examined a number of conclusions can nonetheless be drawn.

A. Structures and levels of R & D activity vary from industry to industry. Policies that may be appropriate for one industry are not therefore necessarily suitable for another. In those industries characterised by large firms and intensive R & D programmes a minimum level of company R & D is probably critical. But even in or around these industries small firms and individuals should not be neglected as they can be a source of significant invention, if not always innovation.

B. Policies aimed at promoting structural change need to take into account the actual products of an industry. Economies of scale are likely to be harder to achieve in a segmented industry where products and expertise are differentiated.

C. While R & D accounts for roughly half of all innovation costs, post R & D activities account for a similar proportion. Policies should neither ignore the financial burdens imposed by these activities nor their intrinsic importance to successful innovation.

D. Knowledge and information relevant to innovation come from multiple sources internal and external to the firm. R & D personnel and thus departments, formally organised or otherwise, are not only repositories and generators of information, but also act as technical interface with the rest of the technological and industrial community. Whilst mechanisms for the transfer of technology, either between public laboratories and private industry or between firms, are of obvious value they need to concentrate on its reception as well as its transmission. Good reception is in part a function of the existence of R & D departments with qualified staff: it is they that assimilate information from outside the firm. General policies should therefore encourage intra-firm R & D.

E. Transfer of technology is likely to be best achieved by close collaboration and personal contacts. Policies should stimulate coupling at this level.

F. The understanding of user needs is crucial to successful innovation. Enhanced understanding is probably best promoted by the active encouragement of contacts and collaboration during development. Where the state is an important customer it is in a strong position to ensure the proper consideration of user needs. On occasion, with their intimate knowledge of the process to hand, users may be best placed to pursue innovation.

G. Product-related services both bolster a supplier's reputation, a valuable competitive commodity, and lessen uncertainty during adoption. Policies should therefore encourage the provision of such services as a necessary accompaniment to innovation and also recognise that they are not cost-free.

H. Diffusion is an integral part of the process of innovation. It is when commercial success or failure is finally decided. The widespread diffusion of new technologies especially can take many years to achieve, during which time continual incremental development may be necessary. The recoupment of costs may also therefore take considerable time, but the expertise built up during the course of initial commercial failure may provide a platform for eventual success. Firms and industries may thus require policies of long-term and continued support.

I. Markets for innovations are of course crucial. For some innovations specific customer industries play an important role in early diffusion. The levels and timing of investment programmes need to be coordinated with policies for stimulating innovations if full benefits are to accrue.

J. While at the macro-level diffusion appears to be reliant upon the notion of relative advantage, adoption is beset by a host of technical and other problems. Thus although subsidy schemes might reduce the cost of adoption they do not necessarily guarantee its success. Adoption is an active process whereby technology is transferred and incorporated. Both the application skills of suppliers and their product-related services need to be encouraged as well as the acquisition of appropriate managerial and technical skills by adopters.

Although recourse will be made to all these points where appropriate in the discussions, particular attention will be paid to what phase of the innovation process - development, prototype, etc. - measures have been intended to affect; whether state funded R + D is located in industry or state laboratories; the form of mechanisms for the transfer of publicly-funded technology to the private sector; how the supplier-user nexus is encouraged, that is whether measures aid the understanding of user needs and the provision of product related skills; the content of diffusion and adoption measures; and whether they are coordinated with policies for the stimulation of innovation.

CHAPTER 3 BRITISH TECHNOLOGY POLICY, 1945-1979

The purpose of this chapter is to provide an account of British technology policy in the period 1945-1979. It is essentially descriptive and is intended to chart the development of policy and locate it within the general context of industrial policy. In particular, the chapter focusses on the institutional framework of technology policy, and it thus reviews the activities and functions of government departments, governmental agencies, and the provisions of relevant legislation. By so doing it acts as a backdrop for the more substantive case studies which follow and avoids unnecessary repetition within them.

3.1 An overview of policy, 1945-1964

The successful harnessing of science and technology to the Second World War effort led to expectations they could be similarly used in the post-war reconstruction of British industry[1]. In an attempt to extend the wartime coordination and control of science to the peace, the Labour Government established the Advisory Committee on Scientific Policy (ACSP) "to advise the Lord President (of the Council) in the exercise of his responsibilities for the formulation and execution of Government Scientific policy".[2] Over the next few years his existing responsibilities for three scientific agencies, the Department of Scientific and Industrial Research (DSIR), the Agricultural Research Council (ARC), and the Medical Research Council (MRC), were increased to include a new research council, the Nature Conservancy, atomic energy (transfered from the Ministry of Supply in 1954 and later institutionalised as the UK Atomic Energy Authority), the National Institute for Research in Nuclear Science, and space research. Located outside the Lord President's and the ACSP's spheres of influence, however, was another new organisation with important technical and industrial functions, the National Research Development Corporation (NRDC), and the research activities of functional Government departments such as the Ministry of Agriculture and Fisheries and the Post Office.

Despite the importance accorded to science and technology by the newly returned Labour Government they were just one element in its wider industrial and economic programme. Wartime controls over building, exports and imports, prices, and the allocation of certain strategic materials such as steel, were continued to curb inflation and control the balance of trade, but they were also regarded by the Labour administration as "heavensent instruments for economic planning".[3] Nationalisation of the gas, electricity, coal, iron and steel, railway, road haulage and civil aviation industries, as well as the Bank of England, represented further attempts to extend state control over the economy.

Efforts were also made to improve industrial productivity and performance. Board of Trade working parties were set up to report on specific industries, while the Anglo-American Council on Productivity, established in 1948, sent various joint teams of employers, managers, and trades unionists to the USA to examine American working practices.

One direct result of the Board of Trade working parties' reports was the Cotton Industry Act, 1949 which attempted to modernise and restructure the industry (Chapter 6.3). Another was the Industrial Organisation and Development Act, 1947 which encouraged the establishment of industry Development Councils with employer and employee consent. Chief among the proposed functions of the Councils was the stimulation of research and development, but they were also allowed to promote work in other areas such as design and education. In the absence of a Development Council, the Act alternatively enabled a levy to be exacted on an industry, again with its consent, for the same ends.[4] Distrust that Development Councils were precursors of more far-reaching government intervention meant that only four were established covering the cotton, furniture, jewellery and silverware, and clothing industries. In addition, just three orders were made under the Act for the collection of compulsory levies, two to finance research in the wool and lace industries - these levies were used to replace membership subscriptions to the research associations - and the third to promote woollens exports. Opposition to the Development Councils continued and with the exception of the Cotton Board they were allowed to lapse in the 1950s[5]

Following the return of a Conservative Government in 1951 those direct controls that remained - some had already been eased - were soon dismantled, but despite its antipathy to nationalisation the new Government returned only iron and steel to private ownership. For the next ten years the emphasis of policy was upon board economic management by fiscal and monetary means. This approach has since been characterised as 'holding the ring', that is, industry "was left to operate on its own within the framework provided by government" which did not include policies that discriminated between firms.[6]

Before the end of the decade, however, two industries were subject to concerted Government intervention in opposition to the main thrust of policy. Rising imports from Commonwealth countries elicited the Cotton

Industry Act, 1959, a second attempt to modernise and restructure the industry[7] (Chapter 6.3). In the case of the aircraft industry, the objective was again restructuring, but this time the threat of withheld orders was used to force the industry to regroup into just five companies. Here, the Government's tactics were to promise "rewards... for the virtuous, and a penalty for the stubborn".[8]

These industry-specific interventions marked the end of strict adherence to laissez-faire economic policies by the Conservative Government. By the end of the 1950s, as the next section will describe, the DSIR was taking its first tentative steps toward awarding civil R & D contracts, while in 1962 the National Economic Development Council (NEDC) was set up in an attempt to emulate France's success with indicative planning. A tripartite body with representatives from government, trades unions, and employers' organisations, the NEDC's objectives are still to consider and seek to remove the obstacles to faster economic growth.[9]

3.2 The Department of Scientific and Industrial Research

The DSIR was established in 1916 as a response to a perceived lack of industrial research which had contributed toward shortages of various strategic materials, previously supplied from Germany, during the early years of the First World War. Under the Parliamentary responsibility of the Lord President of the Council and guided by an Advisory Council the Department took on three main functions : responsibility for most of the government's civil research establishments, the research associations, and university scientific and engineering research.[10]

By the Second World War the DSIR was in charge of nine research establishments, of which the most important, the National Physical Laboratory (NPL), formed in 1899, was transfered to the Department in 1918.[11] While NPL covered a number of disciplines and conducted fundamental research in such significant areas as radio, electricity generation and transmission, and aeronautics,[12] other laboratories tended to be concerned either with social welfare programmes (for instance, the Building Research Station) or promoting the imperial economy (for instance the Forest Products Research Laboratory).[13]

The research associations are non-profit making bodies jointly funded by the state and membership subscriptions. Their formation, like that of the DSIR itself, was spurred by the First World War's exposure of Britain's poor record of industrial research. Initially financed from a £ 1m special allocation administered by the Department (the Million Fund) later funding, albeit on a reduced scale, was arranged from the DSIR's own Parliamentary Vote. By 1939 some thirty associations were in existence usually, but not always, catering for the needs of traditional industries composed of mainly small firms.[14]

Support for university scientific and engineering research was provided by the DSIR in three ways: the provision of maintenance grants to post-graduate students; special awards to research personnel; and the funding of individual research projects. Until after the Second World War, university research was neglected in comparision to the Department's intra-mural spending on its own research stations. In 1938/39, for instance, university research accounted for about £ 26,000 of the DSIR's budget, representing less than 3% of gross expenditure, and less than was spent on headquarters administration. (Table 3.1)

Table 3.1 DSIR expenditures, selected years

		1938/39	1944/45	1954/55	1960/61	1963/64
Headquarters	(£000s)	32	44	342	902	906
	(%)	3.4	3.1	5.1	6.2	3.9
NLLST	(£000s)	-	-	-	-	381
	(%)	-	-	-	-	1.6
Research	(£000s)	665	1041	3788	7567	9962
Establishments	(%)	74.5	73.0	56.7	52.3	43.0
Research	(£000s)	171	334	1335	1928	2465
Associations	(%)	18.4	23.4	20.0	13.3	10.6
Universities	(£000s)	26	5	638	2601	6400
	(%)	2.8	0.4	9.5	18.0	27.6
International	(£000s)	-	-	360	1459	2819
Subscriptions	(%)	-	-	5.4	10.1	12.2
Development	(£000s)	-	-	4	-	139
Contracts	(%)	-	-	0.1	-	0.6
Miscellaneous	(£000s)	9	3	218	10	106
	(%)	1.0	0.2	3.3	0.1	0.5
Total	(£000s)	934	1427	6685	14467	23178

Source DSIR Annual Reports, appropriate years.

At the end of the War the most pressing question facing the DSIR was how it could apply itself to the revitalisation of British industry and ensure that "the tasks for which available resources are used should be, not merely useful, but the most useful that can be undertaken for the prosperity fo the country."[15] How it could accomplish this with its motley collection of statutory functions and responsibilities was a problem that continued to tax the DSIR and contributed to its eventual dissolution in 1965. The ACSP concluded that fundamental research[16] was unlikely to produce immediate industrial benefits and that for "short term results the more effective application of scientific knowledge already available was likely to prove much more effective",[17] and that there was a need to develop "the results of research and (bring) them to the stage of actual production", in which both research stations and the new NRDC could help.[18]

An early initiative by the DSIR to bolster relevant research was to transform NPL's Engineering Division into a separate engineering research station which eventually became the National Engineering Laboratory (NEL). The number of research associations, the main channel of direct DSIR industrial funding, rose in the years following the War to reach 39 in 1950. More pertinently in view of the ACSP's recommendations, the Department also expanded its Intelligence Division to oversee the deflection of its effort into information and advisory services, and short-term investigations,[19] so that by 1955 it was able to claim that a quarter of its energies were taken up by these activities.[20] Examples of this work included the grant-aided Association of Special Libraries and Information Bureaux, and NPL's introduction of an advisory service in 1950 and a series of Notes on Applied Science in 1951, the latter apparently with some success.[21] The Department also encouraged research associations in their information and liaison activities, the need for which was emphasised by an important survey which found that smaller companies and those in traditional industries - the major constituencies of the associations - had poor access to externally generated information.[22]

Even though the exigencies of the Korean War put a temporary brake upon the DSIR's budget it nonetheless increased nearly five-fold in the ten years between 1944/45 and 1954/55 (Table 3.1). But a rising budget was unable to solve, and may have exacerbated, what was fast becoming the DSIR's most immediate problem, that of controlling the activities of its research stations. Mounting concern finally led to the appointment of a Committee of Enquiry, chaired by Sir Harry Jephcott, into the Department's organisation and effectiveness.

Its Report offered the stringent criticisms that "(m)uch is started; but not enough is stopped" and that "many programmes have become too diffuse or too uneven in quality".[23] The principal effects of the resulting Department of Scientific and Industrial Research Act, 1956 were a tightening of internal control and a redefinition and rationalisation of the DSIR's role and functions. The Advisory Council was replaced by a Council for Scientific and Industrial Research with executive powers chaired by Jephcott. Two laboratories with agricultural responsibilities were transferred to the ARC; the Fuel Research Station was replaced by the multifunctional Warren Spring Laboratory; the Tropical Products Institute acquired from the Colonial Office; and various individual research programmes either curtailed or relocated to more appropriate institutional settings. In addition, new posts of Deputy Director were created at both NPL and NEL to deal specifically with the economic aspects of the laboratories' work and their relations with industry.

Besides restating the DSIR's established duties the 1956 Act also formally charged it with official responsibility for the dissemination of the results of scientific research, and to "take steps to further (their) practical application",[24] thus giving explicit recognition to the Department's existing information work, some examples of which have been noted. With the Act's blessing these activities were expanded and institutionalised, most importantly for the scientific community by laying plans for the National Lending Library for Science and Technology - opened in 1962 and now the Lending Division of the British Library - and for industry, by setting up a network of regional information centres, catering in particular for the needs of small firms.[25] Agreeing that, as far as companies were concerned, "the circulation of printed material alone, of whatever kind, (was) largely ineffective",[26] the Department also promoted demonstrations and exhibitions and, from 1959, provided funds to cover two thirds of the costs of similar research association initiatives.

This emphasis upon the dissemination of information was, in part, a reflection of the 'arms length' approach to industry pursued more generally by the Conservative Government. By making access to information easier the Department was providing industrial support without intervening directly. It is also indicative, however, of an implicit adherence to a simple, linear, technology-push model of innovation, in which as Alexander King, then Chief Scientific Officer in the DSIR's Intelligence Division, wrote, "the most important single factor (in industrial progress) is the rate at which new technical and scientific ideas are introduced to industry,"[27] and thus a function of the effectiveness of information services.

Nonetheless, after the 1956 Act and in a climate of increasing concern about the technical backwardness of certain section of British industry (see Chapter 4.3, 5.3 and 6.3), the Department conducted national surveys of industrial R & D expenditure,[28] and studies of the R & D requirements of various industries, including machine tools (Chapter 5.3), textile machinery (Chapter 6.3), and shipbuilding and marine engineering - the only one to be published.[29] Later, the relationship between engineering design and the lacklustre performance of British industry was considered.[30]

The undertaking of these studies is itself suggestive of a more sophisticated and interventionist approach to the difficulties of stimulating technical change. Its most obvious outward sign, however, was the attention the DSIR began to give to the idea of placing civil R & D contracts, similar to those already widely used in defence research. Such contracts had first been mooted by the ACSP in 1953[31] and their utility was accepted by the Department soon thereafter,[32] but although it then held a contract with Ferranti for computer development which had been taken over from the Ministry of Supply, the idea languished until its resurrection in 1956. Even so the first new contract was not awarded until 1961, by which time the ACSP had described the results of the scheme as "meagre".[33] Unfortunately, the scheme did not prove to be a success and in 1965 the DSIR simply commented that it "had hoped that by now more contracts would have been placed".[34] The Advanced Computer Techniques Project, a scheme for civil computer R & D contracting, met with a similar lack of success on its introduction in 1960 (Chapter 4.3).

Although considerable interest and attention was given to civil development contracts, its poor reception meant that it never amounted to a large change upon the DSIR's budget. Perversely, as Table 3.1 shows, the most direct form of industrial funding - support for research associations and R & D contracts - accounted for a decreasing proportion of the Department's expenditure. Instead the rising share was allocated to its 'scientific' responsibilities of academic research, the National Lending Library, and participation in joint European collaborative projects in space and nuclear physics research. Thus, despite the Department's expressions of concern about the need to raise levels of industrial R & D, little was actually achieved.

There are of course difficulties in setting and achieving an equitable balance between priorities, and an expansion of university research, neglected before World War II, was long overdue. Nonetheless, the major shift of resources to this area did not take place until the 1960s, when there was also an accompanying proportional increase in support for technological research and studentships, which until then had accounted for only a small percentage of the DSIR's university budget. Even so, given all the anxiety about Britain's technological standing they accounted for just 21.5% and 22.2% of the total allocations respectively in 1964.

3.3 National Research Development Corporation

As the NRDC remained a constant feature of the British technology policy apparatus until its recent incorporation within the British Technology Group, it is appropriate to concentrate the discussion of its activities in the 1948-1979 period here in one section rather than disperse it over the whole of this chapter. Reference will, however, be made to the Corporation in later sections as necessary.

The NRDC, the main technology policy initiative of the 1945-1964 era, was established under the Development of Inventions Act, 1948 with the twin functions "of securing where the public interest so requires the development or exploitation of inventions" and "of acquiring, holding, disposing of and granting rights... in connection with inventions", especially but not exclusively with regard to those resulting from public research.[35] It was thus charged with bringing the results of British inventiveness to commercial fruition, either by providing risk development finance or through its handling of patents, assigned to the Corporation from publicly funded research. In particular, the NRDC was seen as a way of tranferring the results of such research to the private sector, but whilst this has continued as an important component of its activities, the main focus of the Corporation's development work has shifted to supporting projects originating in private firms.

At its inception the Corporation was located under the Board of Trade to distinguish it from the DSIR as an agent of economic rather than science policy. In the avowedly laissez-faire political climate of the 1950s the NRDC was a strange anomaly, especially as it appears to have been left to pursue its own brand of interventionist policies without Government hindrance. After the return of a Labour Government in 1964, the Corporation was brought under the patronage of the Ministry of Technology, and thereafter the Departments of Trade and Industry, and Industry, thus bringing it within the mainstream of technology policy making. Even though the Development of Inventions Act, 1965 allowed central government departments to contract the Corporation to carry out schemes on their behalf, which they would fund, thus making it a potential direct tool of government policy, only two such instances of directed behaviour are recorded. Firstly, the NRDC administered the Numerically Controlled Machine Tools Trial Period Scheme (see Chapter 5.4) and, secondly, it invested nearly £5m in three separate joint ventures for the development and initial manufacture of microelectronic devices, both at Mintech's request. There are also some examples, however, indicated in the case-studies, where the Corporation acted in concert with other state initiatives, particularly with Mintech, but on the whole the Corporation has remained an essentially independent body, following its own policies.

Government funding of the NRDC has been by Treasury loans. An initial £5m upper limit was successively raised to £10m in 1958, £25m in 1965, and finally to £50m under the Industrial Expansion Act, 1968. Both the Corporation's establishing Act and the Development of Inventions Act, 1954 made provision to waive interest on these loans, but such arrangements were excluded from subsequent relevant legislation. The main purpose of the 1954 Act, however, was to extend the range of the Corporation's activities to allow it to fund research intended to result in an invention, an activity already practised by the NRDC with the Board of Trade's approval. But although the Act therefore clarified the operational status of the Corporation it also blurred the distinction between the industrial research functions of the NRDC and DSIR.[36] Thus in the absence of DSIR support for academic technological research, the Corporation funded early NC machine tool researches at the Manchester College of Technology (Chapter 5.3) and studentships in computer science (Chapter 4.3). In addition, once the DSIR started to show an interest in R & D contracting a joint DSIR-NRDC Committee had to be established to sort out their respective spheres of responsibility.

According to Keith funding by Treasury loan, requiring the Corporation to balance its statutory duty to invest in development projects with the need to earn a sufficient rate of return, had an inhibiting effect on its selection of investments.[37] It was also financially hampered by its exclusion from commercial trading in its own right in its early years, and by the decision of some research associations, particularly the Shirley Institute, to set up companies to exploit their in-house inventions which would otherwise have passed to the NRDC. Nonetheless by limiting the number of investments it took on and through the possession of various lucrative patents, the Corporation was able to restrict its losses to manageable proportions, and in 1971/72 it was able to record a profit for the first time. During the 1970s its license income rose spectacularly to £18.1m in 1978/79, while the return on development projects also rose to a peak of £4.1m in 1976/77. As a consequence the Corporation was able to completely repay all outstanding Treasury loans by 1978/79.

There are various non-exclusive interpretations of why the NRDC took the course of becoming financially independent of government. It could, for instance, be taken as a sign of institutional insecurity, but then again it might be an indication that the Corporation was unable to find development projects with potential rates of return greater than it had to pay as interest to the Treasury. This phase of retrenchment in the 1970s is in contrast to the 1950s, when the Corporation's investments in the computer industry were undertaken in the likelihood of losses (Chapter 4.3).[38]

Extensions to the NRDC's loan facilities resulted in greater numbers of development projects. A dip in numbers of current projects in the early 1970s was blamed by the Corporation on the then recession adversely affecting levels of industrial R & D.[39] However, a low average annual expenditure per project indicates that projects have tended in the main to be small scale (Table 3.2). The particularly high figures for 1965/66 and

1966/67 were due to the Corporation's £4m investment in ICT. (Chapter 4.4).

Despite access to greater loan facilities and increasing levels of patent income the NRDC's expenditures have been comparatively small. In the years up to 1964/65 its total development project investments amounted to approximately £10m, as compared with the DSIR's expenditure of more than £150m over the same period, while its total investment of £40.4m in the period 1970/71 - 1978/79 was less than the Requirements Boards' expenditure in 1976/77 alone of £47.7m (Table 3.6). Thus, while the Corporation made crucially important investments in the computer industry in the 1950s and was brought under the wing of central industrial and technology policy making departments from 1964, its relative lack of resources and low average annual expenditure per project meant that it has become increasingly excluded from high R & D cost areas and increasingly peripheral to the main thrust of UK technology policy.

3.4 The Trend Report

Returning now to the pre 1964 era, dissatisfaction with the organisation of Britain's science and technology policy machinery, and its inability to deal with industry's technical inadequacies, grew rather than dissipated after the internal reforms at the DSIR. Some steps were taken to shift R & D resources from defence to civil applications,[40] but two commentators from within the science policy establishment itself were still left doubting whether "a Government policy on the application of science really exists".[41] In the world economy, Britain's share of manufactured exports

Table 3.2 NRDC development projects : numbers and expenditures 1950-1979

Year	1950	1951	1952	1953	1954	1955	1956
No. of projects[1]	15	15	15	14	16	21	21

Year	1957	1958	1959	1960	1961	1962	1963
No. of projects	32	24	31	35	40	35	44

Year	1964	1965	1966	1967	1968	1969	1970
No. of projects	60	91	121	184	254	334	377
Total exp. (£m)	0.46	0.59	3.5	3.7	2.2	3.6	5.6
Exp. per project (£000s)	7.7	6.5	28.9	19.8	8.5	3.3	14.9

Year	1971	1972	1973	1974	1975	1976	1977
No. of projects	404	337	320	332	327	366	416
Total exp. (£m)	5.9	4.3	3.9	2.5	3.2	4.1	4.4
Exp. per project (£000s)	14.6	12.8	12.2	7.5	9.7	11.3	10.6

Year	1978	1979
No. of projects	440	508
Total exp. (£m)	6.0	6.1
Exp. per project (£000s)	13.6	12.0

Source NRDC Annual Reports, appropriate years

Note
1 Current at end of financial year, 31 March

fell from 20% to 15.5% between 1954 and 1964 whereas West Germany's rose from 15% to over 19% in the same period.[42]

Science too was becoming an issue of some political significance. The Labour Party had appointed a shadow spokesman on science in 1957, and during the General Election campaign of 1959 both it and the Conservative Party made pledges to appoint a Science Minister. Duly, after its return the Conservative Government created a Minister for Science, but "his office was primarily a secretariat for maintaining contact with the research councils and servicing the (ACSP) - it was not an 'administrative' office in the usual sense"[43] - and there were no subsequent changes of substance.

During the early 1960s these factors led to two official reports on the conduct of British science policy. The first, the Gibb-Zuckermann Report, was concerned with the techniques of management and control of R & D, but nonetheless implied that the work of publicly funded laboratories was not tied closely enough to the needs of the industrial community.[44] The wider referenced Trend Report, however, argued that Britain's civil science apparatus did not constitute "a coherent and articulated pattern of organisation", while the rational basis for the coordination and apportionment of resources was "insufficiently clear and precise".[45] Moreover, in the industrial field there was "a clear need for greater concentration of effort" and for some means of ensuring that research was "enlisted in support of those activities which are the most important for the economy as a whole".[46]

Principal among the Report's recommendations was the disbandment of the DSIR and the reallocation of its functions to two new agencies. One, a Science Research Council, would take over the DSIR's 'scientific' responsibilities - higher education and some research stations - and be on the same footing as the existing research councils. The second, the Industrial Research and Development Authority (IRDA), made up of the DSIR's residual 'industrial' functions and the NRDC, would be responsible for industrial research in general. The Report also proposed that the ACSP should be replaced by a new body to advise on all aspects of civil science, and that the Nature Conservancy should be expanded to become the Natural Resources Research Council. To cope with these changes it also recommended that the Minister for Science's Office should be consequently strengthened.

While the Trend Report might be criticised as a limited attempt at reform,[47] it certainly reflected the more interventionist industrial stance being taken by the Government and the growing Conservative Party belief that science and technology policy should be treated as an ingredient of a wider economic policy.[48] As such, its recommendations were on the whole accepted by the Government and included in the Conservative Party's 1964 General Election manifesto.[49]

3.5 An overview of policy, 1964-1970

The victory of the Labour Party in the 1964 General Election brought the return of a Government that, unlike its Conservative predecessors, happily embraced detailed planning and interventionist policies as integral components of its economic programme. During the previous few years the

Party had adopted science and technology as a major campaign issue, partly because of its reflected glamour, but it nonetheless made "serious efforts to develop concrete alternatives to government policy".[50] Technology was to be a part of a fresh approach toward manufacturing industry which was to "go beyond research and development and establish new industries, either by public enterprise or in partnership with private industry".[51] Central to the new Government's plans was the Ministry of Technology, soon to be known as Mintech, an alternative to IRDA which placed technology policy making at the heart of the administrative process, which would make greater use of civil R & D contracts.

Another important new Ministry was the Department of Economic Affairs (DEA).[52] This was given the major task of constructing and overseeing the execution of the National Plan which set performance targets for individual industries, and within the framework of which Mintech was to operate.[53] To help in the planning exercise, the NEDC's Office (NEDO) was expanded and a number of industry-specific Economic Development Committees (EDCs) were established. With the early abandonment of the National Plan in 1966, however, the DEA's purpose was removed and even before it was finally dissolved in 1969 responsibility for industrial policy formulation had been assumed by Mintech.

A third new Ministry, the Department of Education and Science (DES), merged the Ministry of Education and the scientific - as against the technological - responsibilities of the Ministry for Science. It thus took control, inter alia, of the research councils, including the new Natural Environment (not Resources) Research and Science Research Councils (SRC). Also in accord with the Trend Report, the ACSP was replaced by the Council for Scientific Policy (CSP) which reported to the Secretary of State for Education and Science.[54] Later, in 1967, the Central Advisory Committee for Science and Technology (CACST), a joint DES/Mintech body, was formed to provide a link between the two departments.

Besides the creation of the explicitly interventionist Ministry of Technology the Government also took a mixture of other general and specific initiatives aimed at extending its influence over industry. Regional policy became more important than hitherto. Following evidence that tax relief was rarely taken into account in investment calculations, tax allowances were replaced by grants.[55] Consideration was also given to the possible use of procurement policies to improve productivity and technological innovation,[56] but there is no evidence that such policies were widely adopted, except in the case of computers. (Chapters 4.4, 4.5)

Significant intervention also took place in specific industries, ranging from the renationalisation of the iron and steel industry to the establishment of the Shipbuilding Industry Board to administer Government support and initiate the reorganisation of the industry.[57] The aircraft industry, too, came under scrutiny and aid was provided to a number of companies, including Rolls Royce and Short Brothers.[58]

A major institutional innovation was the establishment in 1966 of the Industrial Reorganisation Corporation (IRC) as an independent body with with powers to promote greater concentration and rationalisation in British industry.

The Government's own abilities for direct intervention were extended first by the Science and Technology Act, 1965, which allowed for greater support for research and development, and later by the potentially very powerful Industrial Expansion Act, 1968. The objective of this Act was to "enable the Government to operate more directly and flexibly in support of production itself" whereas previously its powers "to support the exploitation of the results of research and development (were) seriously circumscribed".[59] Under the Act, the Ministry of Technology was empowered to provide "loans, grants, guarantees, and the underwriting of losses of the subscription of share capital,"[60] where the result would be to "improve the efficiency or profitability of an industry", "create, expand or sustain productive capacity", or "promote or support technological improvements".[61] Individual investments did not have to meet commercial criteria but could be justified "because of a divergence between national and private costs and benefits".[62] Although the range of the Act obviated the need for any extra legislation for future industrial schemes, it was only used twice, for the encouragement of the ICL merger (Chapter 4.4) and to provide assistance for the construction of three aluminium smelters in the development areas.[63]

3.6 The Ministry of Technology

Mintech's purpose was "to guide and stimulate a major national effort to bring advanced technology and new processes into industry."[64] To begin with the new Ministry under its first Minister, Frank Cousins, advised by the Advisory Council on Technology (ACT), was based on the industrial side of the DSIR - essentially its industrially oriented reasearch laboratories, such as NPL and NEL, the research associations, now forty five in number, its R & D contracting functions, and the various advisory services set up during the 1950s - plus responsibility for the UKAEA and the NRDC. Full incorporation of the DSIR's activities had to await the Science and Technology Act, 1965 which also allowed the AEA, representing a substantial concentration of R & D resources, to undertake non-nuclear research. Under a separate Act, the NRDC's borrowing powers were increased to £25m.

As a focus for its activities Mintech also took over the sponsorship from the Board of Trade of four industries - machine tools, computers, electronics and telecommunications - "chosen for their special relevance to (Mintech's) objectives".[65] Over the first year of its life the Ministry concentrated on formulating policies for these industries, but late in 1965 its sponsorship function was extended to include the mechanical and electrical engineering industries, including motor vehicles, again transferred from the Board of Trade. In 1966 shipbuilding followed, and the next year Mintech absorbed the Ministry of Aviation in a move which increased its payroll from about 5000 to 36500. "Likened by the press to a gnat swallowing an elephant",[66] the rationale behind the merger was that Mintech's sponsorship of the electronics industry was "meaningless in practice when another department was responsible for very large R & D and procurement orders."[67] By bringing both departments together under one administrative banner the intentions were thus to considerably strengthen Mintech's stake in advanced technology, enable Mintech to utilise Aviation's experience of handling R & D contracts, and aid the transfer of military-oriented research to the civil sector.

But by 1966 science and technology were of less importance to the Labour Government's economic programme than they had been two years before.[68] There are perhaps two related reasons why this change occured. One was the finding from academic research that, internationally, the relationship between economic growth and levels of R & D spending was not as strong as previously believed[69], while the second was the realisation "under the compulsion of economic restraints", that "whenever industrial policy was dominated by technology rather than the market it went wrong".[70] Thus in the words of Anthony Wedgwood Benn, who became Minister of Technology in 1966,

> (i)n Mintech it was quickly recognised that it was not technology that Britain lacked but a strong industrial organisation, good management, real attention to applications and an educational system that raised the level of the average instead of pumping out endless Ph.D's.[71]

British industry's apparent inability to assimilate advanced technology was therefore as much a symptom of its malaise as a cause. According to one commentator the arrival of Wedgwood Benn as Minister was also instrumental to Mintech's change of tack. He soon became aware that "technology was an albatross with which he had to live"[72] but once the Ministry's position was assured by its takeover of Aviation "technology proved advantageous in a tactical rather than substantive sense and remained a useful catchphrase to which the Ministry was wedded by virture of its name."[73] With the implicit broadening of its remit and a huge increase in its resources, Mintech's "technology policy (was now) an industrial policy, it (was) a systematic attempt to strengthen our competitive ability".[74]

At the same time Mintech also began to reconstruct its public image. Gone were the fiery rhetoric of Harold Wilson's famous 'white heat' speech,[75] Frank Cousins - an unpopular Minister - and the National Plan, and in their place were Wedgwood Benn, an energetic, photogenic and young Minister, and the language of partnership with industry. Wedgwood Benn describes this partnership in the first issue of Mintech's glossy house journal, New Technology, itself a part of the new image, thus:

> It is in industry that technological progress will take place. Our task is to assist that progress, so we must win and hold the confidence of industry in our good faith and goodwill, as well as in our competence. We want to be seen as being on the side of industry, and as sharing its long-term objectives, whether or not we share its views of short term issues.[76]

But while Mintech's emphasis changed, technology did not become quite the albatoss that has been suggested, instead it became a means to an end rather than an end in itself. As a part of the new strategy was the economies of scale argument that there was a "necessity in rapidly changing science-based industries, of strong R & D teams which must reach a certain minimum size for viability. The high cost of such a team demands a large firm with a high turnover and profits to finance it."[77] Strong R & D teams could be created by the merger of existing ones or by stimulating more research in particular firms by the award of development contacts. More industry-based R & D would also help avoid the problems of transferring technology to private firms and make for the more efficient use of resources - there had been complaints of a lack of cost consciousness in government laboratories.[78] Larger enterprises could also take advantage of other economies of scale and allow for the most efficient use of scarce good management skills. Mintech's ideas then reflected the thinking that had lain behind the creation of the IRC and was to be applied to the creation of ICL.

During this period, 1967-68, Mintech's activities were concentrated in five main areas: developing and carrying through programmes for its sponsored industries; mobilising and exploiting its own R & D resources; promoting industrial efficiency through various advisory services; promoting awareness of advanced technologies; and carrying out its defence and civil aviation responsibilities, acquired from the Ministry of Aviation.[79] A particular feature of these years was the proliferation of new schemes and agencies, some of which are described in the case studies, and the expansion of the regional information services it had taken over from the DSIR. Organisations such as APACE (Application of Computers to Engineering Chapter 4.4) and the Numerical Control Advisory and Demonstration Service, Chapter 5.4) were attempts to open up the expertise of government laboratories, in these cases the UKEA, and NEL and the Royal Aircraft Establishment, respectively - to industrial users, while others such as the National Computing Centre (Chapter 4.4) and the Institute of Advanced Machine Tool and Control Technology (Chapter 5.4) were entirely new bodies.

In one sense Mintech's role as an industrial department was made easier in these years "because the Ministry did not have the responsibility ... for regulating industry in the public interest"[80] but during 1969 some of these responsibilities, such as those for monopolies and mergers and regional policy, were transferred to Mintech from the Board of Trade. At the same time the Ministry took over the Board's remaining sponsorship functions for manufacturing industry, the Ministry of Power, and the DEA's responsibility for the IRC and industrial planning, thus transforming it in Clarke's view from a Ministry of Engineering to a full-blown Ministry of Industry.[81] According to the Prime Minister, the advantages of this reorganisation lay in bringing together the sponsorship of both user and supplier industries - for instance, textiles and textile machinery, and atomic energy research and electrical power generation - within one Ministry which also had responsibility for raising industrial productivity.[82]

Table 3.3 Ministry of Technology gross expenditures, 1964/65 - 1969/70 (£000s)

	1964-65	1965-66	1966-67	1967-68	1968-69	1969-70
Mintech	49	12267	24249	56545	59261	92958
Industrial services	-	-	-	16384	28888	42764
Aerospace	-	-	-	254825	266582	248633
Purchasing (Replacement services)	-	-	-	12041	4969	1079
Purchase of US aircraft	-	-	-	90050	109141	31036
Special materials	-	-	-	39175	29920	31208
Total	49	12267	2424	469020	498761	447678

Source *Civil Appropriation Accounts*, appropriate years.

The expansion of the Ministry's responsibilities are reflected in the growth of its budget (Table 3.3). Table 3.4 shows that expenditure on civil R & D contracts increased nearly tenfold between 1965/66 and 1969/70. However, as the monies set aside for such contracts amounted to £6.4m in 1967/68 and £6.3m in 1968/69, it is clear that the Ministry had greater plans in this regard than it was able to realise. As a consequence, its estimated provision for development contracts was reduced to £3.9m in 1969/70 to become closer to demand.[83] Another point arising from these tables is that the budgets of the Aviation research establishments were left untouched by their transfer to Mintech and continued to dwarf those of the industrial laboratories. Even if there was some reorientation of their work the bulk of Mintech research activities came to be dominated by the concerns of aviation.

To set these Tables into context, Government R & D expenditure rose from £412m in 1964 to £ 529m in 1969, representing 53.6% and 50.6% respectively of total UK R & D expenditures in these years of £768m and £1045m. Although net Government expenditure on defence R & D fell from £ 260m to £ 239m between 1966/67 and 1967/70, aerospace expenditure rose from £57m to £97m as the Concorde project especially got into full stride.[84]

Table 3.4 Ministry of Technology : expenditure on various services, 1965/66 - 1969/70 (£000s)

	1965-66	1966-67	1967-68	1968-69	1969-70
Research Associations	3030	3725	4050	4031	4068
R & D Contracts	347	753	1707	3581	3079
Advisory + Demonstration Services	-	-	-	704	763
Industrial Research Establishments	9359	10929	10873	11364	12043
Aviation Research Establishments	-	-	26584	27737	57557

Source Civil Appropriate Accounts, appropriate years

3.7 The Industrial Reorganisation Corporation

The IRC was established in December 1966 in order to "provide or assist the reorganisation or development of any industry".[85] One of the most interesting, flexible and openly interventionist of the Labour Government's experiments in industrial policy, the Corporation was empowered to borrow up to £150m from the Treasury, but it was expected to be "self supporting and be able to earn a commercial rate of return on its operations."[86] The Corporation was formed in the belief that British industry was composed mainly of firms too small and industries too fragmented to make effective use of scarce manpower and capital resources. The IRC's purpose was therefore to stimulate greater efficiency and international competitiveness by encouraging greater concentration and rationalisation, in the cause of which it was given exemplary powers to act, as itself stated, as a form of merchant bank whose client was the national interest where that was identifiable.[87]

Altogether in its short lifetime - it was abolished in 1971 - the IRC was involved in 38 main projects, in which it acted as a catalyst in potential mergers, rescued companies in difficultes, and provided investment finance.[78] The main factors taken into account in the selection of its projects were stated to be the impact upon the balance of payments and productivity, especially in key industrial sectors, but other criteria included the impact upon regional employment, the quality of management concerned, and the contribution that could be made to technological development.[89] Indeed many of the Corporation's activities were in areas of interest to Mintech, such as machine tools and electronics, although its largest investment was a £25m loan to ease the merger that formed BLMC, the forerunner of BL.

Whilst under the Parliamentary responsibility first of the DEA and then Mintech, the IRC was placed outside the normal Civil Service structures, emphasising its essential independence from a Government which was not necessarily viewed as sympathetic to the industrial community, and allowing it to act more quickly than it could have done from within Whitehall. Despite this independence from overt political control, the Industrial Reorganisation Corporation Act, 1966 allowed the Government to request the Corporation to act on its behalf. There are also instances where the IRC appeared to act directly in the furtherance of Mintech objectives (see Chapter 4.4, 5.4 and' 6.4). But although Young and Lowe argue that there were implicit limits to the Corporation's range of actions, Hills states that its independence made it a "substitute for clear governmental policy."[90]

3.8 The Science Research Council

As in the case of the NRDC, discussion of the activities of the SRC is concentrated in this one section rather than dispersed over the chapter.

Whilst the industrial side of the DSIR formed the initial basis for Mintech its scientific half, composed of support for academic research, including post-graduate studentships, international collaborative projects, plus some research stations, became the SRC. Between 1965 and 1979 the Council's budget increased in current terms from £28m to £157m, within which the most notable proportional shift of resources was from intramural research to subscriptions to international organisations (Table 3.5), necessitated partly by falls in the value of sterling. Although in real terms the Council's expenditure rose by nearly a half in this period, all of this increase was incurred before about 1972, after which the SRC's real expenditure remained relatively static.[91]

Table 3.5 SRC expenditure, various years

	1965/66		1970/71		1978/79	
	£m	%	£m	%	£m	%
Headquarters	0.6	2.2	1.3	2.6	6.2	3.9
Research labs	11.5	40.7	16.8	32.7	51.5	32.7
Research grants	6.1	21.5	9.7	18.8	30.9	19.6
P-g studentships	4.1	14.7	6.2	12.0	22.2	14.1
International Orgs	5.0	17.5	12.3	24.0	45.3	28.8
Other	1.0	3.4	4.9	9.8	1.4	0.9
Total	28.2		51.3		157.5	

Source SRC Annual Reports, appropriate years

Like the DSIR before it a constant preoccupation of the Council, reiterated in many of its annual reports, was its concern for industrial needs. In 1967, for instance, it stated that it was looking with sympathy at research proposals in technological as opposed to scientific fields, especially those likely to be of value to industy.[92] Conversely though, in the following year the Council decided to regulate its research grants, in general, "in order to free scarce manpower for industry and schoolteaching".[93] Later, in the 1970s, a new but related concern was how it could overcome what it identified as a 'development gap' between the results of the research it funded and their industrial exploitation.[94]

Perhaps the Council's most important initiative in this area, also in line with its policy of selectivity and concentration,[95] was the adoption in 1977 by its Engineering Board of a number of research areas of "national importance" for medium- and long-term coordinated support in which industrial cooperation was actively encouraged. By 1979 there were some eleven medium-term Specially Promoted Programmes (SPPs), as they were then known, including grinding technology, distributed computing systems, dies and moulds, efficiency of batch manufacture, and application of numerical control to manufacturer,[96] together with three long-term support schemes, the Polymer Engineering and Marine Techology Programmes, and the Teaching Company Scheme. The long-term schemes are managed by their own separate Directorates, while the SPPs were served by their SRC cordinator. Under the Teaching Company Scheme, a joint venture with the Department of Industry, academic departments recruit a graduate associate to take part in a firm's research programme which is backed up by access to the department's research facilities. Industrial collaboration was also the idea behind the Cooperative Research Grants Schemes established in 1978 to fund research projects outside of the fields covered by the SPPs and Directorate Programmes. In addition, better contact between academics and industry was also the aim of the network of regional brokers which started with its first two appointments in 1980. As a consequence of the Council's reorientation, over the thirteen years between 1965/66 and 1978/79, the proportion of research grants in technological subjects rose from 34.7% to 44.7% by value of total commitments.[97]

Changes in the structure of post-graduate education also reflected the themes of industrial relevance and collaboration. During the 1960s various schemes - industrial studentships, and science and industry awards - were established as means of fostering the interchange of students between industry and academia. Awards for 'total technology' studentships, combining both management and technology subjects, began in 1973. A further scheme, Cooperative Awards in Pure Science, was extended in the 1970s to include engineering students and renamed Cooperative Awards in Science and Engineering. While these various new arrangements may have increased the industrial orientation of post-graduate training, the number of post-graduate students in technology also rose from 1200 in 1965/66 to 1700 in 1978/79, and as a proportion of total SRC students from 21.2% to 32.1%.[98]

3.9 Policy Proposals

Earlier it was noted that halfway through its reign Mintech decided that technology on its own was not the whole answer to Britain's economic problems, but to be effective had to be incorporated within a wider industrial policy framework. The perceived failure of technology policy to come up with short-term results thus led to a re-examination of its conduct and composition. Blackett, the Deputy Chairman of the ACT, criticised procurement policies for being too fragmented and over-specific, the overconcentration of R & D within government laboratries and its lack of cost-effectiveness, and argued in favour of larger and stronger R & D terms located in industry.[99] In a similar vein, Wedgwood Benn talked of the need to encourage the use of government stations by private firms for contract research as a way of establishing a more intimate relationship between them,[100] a point reiterated by the CACST. More generally, the Council argued that innovation in Britain industry was hampered by a maldistribution of R & D effort, an inadequate level of capital investment, and a shortage of qualified scientists and engineers (QSEs) in industry, especially in non-R & D activities. In this last regard, the CACST recommended, amongst other things, that new science and technology graduates should be encouraged to enter "the management of industrial operations as a whole"[101] rather than just R & D.

This reappraisal of the structure and content of technology policy culminated in Mintech's proposal for a British Research and Development Corporation (BRDC) which would incorporate all of Mintech's existing civil research and development responsibilities - its laboratories, the AEA, and the NRDC - under a single management. By merging these various separate institutions the objective was to resolve the problems of overlapping programmes and conflicts of interest. The BRDC would also be located outside the Civil Service so that it would "be better able to rationalise programmes, to operate more flexibly, and would be freer to associate its research and development resources more closely with industry".[102] The arrangements between the Corporation and others would be contractual because "(a)s a great rule, only the 'customer' knows what he wants, and by his readiness to pay for it makes the 'supplier' aware of his requirements".[103]

In essence therefore the BRDC was an expanded version of the Industrial Research and Development Authority proposed seven years before by the Trend Committee. With an estimated initial 4000-5000 professional staff and annual gross expenditure of about £70m it would have been a very large organisation indeed. Many of the existing responsibilities of the laboratories, for nuclear research, standards, etc, would have remained and been paid for on a contractual basis by state agencies. Some other funds were to be provided as grant-in-aid, but otherwise the BRDC was expected to market its services to private industry.

3.10 An Overview of Policy, 1970-1979

Before any action could be taken on the proposal for the BRDC a General Election returned a Conservative Government implacably opposed to the policies pursued by the former Labour administration. In its election manifesto the new Government had rejected the "detailed intervention" of the previous six years, prefering "a system of general pressures, creating an economic climate which favours, and rewards, enterprise and efficiency".[104] Moreover, the Conservatives promised a slimmer, more cost-effective style of government that would utilise the latest management technques : there had, they said, "been too much government, there will be less"[105] Intervention was "an evil which must be reversed before it stifles enterprise",[106] and the Government was to return to the 'holding-the-ring' policies of the 1950s.

An immediate organisational change was the abolition of the Ministry of Technology and the merger of its responsibilities with those of the Board of Trade, and some from the Department of Employment and Productivity, to form the Department of Trade and Industry (DTI). Responsibility for aerospace eventually passed to the Ministry of Defence.

Rejection of the interventionist ethos of the 1960s was symbolically completed by the Industry Act, 1971 which repealed the Industrial Reorganisation Corporation Act, 1966 the Shipbuilding Industry Act, 1967 and the Industrial Expansion Act, 1968, thereby dissolving the IRC and SIB and deliberately restricting the state's capability to provide assistance to private industry. Additional changes included the replacement of investment grants by tax allowances, the winding up of the National Prices and Incomes Board, and the sale of some public assets such as the National Coal Board's brickmaking works. Six of the twenty two EDCs were also abolished.

In the explicit area of technology policy, a system of Research Requirements Boards was created to allocate the bulk of the DTI's industrial R & D budget outside of certain high cost fields. Further changes in the policy machinery included the establishment of the Central Policy Review Staff, a body given the task of bringing a creative and long-term view to policy matters, and the replacement of the CSP by the Advisory Board for the Research Councils.

However, within two years of its election, against a background of stagnant investment and rising levels of unemployment and catalysed by financial crises at Rolls Royce, Upper Clyde Shipbuilders, and Harland & Wolff, the Government reversed the tack of its industrial policies with the Industrial Act, 1972. "(T)he most interventionist piece of legislation concerning government assistance to the private sector ever to have been passed in Britain",[107] the Act attempted to "stimulate industrial and regional regeneration"[108] by reintroducing grants toward capital expenditure in the development areas, and creating means for selective regional financial support (Section 7) and the selective support of industry in general (Section 8). Special help for the shipbuilding industy was also provided by a scheme of grants and financial credits for the construction of ships and mobile offshore installations. Rolls Royce was taken into public ownership while, in separate actions, a Shipbuilding EDC and the Northern Ireland Finance Corporation were established.

Following the election of a Labour Government in February 1974 the industrial responsibilities of central government were again reorganised. The DTI, which had lost the AEA just prior to the General Election to the new Department of Energy, was split into three - the Departments of Industry (DoI), Trade, and Prices and Consumer Protection to mirror pre-1970 arrangements. Under the DoI the main plank of the Government's industrial policy was the raising of levels of capital investment both through the use of the Industry Act, 1972 and the National Enterprise Board (NEB), a form of investment bank. A central role in developing a flexible planned framework for industrial policy was given to the NEDC whose resources were consequently augmented by thirty nine Sector Working Parties (SWPs) to work alongside the existing EDCs.[109]

The Labour Government's approach to industry was both similiar and different to that adopted in the 1964-1970 period. The NEB was in some ways the IRC reborn. Planning was again resurrected, but the static National Plan was replaced by an attempt to create parallel sectoral strategies which could be refined in the light of experience.[110] This time round though technology was relegated to a subsidiary role, although the setting up of the Advisory Council for Applied Research and Development (ACARD) in 1976 to provide a form of largely independent advice to government on research matters, brought it back to a more public prominence. State influence with respect to industry was further extended by the nationalisation of the aerospace and shipbuilding industries, while some individual ailing firms such as BL and Alfred Herbert (See Chapter 5.5) were taken into public ownership. The creation of the British National Oil Corporation also gave the Government greater control over the exploitation of North Sea oil reserves.[111] Other initiatives included the formation of regional versions of the NEB, the Scottish and Welsh Development Agencies, to cater for special local needs, and a provision for planning agreements contained in the Industry Act, 1975. This, however, was only used with regard to a large investment in Chrysler UK Ltd. The role of finanical institutions in providing funds for industrial investment also came under scrutiny in this period but without any concrete effect.[112]

3.11 The Department of Trade and Industry, and the Department of Industry

The remit of the DTI was "to assist British industry and commerce to improve their economic and technological strength and competitiveness" by establishing "a general framework of requirements, incentives and restraints within which firms can operate as freely as possible to their own individual advantage".[113] Based "on the functions of the Board of Trade",[114] a traditionally non-interventionist department, the DTI's purpose was neither to "bolster up nor bail out companies (where it could) see no end to the process of propping them up."[115]

As part of the process of attempting to redraw the boundaries of the state through limiting its direct involvement in industry, the DTI reviewed the apparatus for support which had been built up, particularly over the previous few years, with a view to dismantling that which did not represent "a proper charge on the state".[116] Various services, such as APACE and parts of NCADS, were cut while spending on R & D contracts dropped. The Pre-Production Order Scheme, instituted as a means of supporting the machine tool industry, fell into virtual disuse (Chapter 5.5). Four research establishments - the Fire Research Station, Forest Products Research Laboratory, the Hydraulics Research Station, and the Water Pollution Research Laboratory - were also transferred to the new Department of the Environment. But conversely many services and organisations remained relatively untouched while some new ones, such as the Small Firms Advisory Bureau, were introduced.[117] Moreover, the DTI's direct industrial responsibilities were increased as it assumed the IRC's investments on the Corporation's abolition.

With the Conservative Government's economic policy aboutturn the DTI's purpose became much more interventionist. Immediate charge of disbursing assistance under the Industry Act, 1972 was given to a new sub-department, the Industrial Development Unit, manned predominantly by staff recruited from outside the Civil Service and under the control of the Minister for Industrial Development. To prevent misuse of the very wide powers of the Act, independent advice on its operation was provided for the Secretary of State by the Industrial Development Advisory Board.

During the remaining life of this Conservative Government the Act was mainly used to provide financial assistance for industrial investment in the development areas, the shipbuilding industry and Rolls Royce. On occasion aid was provided to other individual firms in difficulties, such as the machine tool manufacturers Kearney, Trecker & Marwin (Chapter 5.5), but such instances were exceptions to rather than the rule itself. Where R & D support was provided it was either channelled though the Research Requirements Boards, or more rarely under the Science and Technology Act, 1965.[118] The lone example of more concerted organised support under the 1972 Act was the Wool Textile Industry Scheme, introduced at the end of 1973 under pressure from the Wool Textile EDC[119] to encourage investment in the industry, and its restructuring, by providing grants for the modernisation and rationalisation of productive facilities.

On the return of a Labour Government in 1974 the Department of Industry emerged as the new focal point of industrial policy which continued the stress upon capital investment. Between the middle of 1975 and end of 1978, twelve further sectoral schemes, as well as a second stage of the Wool Textile Industry Scheme were introduced with varying amounts of provision. Three schemes - machine tools (Chapter 5.5), textile machinery (Chapter 6.5) and printing machinery -allowed for the support of product development as well as investment and rationalisation. While the majority of schemes were aimed at financing mainly small-scale projects in unglamourous industries, composed usually of small firms,[120] two more general schemes, the Accelerated Projects Scheme and its successor the Selective Investment Scheme, were intended to encourage additional or bring forward large capital investment projects throughout manufacturing industry. Applications to the new sectoral and general schemes were claimed to be assessed in terms of the Government's overall industrial strategy.

Under the DoI the Industrial Act, 1972 was also used more often than hitherto for the *ad hoc* rescue of individual companies, including Chrysler UK, British Leyland, the machine tool manufacturers Alfred Herbert and Kearney Trecker & Marwin (Chapter 5.5), the remains of the UK motocycle industry, and a small number of workers' cooperatives.

Support for product development outside of the three industry schemes noted was, as under the DTI, largely left to the Requirements Boards and the NRDC. The principal emphasis of the DoI on promoting large-scale or targetted investment in particular industrial sectors can, in one sense, be seen as a reaction to the 'technological illusion' of Mintech and the commercial failure of expensive and prestigous projects such as Concorde, rather than as a response to various studies that had over the years argued that low levels of investment had retarded effective innovation.[121] Under this new emphasis technology policies became increasingly uncoordinated[122] and little was specifically done to raise the levels of intramural industrial R & D expenditure which, by 1975, had fallen by 11½% in real terms since 1969.[123] But by the end of the 1970s the pendulum began to swing back to the need to provide more public assistance for R & D and innovation within the context of the Government's industrial strategy. Both the Requirements Boards and the SRC recorded their intent to work within the strategy, while the DoI introduced the Product and Process Development Scheme (PPDS) in 1978 under the Science and Technology Act, 1965 to support innovation projects that would otherwise have not been undertaken or would have taken considerably longer to complete, and which also contributed to the strategy.

PPDS support usually took the form of a 25% grant toward development costs, though for appropriate projects shared costs contracts could be offered with the DoI recovering its funding by way of a levy on sales. The scheme also resurrected provision for pre-production orders which had been allowed to lapse since the 1960s while in 1979, the Advanced Computer Technology Project which had been running for nearly twenty years under various banners, was also incorporated within the Scheme.

Whilst PPDS was a general scheme for the support of innovation, the DoI also launched in 1978 two schemes specifically aimed at recovering ground lost in microelectronices technology to foreign competitors.[124] £55m was committed to the Microelectronics Industry Support Programme over five years in order to expand the production of standard and special integrated circuits. Given the evidence of a wide potential for microprocessors in industrial products and processes,[125] the purpose of the Microprocessor Applications Project, to which another £55m was eventually allocated, was to speed the diffusion of microelectronics equipment by providing awareness and training schemes, consultancy support, and funding for the development of microprocessor applications.[126]

3.12 The Research Requirements Boards

A major organisational change in how the DTI, and later the DoI, disbursed funds in support of industrial R & D occured in 1972 with the formation of the Requirements Boards. Their creation followed the recommendation of the Rothschild Report which advocated the wide application of the 'customer-contractor' principle - "the customer says what he wants; the contractor does it (if he can); and the customer pays"[127] - to government-funded applied research. The ideas of the need for the primacy of customer requirements in setting R & D objectives and a contractual relationship between customers for, and suppliers of, R & D had been contained in Mintechs' proposal for the BRDC but, placed by Rothschild in the context of intramural cost-effectiveness and accountability rather than an extramural government agency, they found favour with a Conservative Government interested in new management techniques and cost-effective government.[128]

More specifically the functions of the Requirements Boards were to help "identify those areas which will most benefit from Government supported R & D" and "to determine the objectives and balance of research and development programmes to support departmental policies, within the broad allocation of funds available to them".[129] With appointees from industry it was hoped that the Board would help solve the perennial problem of aligning governmental research, particularly that carried out by its research establishments, with the wants and needs of industry. Previously, as described by the DTI's Chief Scientist, their research programmes were "more or less invented within the IRE's and then endorsed by a process of advisory committees and ultimately by myself."[130]

Eight Boards were established by 1973, and nine were in existence in 1979. One, the Chief Scientist's Board, was intended to cater for the research needs of those areas not covered by the other Boards which had more specific industrial fields of interest. Even so, not all of British industry was covered by the Boards and neither was all of the DTI's R & D expenditure channelled through them. Thus, areas of major DTI R & D funding - nuclear energy before its transfer to the Department of Energy, aircraft and aeroengines, and space research - were completely outside the Boards' influence. Moreover, by reserving the right to support extramural research without the approval of a Requirements Board where the object was to provide direct industrial assistance[131] the R & D assistance to ICL (Chapter 4.5), the development provision of the sectoral schemes, and the later PPDS, MISP and MAP - provided means of R & D funding which if not quite duplicating the Boards' work were parallel to it. In total, the Requirements Boards accounted for less than 40% of the Department's overall funding of research and development during the 1970s, a percentage which appears to have declined as the decade progressed and as PPDS etc. came on stream. (Table 3.6)

While the Industry Departments' own research stations were the main target of the Rothschild shake-up, the Requirements Boards also disbursed research funds to the laboratories of other Government departments, universities, industries and research associations, for which contractual support gradually replaced grant-in-aid as the main form of state funding. Despite some hopes that the new arrangements would encourage a shift of sponsored research from government laboratories to industry no such shift appears to have occured. (Table 3.7)

There was considerable variation, however, between the funding patterns of individual Boards, depending mainly on the institutional R & D framework available. For instance, while 83% of the Garment Board's funding went to research associations in 1978/79 reflecting the importance of the textile research association as a location of textiles research, all of the Metrology and Standards Boards's funding in the same year was spent in DoI laboratories. On the other hand, half of the Computers, Systems and

Electronics Board's expenditure was accounted for by industry-based projects, mirroring the existence of greater levels of industry-performed R & D in that industry.

Table 3.6 Requirements Board expenditures, selected years (£m)

BOARD	1973/74	1976/77	1979/80
Chemical and Mineral Processes and Plant	3.6	4.4	6.7
Chief Scientists[1]	2.3	2.3	1.1
Computers, Systems and Electronics	5.5	10.4	6.8
Engineering Materials	3.1	5.3	8.7
Electrical Technology[1]	-	-	2.1
Fundamental Standards[2]	1.1	-	-
Garments and Allied Industries	-	1.0	2.1
Mechanical Engineering and Machine Tools	5.5	8.8	13.0
Metrology and Standards[2]	3.3	9.2	11.0
Shipbuilding and Marine Technology	4.4	6.4	4.2
Total (a)	28.9	47.7	55.8
DTI/DoI gross R&D expenditure (b)		124.3	176.9
$^a/_b$ (%)		38.4	31.5

Source Requirements Board, Reports, appropriate years

Notes

1 The responsibilities of both the Electronic Technology and Garments and Allied Industrial Requirements Boards' were, before their formation, under the Chief Scientist's Board.

2 The Fundamental Standards Board later merged with Metrology and Standards.

TABLE 3.7 Requirements Boards' expenditures by institutional location (%)

	1973/74	1978/79[1]
DTI/DoI laboratories	56.2	50.9
UKAEA	8.5	6.7
Other Government laboratories	7.0	5.9
Research Associations	10.2	16.8
Universities	0.4	2.3
Industry	15.8	17.0
Other	1.9	0.5

Source Requirements Boards, Reports, appropriate years.

Notes

1. Error in total due to rounding.

To begin with the Boards concentrated on funding research and development, but within a couple of years, finding that problems more often lay "in the application of existing technology" than in its generation,[132] some Boards started to emphasise the importance of transferring technology into industry. The Mechanical Engineering and Machine Tools Board, for instance, shared the sponsorship of the Teaching Company Scheme with the SRC, while the Garments Board helped to set up a number of 'shop-window' factories to demonstrate new production techniques in a real setting.

3.13 The National Enterprise Board

Established under the Industrial Act, 1975 the NEB was charged with the general tasks of aiding industrial undertakings, promoting or assisting the reorganisation of industries, extending public ownership into profitable areas of manufacturing industries, promoting industrial democracy in companies under its control, and holding state-owned equity investments. In pursuit of these functions the Board was required to act in furtherance of the Labour Government's industrial strategy, to take into account the need to increase capacity in key sectors of the economy, and give due regard to the impact of its activities on the balance-of-payments and regional employment.[133]

With up to £1bn of Treasury loans at its disposal the Board was intended to act as both state investment bank and, like the IRC created by the previous Labour Government, entrepreneurial agency, but one which took various social criteria into specific consideration. Like the IRC too the NEB was set up and staffed from outside the Civil Service, but in comparison with the Corporation its entrepreneurial activities were under much tighter political control: ministerial approval was required for the acquisition of 30% or more of a firm's share capital, or more than 10% if acquired without the company's consent, or for any shareholding exceeding £10m in value. Moreover, the 1975 Act allowed the Government to direct the NEB to act an an agent on its behalf, in which case its costs would be reimbursed. This "lame duck provision" thus provided for the rescue of companies[134] without impinging on other general directives to the Board that it should charge "a rate of interest not less than that paid by commerical companies of the highest standing when raising finance",[135] and make an adequate return on its investments.

The Board's freedom of action was thus seriously constrained in comparision to the IRC. It was allowed to make relatively small and uncontroversial investments and was required where specified to act as a direct instrument of Government policy, but it was prevented from making large investments or indulging in the contentious manipulation of mergers in the manner of the IRC without the express agreement of its sponsoring Minister.

In practice much of th NEB'S financial and managerial resources were absorbed by the directed rescue of companies. By the end of 1979 just three companies -BL, Rolls Royce, and Alfred Herbert - accounted for more than 90% of the Board's total book investments. On the other hand 35 of the 64 investments then standing involved an outlay of less than £1m each, while as at September 1978 only 3% of total loans outstanding were for non-transferee companies.[136]

It has thus been argued that although the Board accounted for nearly 30% of total general state aid to industry in the period 1975/76 to 1978/79 - £608m out of £2060m - it "played little more than a peripheral role" in the conduct of industrial policy.[137] This is true in many respects, but the Board's almost single-handed support for the computer services industry in the late 1970s was crucial to its later success (See Chapter 4.5) In addition, the part played by the NEB in establishing and financing INMOS, an independent UK standard chip manufacturer in the face of strong opposition from multinational electronics companies, the Treasury, and DoI officials showed the Board was able to argue for its own policies on occasion.[138]

3.14 Conclusions

This chapter has described the evolution of British civil technology policy and its institutional framework in the years 1945-1979. Its purpose has been to provide an adequate background for the following three chapters, case-studies of policy toward the computer, machine took, and textile machinery industries, but before embarking on those chapters it will be worthwhile making a few last points about the general conduct of policy and national patterns of R & D expenditure.

Since 1964 a feature of policy is how its administrative structure has been continually reorganised. Before 1964 technology policy in its loose form was enacted through the DSIR and NRDC. The scientific and industrial functions of the DSIR were separated in 1965 with the former becoming the SRC and the latter the basis of Mintech, which at the same time assumed Parliamentary responsibility for the NRDC and AEA. Gradually Mintech acquired all the industrial sponsorshop functions of the Board of Trade, incorporated the Ministry of Aviation, and took over the recently created IRC and operation of the Industrial Expansion Act, 1968. Between 1970 and 1972, Mintech and the IRC were abolished, the 1968 Act repealed, aviation transferred to the Ministry of Defence, and a system of Requirements Boards created to oversee a portion of the new DTI's spending on R & D. But between 1972 and 1974 the Industry Act, 1972 reintroduced many of the Government's abilities to intervene in industry, overseen by a new DTI sub-department, the Industrial Development Unit, and the AEA was passed to the Department of Energy. After the return of a Labour Government, the industrial side of the DTI became the DoI, the NEB was created, and toward the end of the 1970s three new schemes for the support of industry-based R & D were set up outside the framework of the Requirements Boards.

Behind these successive reorganisations has lain the different political conceptions of the appropriate form for and locus of technology policy held by the Conservative and Labour Parties, in general respectively antipathetic and sympathetic to interventionist policies. On reaching office in 1964 and 1970 the new Labour and Conservative Governments both decided to introduce policy reforms different to those recommended by recent reports commissioned by their predecessors. Thus the Trend Report's proposal for IRDA was rejected in favour of the Ministry of Technology, while Mintech's proposal for the BRDC, which contained some of the ideas for structural reform incorporated in IRDA, was rejected in favour of the Requirements Boards, which in turn contained some of the elements crucial to the proposed BRDC.

Two other unresolved conflicts underlying the continual reorganisations of the post-1964 period, emphasised by the proposals for IRDA and BRDC, were whether the formulation and execution of policy should be centralised or decentralised, and whether it should be located inside or outside the administrative structures of central government. Indeed, these conflicts were apparent in the dichotomous arrangements existing before 1964 when the DSIR was situated within government, the NRDC outside the civil service, and each pursued in its own policies largely in isolation from one another.

Mintech's assumption of more and more responsibilities represented one attempt to centralise technology policy within central government, but although legislation meant that both the NRDC and IRC could be requested to act as direct tools of Government policy each retained its essential independence from government. Moreover, the creation of several new bodies and schemes would also have tended to disperse policy and make coordination more difficult. The Requirements Boards too were implicitly aimed at rationalising the structure of Government industrial R & D expenditure, but the continued existence of the NRDC, their lack of control over the areas of aerospace and nuclear energy, and the development support on offer under the Science and Technology Act, 1965 and the Industry Act, 1972 meant that this attempt was effectually limited.

If the proposals for either IRDA or BRDC had been accepted much of the Government's R & D resources would have been amalgamated under a single management outside Whitehall. As with the NRDC, IRC and NEB, the perceived advantages of a non-civil service setting are the abilities to respond quickly and flexibly, and the access to recruits from the industrial and business communities. Additionally, in a more commercial setting it was hoped that the BRDC (and presumably IRDA) would have found it easier to orient the activities of government laboratories to the requirements of industry. On the other hand the disadvantage of such quasi-autonomous agencies is that they lie outside what, in the end, has to be the mainstream of policy-making within government itself. Something of a half-way solution is represented by the Requirements Boards, with their appointees from industry and adherence to a commercial contractual relationship with government laboratories.

TABLE 3.8 Government R&D expenditure, 1964-1979

YEAR	LOCATION			PURPOSE			
	Extramural £m 1975 prices	Extramural % of total	Intramural £m 1975 prices	Defence £m 1975 prices	Defence % of total	Civil £m 1975 prices	Total £m 1975 prices
1964	720	54	610	813	61	517	1330
1966	666	53	594	677	54	583	1260
1967	661	52	599	607	48	653	1260
1968	662	53	590	559	45	693	1252
1969	663	53	587	531	443	719	1250
1970	671	54	573	576	46	668	1244
1971	701	54	592	562	43	731	1293
1972	734	56	572	596	46	710	1306
1973	761	58	556	613	47	704	1317
1974	788	58	578	635	46	731	1366
1975	789	58	574	664	49	699	1363
1976	756	58	551	651	50	656	1307
1977	740	58	539	671	52	608	1279
1978	813	60	530	712	53	631	1343
1979	897	62	556	792	55	661	1453

Source: Derived from Bowles, J. R. Research and Development : expenditure and employment in the seventies. Economic Trends, 334, 94-111, August 1981.

However, the effect of continual reform has been to complicate and fragment, and make additions to, rather than simplify or rationalise the machinery of policy and the provision of direct support to industry. Thus whilst support was available from just the DSIR and NRDC in the 1950s, a quarter of a century later it was available from the NRDC, NEB, Requirements Boards, in collaboration with the SRC, and under the Science and Technology Act, 1965 and Industrial Act, 1972 either in concerted form such as PPDS or the sectoral schemes, or on a more *ad hoc* basis. Moreover, agencies and schemes with specific but often overlapping functions proliferated, especially during the Mintech era, with the result that in particular technological or industrial fields support and advice was on offer from many competing sources.

Perhaps the main reason for the various major reforms, either implemented or proposed, has been to make intramural government research more responsive to the needs of industry. Generally it has been argued that immuned within the civil service and without enough industrial contact, government lavoratories have been allowed to set their own research aims without enough reference to economic priorities, and without the appropriate mechanisms to transfer technology to the productive sector. Nevertheless, attempts to relocate government funded industrial R & D, for instance by the Requirements Boards, have met with little success (Table 3.7). However, in terms of overall government R & D expenditure a noticeable though small shift from intramural to extramural spending took place in the 1970s. (Table 3.8).

An analysis of official R & D statistics also reveals that while total UK R & D expenditure rose from £2201m. in 1964 to £2328m in 1967 at 1975 prices, it thereafter declined to £2151m in 1975 before reaching £2365m in 1978. During this same period the amount performed within industry varied between 62% and 66%, although the amount financed by government has averaged about 50% (Table 3.9) As a percentage of GDP, spending fell from 2.32% in 1964 to 2.06% in 1975 (Table 3.9), representing the only clear decline experienced by any major OECD country over the same years.[139] However, a considerable but variable proportion of UK Government expenditure has been devoted to defence rather than civil ends (Table 3.8), and not all civil R & D expenditure is directly dedicated to industrial objectives. In 1978/79, for instance, just one third of civil R & D spending was bracketted under the heading of industry, trade and employment. Even so the bulk of these expenditures have over the years been concentrated in the areas of aerospace and energy (Table 3.10). As a result, as Sir Ieuan Maddock argued in 1975, the pattern of Government R & D expenditure has borne little relationship to the shape of British industry. He showed, for example, that in 1972 the Government provided £176m (85%) of the £208m. R & D spending in the aircraft industry, whose net output in the

same year totalled £592m. In contrast it contributed just £3m (6%) toward R & D expenditure of £54m in the economically much more important mechanical engineering industry, whose net output was £2617m.[140] Moreover, where defence is the main objective of Government R & D expenditure, as in the electronics industry in which civil support of £20m accounted to just 6% of the total Government contributions of £312m in 1978,[141] civil benefits may be small.[142]

TABLE 3.9 UK R&D expenditures, 1964-1978

	Total	As %	Locations of R&D performed[1]				Financed
	£m	of GDP	Govt	Industry	Higher Ed.	Other	by Govt.
			%	%	%	%	%
1964	768	2.32	28	64	6	3	54
1966	888	2.34	26	65	6	3	49
1967	929	2.32	26	65	7	3	49
1968	986	2.28	25	65	7	3	49
1969	1045	2.25	25	65	8	2	51
1972	1313	2.07	26	63	9	2	49
1975	2151	2.06	26	62	8	3	52
1978	3510	2.14	22	66	9	3	47

Source: Bowles, J. R. Research and development : expenditure and employment in the seventies, Economic Trends, 334, 94-111, August 1981.

Note

1 Totalling errors due to rounding.

Government support for civil R & D in the bulk of manufacturing industry has therefore been small in comparison with its total R & D bill, and even with its expenditure on glamourous 'strategic' industries such as aerospace and nuclear energy. Although R & D expenditure and measures do not comprise by any means the whole of technology policy they are an important component. During the next three chapters the range of policy measures used with regard to the computer, machine tool, and textile machinery industries are examined in more detail.

TABLES 3.10 Net government civil R&D expenditures on industry, trade and employment, 1966-1979

	Total	Aerospace	Energy	Other Expenditures			
	£m	£m	£m	£m	£m 1975 prices	% of total	% of total govt. R&D exp.
1966	117.5	57.2	50.5	9.8	25.4	8.3	2.0
1967	134.4	76.2	46.1	12.1	30.3	9.0	2.4
1968	152.3	86.6	47.8	15.9	37.5	10.4	3.0
1969	159.9	96.9	45.1	17.9	39.8	11.2	3.2
1970	158.9	91.4	47.4	20.1	41.3	12.6	3.3
1971	178.5	104.0	51.8	22.8	42.2	12.8	3.3
1972	183.6	102.6	50.1	30.9	52.0	16.8	4.0
1973	197.8	106.3	56.2	35.3	53.3	17.8	4.0
1974	235.7	125.9	68.4	41.4	52.7	17.6	3.9
1975	274.9	128.2	94.4	52.3	52.3	19.0	3.8
1976	258.1	101.0	113.5	43.6	37.6	16.9	2.9
1977	255.5	87.1	125.8	42.6	32.8	16.7	2.6
1978	294.8	106.3	132.8	55.7	38.5	18.9	2.9
1979	373.1	146.1	154.1	72.9	44.1	19.5	3.0

Source Bowles, J. R. Research and development : expenditure and employment in the seventies, Economic Trends, 334, 94-111, August 1981; CSO, Research and development expenditure and employment (Official Studies in Statistics, 27), London, HMSO, 1976; CSO Research and development expenditure (Official Studies in Statistics, 21), London, HMSO, 1973.

CHAPTER 4 THE COMPUTER INDUSTRY

4.1 Introduction

A computer system is made up of a combination of hardware, including the central processing unit (cpu) and peripheral equipment, and software, the coded instructions or programs which instruct the computer in its tasks. The cpu in turn comprises control and arithmetic units and a small working store, while the term peripheral equipment covers all input-output devices and additional memory storage.

The history of computers is often described in terms of 'generations' distinguished by their componentry. First generation machines utilised thermionic valves for both circuitry and data storage, although mercury delay lines were soon introduced for the latter task. Because of their use of valves these first machines were very large, consumed vast amounts of power, and were notoriously unreliable.

A major advance occured when valves were replaced by the much smaller and more reliable transistor in the middle 1950s. Ferrite core memories were also introduced at roughly this time. A third characteristic associated with this, the second, generation of computers was the use of higher level programming languages, the first of which, FORTRAN, was developed by IBM.

The third generation of computers based on integrated circuits became available in the early 1960s. Although the major market continued to be for large 'mainframe' computers, the possibilities of vastly improved size/performance and performance/cost ratios spurred the development of minicomputers in the middle of the decade. Time-sharing and multiprogramming are also commonly linked with third generation computers, as is the concept of families, or series, of compatible computers. As software had become proportionally more expensive as a part of total system costs, computer ranges became standardised so that the same software could be used with different machines in the same range. Compatibility now exists between ranges so that programmes written for one machine can be run on its successor from the same manufacturer. Examples of third generation computers include the IBM System/360, the ICT 1900 Series, RCA Spectra 70 Series and English Electric System 4.

The distinction between the third and fourth generation is less clear. The fourth is closely associated with the incorporation of large scale integrated (LSI) circuits, and with the introduction in the middle 1970s of the successors, such as the ICL 2900 Series and the IBM System/370, to the third generation families. LSI also allowed the advent of micro-processors, in which central arithmetic and logic units are contained on a single semiconductor chip, and thus microcomputers.

The technical development of computers has progressed hand-in-hand with the extension of their applications and market. The bulk of first generation computers were used for scientific and engineering computation, where the requirement was for the complex manipulation of relatively small amounts of data and where, in general, in-house technical resources were available for programming in machine code and machine maintenance. Widespread use in business applications where such expertise was not normally available awaited the development of more reliable second and third generation machines, higher level programming languages and, importantly, because commercial applications usually involve simple manipulations of relatively large amounts of data, fast input/output devices and appropriate computer architectures. The low cost of minicomputers opened up new markets largely separate from those for mainframe computers, both with new customers and for specific applications with existing user organisations. For instance, many of the first minicomputers introduced in the UK were for dedicated laboratory or process control applications. Micros have further extended the computer market to include personal usage, and applications to include intelligent terminals and word processing facilities.

4.2 The Computer Industry

For the sake of this chapter, the computer industry is taken to include the manufacture of computers and peripheral equipment, and also firms providing computer services - software houses, computer bureaux, computer leasing companies, etc. While computer innovation has been profoundly affected by innovation in electronic components, the electronics components industry is excluded from this case-study, except where explanatory reference is necessary.

Unlike machine tools or textile machinery, computers date only from the end of the Second World War. During the War itself automatic electro-mechanical calculators were developed independently in the USA, UK and Germany, but the first true computer incorporating a stored programme, the Manchester Mark 1, first operated successfully in June 1948. The dramatic rise in output of the UK industry since then can be seen in Table 4.1. From less than £10m in 1960 output of the computer manufacturing industry increased in current terms to more than £1100m in 1980, while computer services billings reached more than £500 m in the same year. Employment in computer manufacture grew during the 1960s, fell back in the early 1970s, and then rose again to reach nearly 48,000 in 1980, when employment in computer services was 26,000, double what it was ten years before.

Table 4.1 The UK computer industry: employment and output, 1958-1980

	COMPUTER MANUFACTURE		COMPUTER SERVICES	
Year	Employment 000s	Sales £m	Employment[1] 000s	Billings £m
1958		5.3		
1959		7.7		
1960		8.2		
1961		10.9		
1962		13.4		
1963		24.8		
1964		44.2		
1965		34.7		
1966	35800	74.8		
1967	41600	94.4		
1968	45100	109.5		
1969	48800	141.8		
1970	52400	209.2		
1971	47700	193.4	14400	
1972	43400	205.3	14900	
1973	45700	352.7	17000	
1974	44500	412.7	19000	
1975	43300	486.6	19000	164.3
1976	42200	591.0	20100	220.7
1977	42900	674.3	20500	265.4
1978	45900	817.6	22300	331.9
1979	47600	1051.6	23900	429.9
1980	47900	1148.7	26200	536.5

Sources: Stoneman, P.L. Computers, pp. 154-178, in Johnson, P.S. (ed.) The structure of British industry. London, Granada, 1980; Department of Employment Gazette, appropriate years; Business Monitor SD9 Computer Services, appropriate years; Annual abstract of statistics, appropriate years.

Note 1 Full-time employment only.

The UK computer manufacturing industry is currently made up of one large UK-owned company (ICL), subsidiaries of three major US computer firms (IBM, Burroughs and Honeywell), and a small number of mini and microcomputer makers, usually UK-owned, of which perhaps the best known are Systime, ACT, Sinclair and Acorn. Independent computer peripheral manufacture is not well represented in the UK. Computer service firms tend to be small and medium sized.

Table 4.2 Share in value of the world stock of installed computers, 31.12.77.

Company	% of value
IBM	71.0
Honeywell	8.3
Univac	7.5
Burroughs	5.7
CDC	2.4
NCR	2.3
DEC	0.8
Amdahl	0.4
Others	0.6

Source Computer Weekly, p. 13, 11 May 1978.

ICL's predominance among British firms can be roughly gauged by comparing its turnover and UK employment with those of the industry as a whole. In the 1970s ICL's turnover was £130.8m and in 1979 £624.1m, equivalent to 63% and 59% respectively of the industry's output. ICL's UK employment in the same years (30638 and 25313) was equivalent to 58% and 53% respectively of the industry totals. These data for the industry and ICL are not directly comparable, as some of ICL's output is generated in other industries and abroad, but nonetheless indicate the company's size with respect to the rest of the industry.

Despite its predominance over other UK-owned firms, ICL is small in world terms, especially in comparison with IBM, which accounts for about 70% by value of the world installed base of computers (Table 4.2). Nonetheless, ICL has been able to vie with IBM for leadership in the UK market (Table 4.3). In this Table, later market share data (1978-1980) are calculated from differences in year to year installed market shares. At the end of 1979, ICL held 30.5% by value of the total UK installed computer stock, and IBM 29.2%. Only in Japan is there comparable indigenous competition to IBM. Apart from the Japanese manufacturers, Fujitsu, Hitachi and NEC, other major mainframe makers - Honeywell, Univac, Burroughs, CDC and NCR - are all American-owned.

Table 4.3 The UK computer market, 1954-1980

Year	Number[1]	Number[2]	ICL Share[2,3] by value of annual market	IBM Share[2,3] by value of annual market
1954	12			
1955	23			
1956	40			
1957	87			
1958	161			
1959	220			
1960	306			
1961	417			
1962	620			
1963	875			
1964	982		41.4	40.0
1965	1424		32.0	35.1
1966	1956		34.4	43.2
1967	2595		32.4	42.5
1968	3522		41.0	23.4
1969	4319		49.4	27.7
1970	5470			
1971	6059			
1972	6792		34.7	38.4
1973	7516	4360	32.9	39.7
1974		4824		
1975		4938		
1976		4737		
1977		5017		
1978		5706	21.8	27.4
1979		6504	34.0	21.7
1980		7033	31.6	8.9

Sources: 1. Computer Surveys, appropriate years. 2. Pedder Associates Ltd. Annual Census of United Kingdom Computer Installations, appropriate years; 1973-1976 mainframe computers, 1977-1980 systems of £100,000. 3. Moonman, E. (ed.) British computers and industrial innovation London, Allen & Unwin, 1971. p. 80; SCST ... (Session 1972/73, HC 97-I), pp. 184-5; SCST ... (Session 1974, HC 199-i), p. 23.

Table 4.4 UK computer industry : trade data, 1961-1980

Year	Exports (£m)	Imports (£m)	Balance (£m)	Year	Exports (£m)	Imports (£m)	Balance (£m)
1961	1.6	n.a.	..	1971	90.8	152.3	- 61.5
1962	3.7	n.a.	..	1972	137.8	170.4	- 32.6
1963	3.9	n.a.	..	1973	160.5	256.8	- 96.3
1964	7.2	15.2	- 8.0	1974	208.7	345.7	- 137.0
1965	7.2	18.6	- 9.4	1975	240.3	383.2	- 142.9
1966	15.0	35.9	- 20.9	1976	404.9	552.5	- 147.6
1967	37.8	56.5	- 18.7	1977	499.2	692.0	- 192.8
1968	47.6	74.8	- 27.2	1978	629.4	832.7	- 203.3
1969	56.7	97.5	- 40.8	1979	833.9	1023.6	- 189.5
1970	77.4	148.4	- 71.0	1980	937.6	1082.5	- 144.9

Sources: 1961-1964, HoCPD, 747, 180w, 6 June 1967, covers only complete systems and cpus until 1963; 1964 includes peripheral equipment but not parts and accessories; 1965-1969, SCST ... (Session 1969/70, HC 137), p. 355. Figures for 1965 and 1966 do not include parts and accessories; 1970-1971, National Economic Development Office Electronics Economic Development Committee. Annual statistical survey of the electronics industry. London, 1972; 1972-1980, Annual digest of statistics for appropriate years.

A comparison between export (Table 4.4) and production data (Table 4.1) shows that the UK industry has become apparently increasingly export orientated over the years. Exports were equivalent to 20% of production in 1965, 37% in 1970, 49% in 1975 and 82% in 1980. However, as overseas sales figures includes re-exports these trade data probably overstate the true position. As a reference, a geographical analysis of ICL's turnover reveals that 35%, 39% and 44% of its sales were generated in foreign markets in 1970, 1975 and 1980 respectively. On the other hand computer services are restricted much more to the domestic market : in 1975 billings to foreign clients amounted to £7.6m or 4.6% of the total.

Overall, Table 4.4 shows that there has been a permanent trade deficit in computer equipment, but as Table 4.5 demonstrates this has generally been due to trade in peripheral equipment and parts. Usually there has been a small favourable balance in cpu's and complete computer systems.

Since reaching its pre-eminent position in the 1950s, the main sources of competition to IBM have been in newer markets. Minicomputers offered an avenue for companies like Hewlett-Packard and DEC to grow as large as the second rank of mainframe makers. Micros have yet to emerge with the same potential, but areas such as word processing, intelligent terminals, etc. have been exploited both by new companies like Wang, but also by established firms from related technical fields such as Olivetti, Siemens, and Ericsson. Other competition to IBM has come recently from what are known as plug-compatible manufacturers, much as Amdahl and NAS, which have developed large computers, cheaper or more powerful than their IBM equivalents, but which can directly execute applications programs and systems software written for IBM computers. IBM compatibility has also been an innovation strategy followed by various peripheral equipment suppliers to tap the huge installed IBM computer base. An impression of the size of this market can be gained from ICL's estimate in 1968 that the cpu constituted about 39% on average of the total hardware costs of a computer system[2].

Table 4.5 Analysis of trade data: 1968, 1973, 1978 (£m)

		1968	1973	1978
Cpu's and complete systems	Imports	24.9	37.9	164.0
	Exports	25.6	62.7	171.9
	Balance	0.7	24.8	7.9
Peripheral equipment	Imports	26.7	69.9	361.5
	Exports	4.3	85.9	263.0
	Balance	- 22.4	16.0	- 98.5
Parts	Imports	22.9	151.5	183.6
	Exports	17.2	12.9	16.9
	Balance	- 5.7	- 138.6	- 166.7

Sources: SCST ... (Session 1969/70, HC 137), op. cit., p. 355; Business Monitor, PQ 366 Computers, appropriate years.

Conversely, non-compatibility has been the basis of the strategies of most other mainframe manufacturers such as Burrroughs and ICL. Compatibility with IBM is an important factor in computer markets because of established users' investments in software. In one example of large scale computer use, Stoneman reckoned that half of the total accumulated investment was in programming effort, and more generally that "while

Table 4.6 Major computer manufacturers: sales, profits and R & D expenditure, 1976.

	Sales $ m	Pre-tax Profits $ m	Profits/ Sales %	R & D exp. $ m	R & D exp./ sales %
IBM	18304	4519	28	1012	6.2
NCR	2313	173	7	94	4.1
Burroughs	1902	315	17	108	5.7
Sperry Univac[1]	1438	96	7	159	11.1
Honeywell[2]	1428	117	8	126	8.8
CDC	1358	92	7	59	4.3
DEC	736	119	16	58	7.9
ICL	502	40	8	50	10.0

Source Economist, 264, 64, 13 August 1977.

Notes

1. R & D expenditure of whole Sperry Rand Group. 2. Sales and profits of the Honeywell Group, R & D expenditure of Honeywell Information Systems, including CII-Bull.

hardware value depreciates, the total software investment increases."[3] Thus, to protect their investments on changing computers users have to install a compatible machine. The customer base of non-IBM compatible computer makers is therefore relatively safe from the predations of other manufacturers, especially IBM, and competition is largely restricted to new customers. On the other hand, the makers of IBM compatible computers have access to the large IBM replacement market, but so does IBM to theirs.

Another factor affecting the mainframe computer market has been the widespread practice of leasing, either by manufacturers themselves or by leasing companies. But again, because of the size of software investment involved leasing does not make changing suppliers any easier.

The computer services industry has evolved pick-a-back to the computer industry because of the need for specialist customer services that computer makers have been unable or unwilling to provide. Tailored computer systems or applications programs offer little scope for economies of scale to computer manufacturers, but a lucrative market for small firms or individuals without high overheads. Moreover, the continued shortage of skilled computer personnel means that they are best placed to secure highest remuneration in consultancy type enterprises.

Despite its market dominance IBM's products have been called highly priced but technologically dull.[4] One commentator has reported that the performance and efficiency of IBM systems has in many cases been inferior to models produced by competitors.[5] IBM's success instead has been it its ability to market reliable, easy-to-use machines backed up by a comprehensive sales and servicing organisation.[6] Nonetheless, IBM's strategy has been underpinned by massive research and development spending. The total cost of launching its System 360 Series is reputed to have been more than $5bn. over several years.[7] Such large scale R & D investments are of course common to the industry as a whole, but the efforts of other companies are dwarfed by that of IBM (Table 4.6), as is that of the UK industry as a whole (Table 4.7).

Table 4.7 UK computer industry: R & D expenditures, 1969-1978

	1969	1972	1975	1978
R & D exp. (£m)	22.9	27.3	51.0	125.0
% of sales	16.2	13.3	10.5	15.3

Sources Economic Trends, 309, 100-124, July 1979; Central Statistical Office. Annual abstract of statistics, 1982. London, HMSO, 1983. Table 4.1.

Given the costs of R & D it is not surprising that many erstwhile computer manufacturers, even when otherwise large, such as the American companies General Electric, Rank Xerox, and RCA, have decided to quit the computer business. ICL itself is the result of a series of mergers that will be described in following sections. With such costs, economies of scale are important to the industry, and it has been argued that with its long production runs and large customer base IBM's unit costs are approximately half of its European competitors.[8] They are also reflected in the profit/turnover ratios of major computer manufacturers (Table 4.6), which reveals that, at 28%, IBM's profitability is way beyond those of its rivals.

4.3 State policy, 1945-1964

In the years following the Second World War computer development was well underway in the UK and USA.[9] Research was in progress at several British centres, including the Universities of Cambridge,[10] London[11] and Manchester,[12] NPL,[13] the Telecommunications Research Establishment, Elliott Brothers Ltd.[14] and, for a short period, the GPO Research Establishment.[15] The Admiralty was sponsoring Elliott's research into computer-controlled ship borne fire control systems. While the Royal Society was the initial supporter of the work in Manchester which produced the Manchester Mark I,[16] later funding came from a £100,000 Ministry of Supply contract to Ferranti Ltd. for the construction of a computer on the basis of the Manchester design.[17] Other industrial involvement at this time included crucial support from J. Lyons & Co. Ltd. for the Cambridge EDSAC project,[18] and engineering support under a study contract from English Electric at NPL.[19] All the research groups were small, their funding though ultimately from public sources haphazard, and coordination between them at best informal. One attempt by the Director of NPL to concentrate resources into a "single national effort" failed,[20] but a second initiative to coordinate computer research led to the establishment of the Advisory Committee on High-Speed Computing Machines (the Brunt Committee) by the DSIR, with representatives from the Ministry of Supply, Admiralty, Royal Society and the new NRDC. Even though the Committee's terms of reference were:

a) To keep under review the progress in the design, construction and use of high speed calculating machines in Universites, Industry and Government Departments.

b) To examine the main fields in which these machines are likely to prove useful.

c) To make recommendations to the Secretary (DSIR) on the most suitable types of machine with a view to promoting their construction and use.[21]

it decided at its first meeting in October 1949 to exclude industrial representatives until "the future pattern of development is more clearly defined."[22]

The National Research Development Corporation

Possibly spurred by the lack of Committee contact with industry, and waiting to exploit its holdings of computer patents including an important batch from Manchester University,[23] the NRDC took the lead in setting up two panels, to attempt again to coordinate commercial development. Representatives of all the major British firms likely to be interested in developing computers were invited to the Advisory Panel on Digital Computers,[24] while the Electronic Computer Users' Advisory Panel was attended by representatives from the two punched-card equipment firms, British Tabulating Machines (BTM) and Powers-Samas.[25] At the only meetings of each panel the Corporation urged cooperation between companies. It argued that no single firm had the necessary knowledge of computation, facilities for large scale productions, or the organisation able to service computers while in customers' hands. But the unwillingness of

BTM and Powers-Samas, either to collaborate with each other or with any of the electronics firms, put an end to any hope of syndicated development projects.

This lack of response to its efforts convinced the NRDC that it should end its policy of "exhortation and encouragement of manufacturers" and instead place contracts for computer development with individual firms.[27] The Corporation had been willing to help BTM financially in the company's reported intent "to enter the computer market with the object of performing the same part in (the UK) as is performed by IBM in the USA"[28], but instead its first contract was placed with Ferranti in 1951 for Mark 1* computers, developed between Ferranti and Manchester University under the Ministry of Supply contract. Later the NRDC contract was extended to cover the purchase of six Mark 1* computers which Ferranti was to sell on behalf of the Corporation, which invested a total of £400,000.[29]

Despite BTM's intentions Ferranti was regarded by the Brunt Committee as the only British company capable of developing a computer at this time.[30] Two years later, however, the Corporation placed a second contract with Elliott Bros. for the development of a prototype of a small commercial computer, the 401, which was demonstrated at the Physical Society Exhibitions early in 1953, less than nine months after the contract was signed. Problems within the Elliott design team, however, led to the machine's further development being transferred to Ferranti, with which the NRDC placed a second prototype and production contract, this time worth more than £500,000 for a total of ten machines.[31] This computer, which became the Pegasus, was first delivered in 1956 and a total of 37 were sold for both scientific and commercial data processing applications.[32]

The Corporation's next contract was awarded to EMI in autumn 1955 for the development of its 1100 and 2400 computers. This project, involving the NRDC in an investment of some £620,000,[33] represented "an attempt to bypass the stage of development through which computers in the USA have evolved in the last three or four years", and thus catch up with the use of transistor componentry.[34] Although this project was a technical success, the 2400 was unable to compete with the IBM 1401, launched at roughly the same time in the early 1960s.[35]

The same technical disparity between UK and US computers also led the Corporation to contemplate arranging the construction of a 'super computer' to be used for scientific applications which would compete with the American LARC and STRETCH projects and which would restore some technical advantage to the British industry.[36] Various strategies were considered, and eventually the NRDC offered loans to EMI and Ferranti to support two separate projects. EMI finally decided not to take up the offer made to them, but with Corporation backing Ferranti went on to develop the Atlas based on Manchester University designs. Only five machines were built, the first of which was installed in 1962, but Atlas has since been regarded as a major technical achievement.[37]

While these five contracts, three with Ferranti and one each with EMI and Elliott Bros., represent the core of the NRDC's computer development work during the 1950s, the Corporation was also involved in other computer related activities. It underwrote, for instance, two attempts, neither successful, to develop magnetic tape storage devices, the first with Pye Ltd. on the basis of a prototype produced at Cambridge University and the second with Epsylon Ltd.[38]

In regard to computer applications, the Corporation rented the Elliott 401 whose development it paid for, to Rothamsted Experimental Station.[39] It also purchased an Elliott 405 for installation at Siemens Limited telephone works at Woolwich for production control purposes.[40] Full implementation, however, was not achieved because of hardware and systems design difficulties. A third project involving Elliott concerned the application of computers to process control. Although begun in 1959/60, the bulk of the work on this the ARCH project was carried out after 1965.[41] A prototype EMI computer was also installed at Austin's Longbridge works in 1958 as a part of the Corporation's funding of the EMIDEC 2400 development,[42] while a short study of the possible uses of computers in the shipbuilding industry was additionally funded by the NRDC.[43]

The Corporation also made some small-scale but nonetheless important initiatives to help cultivate computer expertise and establish a British computer community. From 1953 to 1959 it made computer science studentships available at the Universities of Cambridge and Manchester. Response, however, was said to be "small" in 1955.[44] Moreover, the NRDC acted as midwife to the birth of the British Computer Society in 1957-58 by providing it with temporary premises and facilities, and underwriting the initial printing and publishing costs of the Society's journal.[45] In addition, the Corporation took the lead in discussions which led to the 1958 computer exhibition at Olympia and provided its organisers with secretarial assistance.[46]

The Corporation's other major computer activity in this period concerned the exploitation of its patent holdings. By 1952 it was holding the rights to 99 inventions, in respect to 74 of which it applied for 479 patents in 10 countries.[47] Four years later the NRDC was administering 733 computer patents in the UK and overseas resulting from 201 investions. "As an example of the resulting income, the total receipts from the sales and licensing of certain Manchester patents to IBM had amounted to £125,712 by the end of 1956",[48] a sum well in excess of the £101,000 paid out in patent fees by 1957.[49] In this year the Corporation created a Patents Pool "to liberalise the patent situation and to secure to manufacturers the maximum freedom to use patents".[50] The Corporation and seven British companies, British Thomson-Houston, EMI, Elliott Bros., English Electric, Ferranti, Metropolitan-Vickers, and STC, placed all their relevant patents for common use into this Pool, but without the cooperation of BTM, Lyons, Powers-Samas, and even GEC and AEI, it is difficult to believe that the Pool's full potential could ever be achieved. BTM especially was beginning to emerge as one of the four leading UK computer companies, and had taken out 117 British patents between 1951 and 1958 for computing, calculating and registering machinery.[51]

Throughout the 1950s computer development was the single most important aspect of the NRDC's activities. By 1954 more than £325,000 of its expenditure to date of £928,000 was accounted for by its computer activities.[52] This increased to £1471,000 in 1957 [53] and, excluding the ARCH project, to £2,033,000 by 1964,[54] the bulk of which went on computer development. However, around 1960, after advice from the Government the Corporation consciously decided to withdraw from future mainstream activities in the computer industry.[55]

NPL, ACE and the DSIR

While the NRDC was the main channel of state support to the computer industry in the 1950s, NPL was independently involved in the development and construction of its own Automatic Computing Engine, the ACE. Development started in 1946, and with the help of a small group of engineers from English Electric a prototype, the Pilot ACE was completed in 1950. For NPL, Pilot ACE was "designed purely as an experimental machine with the object of demonstrating the competence of the team as computer engineers",[56] but fully engineered it became English Electric's first computer, the DEUCE. Two further versions of DEUCE were developed, DEUCE 2 and DEUCE 2A, and it became the first British computer to sell in any quantity.[57]

Following English Electric's decision to concentrate on DEUCE work on the full-scale ACE had halted but restarted in 1953. Delays plagued its development so that it was said to be "almost complete" in 1958,[58] "largely completed" in 1959,[59] and "developed to a stage where it can be considered to be a fully working computer" in 1960.[60] Only one ACE was built and it remained at NPL. Its development cost was stated to be of the order of £250,000.[61] Incorporating mercury delay lines and valve circuitry ACE was rooted in first generation computer technologies, and thus had little influence upon mainstream computer development. In the words of one of the engineers on the project, ACE "really belonged to the past even when it was brand new."[62]

Near the end of ACE's development the emphasis of NPL's computer activities shifted from computer design and development to applications and component technology.[63] This is reflected in the successive reorganisations of the Laboratory's Control Mechanisms and Electronics Division[64] which left it in 1960 - when it was renamed the Autonomics Division - with four sections - Very High Speed Computing (dealing with componentry), Mechanical Translation, Automatic Process Control, and Pattern Recognition.[65]. From 1960 too the Division's complement was increased by some 20 extra scientific staff as it took the leading role in the DSIR's Advanced Computer Techniques Project (ACTP), the motive of which was "to increase the overall effort on research and development in computers and to provide improved co-ordination of work in this field in industry and Government."[67] Besides making its own research contribution NPL coordinated the placing of R & D contracts for the development of new components and techniques which were intended to be the basis of pre-prototypes of new commercially suitable computer systems. Contracts with industry were to be on a 50:50 shared cost basis. Neither software nor peripheral equipment were at this time eligible for support.[68] Although industry-based research was the main operational objective of the Project, the first contract involving a private company was not awarded until June 1963. Over the next eighteen months nine such contracts were placed with a total value of £461,000.[69]

Meanwhile, the DSIR made its first grant concerning computer science to a university, when it awarded £ 110,000 to Drs. Wilkes and Barron at Cambridge University in 1964. The grant was for the 'establishment' of a research group in computing science, a group which had in effect been in existence since the late 1940s.[70]

The UK computer industry

By the mid-1950s then three companies, Elliott Bros., English Electric and Ferranti, had introduced computers with state assistance, either from the NRDC or, in English Electric's case, on the basis of its involvement with NPL. Together with LEO Computers Ltd and BTM, both of which had developed computers from university designs, these companies comprised the incipient British computer industry. (LEO, however, did not deliver a computer to another organisation until 1957[71]). These five firms and IBM were competing in a small UK market which was at this time mainly made up of scientific applications - no more than 7 of the 40 installations in 1956 were for commercial data processing.[72] Of the eight British computers which were or had been available only two, the BTM 1201 and Elliott 405, were specifically designed for business applications. On this subject a DSIR Study Group commented that "computers designed for scientific work are not as they stand ideal for business work, and in many cases are impractical for the purpose because of the lack of suitable equipment". No such equipment was available from British suppliers although it was in "extensive use" in the USA[74] where the commercial use of computers was already widespread.

During the early 1960s the technical superiority of American computers, especially for commercial applications, became increasingly clear as IBM's presence in the UK market grew, and the British industry became increasingly reliant upon imported American technology. The award of a computer contract to IBM by the Army Pay Corps in 1959 "caused considerable perturbation among ... the British firms making computers",[75] while by July 1960 the 53 British orders for the IBM 1401 made it at that time the largest selling computer in the UK[76]. Moreover, Elliott Bros. were assembling the NCR 315 under licence, the ICT (BTM) 1500 - first delivered in 1962 - was the RCA 301, while GEC's entry into the market was through its subsidiary, International Systems Control Ltd (ISC), established in conjunction with Bunker-Ramo.

There were also however criticisms that a "small and unreceptive" UK market was hampering the developing of the domestic computer industry.[77] By 1964 it was estimated that there were almost 22000 computers installed in the USA, including approximately 1767 in civil government, 2000 in the Department of Defense, and another 2000 or so used by government contractors at government expense.[78] In contrast, less than 1000 computers were installed in the UK by the same date, of which only 56 were in civil government departments.[79] On another tack, the relative sophistication of American users was highlighted by a European Productivity Agency report which pointed to the amount of computer training in US business administration courses,[80] while elsewhere it was argued that the low level of use of punched card equipment in the UK was also hindering the diffusion of commercial computers.[81]

The problems posed by the small size of the UK market were compounded in the late 1950s by the increasing number of competing British manufacturers. Since the mid-fifties EMI, again on the back of a NRDC contract, STC and AEI, as well as GEC, had all entered the business. But given the small size of the market, the predations of IBM, and the liklihood that most of the UK firms were subsidising their computer businesses[82] it is not surprising that the industry underwent considerable rationalisation.

BTM merged with Powers-Samas in 1959 to form International Computers & Tabulators Ltd (ICT), which then took over GEC's computer subsidiary, ISC, and then, in July 1962, EMI's data processing department for the equivalent of £1 1/4m. This move, greeted by the Times as "a valuable contribution to the obviously needed rationalisation of the British computer industry",[82] was capped in 1963 by ICT's takeover of Ferranti's computer department, said to be the most advanced in the UK, for £8½m.[84] Ferranti's interests were mainly in scientific rather than business computers, but its commitment to R & D was welcomed as an antidote to ICT, regarded as an underinvestor in development. This successsion of mergers, however, left ICT with ten different models of computers on its books and an urgent need for product rationalisation, but with the Feranti deal came the design which became the basis for ICT's later 1900 Series.[85]

In parallel to ICT's acquisitions, a second major computer group was forming around English Electric, which first took over LEO Computers in 1962,[86] and then Marconi's computer divison in 1964 to form English Electric-Leo-Marconi Computers Ltd. But in the meantime both AEI and STC had quit the computer industry, so that in 1964 just three British computer manufacturers were left, Elliott Bros., the English Electric group and ICT.

4.4 State Policy, 1964-1970

On winning the 1964 General Election the new Prime Minister, Harold Wilson, singled out the computer industry for immediate attention because of his belief that "if action was not taken quickly, the British computer industry would rapidly cease to exist"[87]. Consequently, Wilson reports that he told Frank Cousins, the first Minister of Technology, that he had "about a month to save the ...industry and that this must be his first priority"[88]. Mintech thus soon took over the sponsorship of the industry from the Board of Trade, while in a parallel move, an Electronics EDC was established at NEDO.

Behind Wilson's rhetoric there are probably a number of reasons why computers attracted especial attention. The balance of payments was an important general consideration for the new Government, and although computer import statistics were not separated until the end of 1964, it is likely that it was appreciated that a trade deficit existed, albeit as yet small.[89] More important factors, perhaps, were that the technological glamour of computers fitted the Labour Party's self-promulgated progressive, technocratic image, and the belief that computers were likely to be a strategic resource so that in the 1970s and 1980s "independence in computers and advanced electronics would matter more than independence in nuclear weapons."[90] But possibly the most influential single factor was the public relations work of ICT which, before the Election, had appointed a full time Government Relations Officer and prepared its own policy document dealing with government-computer industry relations which, the company claims, was "injected into every level of government and Parliament."[91]

Very briefly, the document laid out the contributions that a stronger computer industry could make to the national economy and made three proposals for government action. It recommended an expanded and forward looking state procurement policy, covering both central government and higher education, some kind of central organisation to assist in the "planning, coordinating, storing and providing of software", and an expansion of hardware R & D through the NRDC and DSIR.[92] For its part, ICT obviously wanted to gather and secure government orders for its 1900 Series computers, recently launched in direct competition to the IBM System 360.[93]

When eventually unveiled in March 1965, Mintech's objectives were "a rapid increase in the use of computers and computer techniques in industry and commerce" and "a flourishing British computer industry." Because the industry had been "allowed to get into a parlous state during the last few years" it needed "all the assistance it can get."[94] More specifically its policy initiatives closely followed the ICT proposals. A Computer Advisory Unit was set up within Mintech to "advise on computer requirements over the whole public sector", while there was also to be a review of the computer needs of higher education with a view to ordering £10m worth of new equipment in a five year programme. Secondly, the Ministry was to establish a National Computer Programme Centre in collaboration with computer users and makers which would form a library of computer programmes; and thirdly, Mintech promised to expand public support for R & D.

Although Cousin's statement came very close to ICT's proposals - some sort of procurement policy was strongly hinted at - the Economist complained that Mintech's actions were "chicken feed" and "not impressive". What the industry wanted, it argued, was more Government orders, and either further rationalisation or link-ups with foreign companies.[95]

Rationalisation and the creation of ICL

Behind the scenes the continued rationalisation of the industry was indeed being pursued as the principal objective of Mintech's strategy, which its announcements regarding R & D and procurement were also intended to promote.[96]

The first concrete step along this path came in 1967 when the IRC, in one of its first interventions, smoothed the way for the takeover by English Electric of Elliott Automation by providing a loan of £15m., interest free for two years, to alleviate post-merger rationalisation problems.[97] The two companies had been in negotiation for some time but lacked the finance necessary to ensure a satisfactory merger.[98] According to the Economist the merger "pleased everybody" including Mintech, the two companies involved, and the IRC.[99]

"The culmination of a policy which (Mintech) had been pursuing for three and a half years",[100] in which the English Electric - Elliott Automation merger was "a very valuable step",[101] came in the following year when the Ministry finally engineered the takeover of English Electric's data processing assets by ICT to form International Computers Ltd (ICL). Under the agreement reached by the parties concerned, Mintech acquired 10.49%

of ICL's equity for which it paid £3.5m., £350,000 immediately with the remainder payable in September 1972. Other major shareholders in the new company were English Electric, which was given a 17.98% shareholding and £21m. in cash and loan stock for its computer interests' and Plessey which paid £18m over the next three years for a similar stake. In addition, the Ministry agreed to contribute £13.5m. toward ICL's R & D budget during the following three and half years[102] to help the new company "through a period of very heavy expenditure, arising mainly from the need to increase its research and development expenditure for the next generation of computers."[103] For its investment, Mintech was allowed one director on ICL's Board and entitled to some say in the framing of the company's R & D policy. The Minister was also given some powers relating to the appointment and removal of ICL's Chairman and Chief Executive, and his approval was required for any association with a foreign-controlled company. Otherwise the Ministry agreed not to interfere in any way in ICL's day-to-day management.

Under the agreement, ICL was committed to continue to "develop, manufacture, market and service" both the English Electric System 4 range and the ICT 1900 Series, as well as continuing to produce the 4100 range inherited from Elliotts. More importantly, ICL was to develop a new range of computer systems for the 1970s. Apparently, it was the technical concord between the ICT and EE design teams on a rough design which would supercede and be compatible with the currently incompatible ranges, which "broke the back of the opposition to the merger."[104] Moreover, the industrial parties to the merger agreed to split up the computer market between them leaving ICL the business and scientific markets, but allowing English Electric and Plessey the specialist defence systems, industrial automation, and process control markets.[105]

Generally, reaction to ICL was favourable. The Conservative spokesman on technology, for instance, looked forward "to the world beating a path to ICL's door", although he wondered if the £13.5m. R & D support would be sufficient in the light of the company's future development plans.[106]

As a result of the takeover ICL emerged as the world's fifth largest computer manufacturer after IBM, Univac, Honeywell and CDC, and the largest owned and controlled outside the USA. About two thirds of ICL's turnover and workforce of £115m. and 34,000 respectively 1968/69 were inherited from ICT, whose 1900 Series was continuing to sell reasonably well - nearly 950 were delivered in the four years to September 1968.[107] From English Electric, however, ICL had to absorb a trading loss on a System 4 range in grave difficulties. During 1967 one model, the 4/10, had been withdrawn while another, the 4/30, had failed to meet specifications. In addition, the development of the more powerful machines in the range was reported to be "well behind schedule."[108]

Rationalisation, therefore, left the UK computer industry with a single mainframe manufacturer which became the focus of Mintech's and later industry Departments' computer policies. Independent minicomputer makers, beginning to appear in the mid 1960s, were left largely without state assistance, although two small companies Digico and Arcturus Electronics received some support from the NRDC. A third company, Computer Technology Ltd., was left wandering the corridors of Whitehall trying to drum up support but without success.[109] Moreover, under the small print of the ICL merger agreement, Plessey and English Electric, were precluded from competing in business computer markets, even if they were not in direct competition with ICL. On its takeover of English Electric, GEC was similarly excluded from these markets. On the other hand, the defence equipment market was closed to ICL. To complicate matters, the Ministry of Defence was in any case, already funding the development under contract by Plessey of the Linesman air defence radar network, utilising Plessey's own range of XL military computers. These computers turned out to be "obsolete and unworkable" and their development was abandoned in 1973 at a reported cost of £200m. Their replacement instead came from IBM.[110]

Procurement policy

Apart from its objective of rationalisation, to which it must be seen as closely linked, Mintech's main other initiative toward the industry was its policy, largely covert, of preferential procurement. A procurement policy had been strongly hinted at in Cousin's policy statement which led to the creation of the Computer Advisory Service (CAS) located within Mintech[111] and following the recommendations of a joint Mintech/DES working party, the Computer Board for Universities and Research Councils.[112] The Computer Board was to oversee a £30m computer re-equipment programme for the universities, planned over six years, and in considering specific proposals for foreign computers was required to bear in mind "the availability of comparable British equipment and the balance of payments position."[113] Similarly, in coordinating and offering technical advice regarding computer purchases in central government the CAS had to "ensure that appropriate consideration is given to the products of the British computer industry."[114]

Given the presence of substantial American computer manufacturing interests, particularly in Scotland, what 'British' meant in this context was open to debate. However, the British computer industry was soon defined as consisting of those firms "whose policies in respect of production, research and development are determined in this country"[115] and then, more precisely, as ICT, Elliott Automation, the English Electric group, and Ferranti, which was still involved in making computers for military purposes.[116]

While these definitions clarified what Mintech meant by a British computer, its other statements concerning the criteria taken into account in 'appropriate consideration' - the import/export balance, scope for replacing older machines, and the possibility of using government orders to stimulate the design and development of advanced computers[117] - merely served to obscure the fact that the Ministry was operating a covert preferential puchasing policy, the terms of which were not revealed until 1970. It was then stated in evidence to the Select Committee on Science and Technology that such a policy in various forms had been in existence since 1965. To begin with, 'British' computers had been preferred provided that they were technically suitable, could be delivered on time, and that there was "no undue price differential". From April 1968 a selective tendering procedure was introduced whereby at least one British system had to be considered for each contract, while later in the year single tendering was adopted for machines for particular applications. After the creation of ICL the whole system became centred on the new company. The Government then bought from ICL by single tender all the large computers - those equivalent in power to Atlas or larger - it required, plus any smaller lead-in machines, subject to satisfactory price, performance and delivery date.[118]

While a price differential favouring British firms was implicitly admitted, its level has never been officially reported. However, in interview, Dr. Bray, Under Secretary of State at the Ministry of Technology at this time, confirmed that it was something like 15% - "quite trivial".[119] Elsewhere, it was rumoured to be 20%.[120]

As Hills argues, Mintech's reasons for being so discreet about public purchasing procedures lay in its portfolio of conflicting responsibilities, which included both sponsorship of the domestic computer industry and responsibility for regional policy. Thus the Ministry had to balance its desire to encourage multinational investment in the development areas, with that of ensuring that increased foreign competition in the data processing field would not damage the prospects of UK computer manufacturers, especially those of ICL in which Mintech had a specific vested interest.[121]

Market share data for the years 1964-1969 (Table 4.8) shows that by the end of the sixties ICL had more than recovered the total market position held by its prior constituent parts in 1964. Although its share of all market segments except, strangely enough, central government had increased, there was nonetheless a noticeable differential between its share of private and public sector purchases enjoying, for instance, twice as great a share of the local authority market as the private market. But because the private sector market was on average twice as large as the whole of the public market, ICL's total market share was less than it held in the public sector. Given the particularly high levels of ICL purchases by local authorities and public corporations it is probable that either Mintech was able to exert some influence over their computer procurement policies, or that they truly took the Ministry's invitation to take into account the desirability of supporting the British industry to heart.[122] In the discussion at the end of this chapter an attempt will be made to make a more formal evaluation of the effects of public sector preferment upon orders for ICL.

Table 4.8 UK computer market : ICL shares, 1964-1969 (%)

	1964	1965	1966	1967	1968	1969
Private	34.6	29.1	28.4	28.5	33.6	39.9
Central Government	69.2	37.9	39.5	41.6	51.2	69.2
Local Government	51.2	50.4	50.4	52.2	55.5	81.1
Public Corporations	35.7	35.5	53.5	34.6	59.4	75.6
Weighted Average	41.4	32.0	34.4	32.4	41.0	49.4

Source Moonman, E. (ed) British computers and industrial innovation. London, Allen & Unwin, 1971 p. 80.

Research and development policy

An immediate effect of Cousin's policy statement was, as promised, increased computer and computer-related R & D expenditure through the ACTP, Mintech extra-mural contracts, NRDC and, in academia, by way of the new SRC. ACTP was soon expanded to include both peripheral equipment and software development, and to reflect this change it became the Advanced Computer Technology Project. The effect of this extension was that of the 105 ACTP contracts placed by the end of 1970 with a total Mintech commitment of £3.2m., 26 were concerned with software development (£0.89m) and 32 with peripherals (£1.05m), as against 31 with processor technology (£0.84m), 13 with storage media (£0.36m), and 3 with other developments (£0.06m).[123] These contracts were all shared cost and allowed for a return to Mintech by way of a levy on resulting sales or license royalties. Of the 76 contracts completed by 1971, 21 led to directly exploitable results, 17 to further ACTP contracts, 11 to the dissemination of the results of feasibility or software contracts, while the remaining 27 did not lead to any exploitation.[124]

Table 4.9 ACTP and Ministry of Technology computer R & D contracts : expenditure, 1964/65 - 1969/70 (£000s)

	1964/5	1965/66	1966/67	1967/68	1968/69	1969/70
Mintech contracts	..	..	40	133	313	313
ACTP	84	120	312	409	530	425

Source House of Commons Select Committee on Science and Technology. Prospects for the United Kingdom computer industry in the 1970s, Vol. II. (Session 1970/71, HC 621-II). London, HMSO, 1971, pp. 327-335.

Outside of the ACTP framework Mintech also provided funds for extra-mural computer R & D contracts. The form and size of these contracts varied considerably. Most appear to have been located in or involved universities or polytechnics, but some were with other public laboratories or sited in industry. Usually Mintech bore the whole cost except where industry was involved. The projects covered a variety of topics including applications, software and processor technology. The largest contract, worth £940,000 and involving Mintech in a cost of £295,000, concerned the joint development of a computer control system for a cold rolling steel mill by Imperial College, London and AEI,[125] while the second largest, involving a total of £537,000 funding including £256,000 from Mintech, was for the development of the software for a multi-access system by Edinburgh University for the English Electric System 4/75 computer.[126] Year-by-year expenditures on both ACTP and extra-mural contracts are given in Table 4.9.

Greater, than Mintech's own financial commitment to research in this period was that of the NRDC. After its investment in the development of the Atlas, the Corporation had withdrawn from mainstream computer activities, but with the return of the Labour Government it entered into one last major computer development project, as well as supporting 16 smaller projects, mainly in computer applications. Applications supported included computer typesetting and shipboard engine room automation. Three further projects concerned the development of software, one of which with Miles Roman Ltd. failed but the other with John Hoskyns & Co. Ltd. resulted in a highly successful integrated management system for manufacturing companies. Four peripheral equipment development projects were also financed by the Corporation, including two for magnetic tape recorders, and one concerning a computer graphics device with Ferranti.

However, the Corporations main project was an agreement to provide ICT with up to £5m. to finance further hardware and software development for the 1900 Series. Software development was viewed as being especially important because it was in this area that IBM was "particularly efficient."[127] Concluded in November 1965, the agreement covered approved development work over the period September 1964 to September 1969, thereby - unusually - providing retrospective R & D support. The venture was also unusual in that it was not tied to a specific development project but to ICT's general R & D activities to extend and improve the 1900 Series. A final point is that while the NRDC later claimed, rather innocently, that it acted in the knowledge of Mintech policy but without any formal representations from the Ministry,[128] by concentrating support on the most likely of Britain's computer manufacturers it clearly acted in accord with Mintech's longer-term aim of further rationalisation in the industry, thus removing the need for the Ministry to make a relatively large-scale investment from its own as yet limited resources. By the time of the ICL merger ICT had received nearly £4m of the £5m agreed. Early repayment was then arranged and between 1970 and 1972 more than £6.7m was returned to the Corporation.[129]

During this period the Corporation also made investments in two of the first British minicomputer manufacturers, Digico Ltd., and Arcturus Electronics Ltd., in 1966/67 and 1969/70 respectively. The investment in Digico was quite small but that in Arcturus involved nearly £170,000.[130] Neither company was eventually successful, and their failure was one reason for British manufacturers poor representation in the UK minicomputer market when it developed in the 1970s.

Table 4.10 SRC Computer Science research grants and studentships, 1965/66 - 1969/70

	1965/66	1966/67	1967/68	1968/69	1969/70
Computing Science Commitments (£000s)	447	783	1259	2310	2633
% of Total Commitment	2.5	3.6	6.0	9.4	8.6
Notional Yearly Expenditure[1] (£000s)	151	267	508	792	788
Number of Computing Studentships	..	31	88	148	198
% of Total number of Studentships	..	0.5	1.4	2.2	2.8

Source SRC Annual Reports, appropriate years.

Notes

1. Notional yearly expenditure is calculated by multiplying the percentage of total commitment devoted to computing science (row 2) by the SRC's annual research grant expenditure, not given in the Table.

Total investments of the Corporation in computer and computer-related development projects entered into between 1964 and 1970 amounted to just over £6m., nearly two thirds of which went to ICT.[131]

The fourth strand of what could be called the state's computer R & D policy consisted of the SRC's support for research in higher education. As Table 4.10 shows, the value of SRC computing research grants underwent considerable expansion in the second half of the 1960s, from a commitment of £447,000 in 1965/66 to £2,633,000 in 1969/70, representing 2.5% and 8.6% of total SRC research grants commitments respectively. Similarly, the number of SRC post-graduate studentships in computing also rose from 31 in 1966/67 to 198 in 1969/70.

The importance of university research in computing should not be underestimated. University research provided the basis of the first BTM, LEO and Ferranti computers. Ferranti continued their collaboration with the Manchester University team in their development of the Pegasus and Atlas. Moreover, during the late 1960s, and early 1970s the University's fifth computer, the MU5, had considerable influence on the design of ICL's next range of computers, the 2900 Series.[132]

Adoption and diffusion measures

Although Cousin's had announced Mintech's intentions to set up a National Computer Programme Centre, it was the National Computing Centre (NCC) which was actually established in July 1966. By then the original aim of a national computer programme library was considered unrealistic,[133] and the objectives of the NCC were, instead, "to standardise and simplify the programming of computers, and to advise on the training of systems analysts and programmers"[134], in the task of making it "easier and cheaper for as many firms and organisations as possible to make use of computers."[135] As a quasi research association, the NCC was a non-profit making organisation in receipt of Mintech grant-in-aid. Eventually the NCC was intended to be self supporting[136] but this has yet to be achieved.

The NCC was the first of three organisations set up to increase expertise in computer use and extend the range of available applications. While NCC was aimed at computing in general, the other two, the Aldermaston project for the Application of Computers to Engineering (APACE) and the Computer-Aided Design Centre (CADC), were specifically aimed at industrial applications. APACE was formed partly to increase the range of the UKAEA's non-nuclear work but also to open up state expertise to industrial users, whilst its function was to assist firms gain experience in the application of computers to industrial problems, mainly by running training courses and providing consultancy services. CADC on the other hand was established in 1967 with the objective of developing the use of computers in engineering design which, it was hoped, would "lead to an improvement in the speed and quality of engineering design, with a consequent reduction in manufacturing costs."[137] Mintech funding of all three agencies is given in Table 4.11.

Table 4.11 APACE, CADC, and NCC : grant-in-aid, 1966/67 - 1969/70 (£ 000s)

	1966/67	1967/68	1968/69	1969/70
NCC[1]	-	797	550	596
CADC[1]	-	598	1136	454
APACE	34	85	119	127

Source Civil Appropriation Accounts, appropriate years.

Note 1 Higher grant-in-aid in the early years is accounted for by start up equipment and building costs.

Table 4.12 Computer investment grants expenditure, 1967/68 - 1973/74

(£m)

	1967/68	1968/69	1969/70	1970/71	1971/72	1972/73	1973/74
Expenditure	7.0	20.0	35.8	36.1	52.0	17.2	9.5

Sources 1967/68 - 1969/70, SCST ... (Session 1970/71, HC 621-II), op. cit., pp. 327-335; 1970/71-1972/73, HoCPD, 887, 29200, 3 March 1975.

Note that although grants could be applied for from the beginning of 1966, payments started in 1967/68. Similarly although the scheme closed in 1970, payments continued as shown.

Whereas the NCC, APACE, and CADC were all implicitly intended to raise rates of diffusion of computers by increasing the amount and availability of expertise open to users, an investment grant scheme, started in 1966, provided financial subsidies for computer purchases. Under the Industrial Development Act, 1966, which provided grants for industrial equipment purchases in the Development Areas, computer systems were singled out among office equipment to qualify for a 20% grant, available nationally. Later, after representations to the Ministry of Technology, the grants were extended to cover purchases of peripheral equipment and software made in the absence of a cpu "in order not to discourage the growing trend towards time-sharing and the use of computer bureaux."[138] This extension can be viewed as a direct aid to the fledgling computer services industry. Expenditure on computer investment grants is given in Table 4.12.

4.5 State Policy, 1970-1979

Conservative policy and the Select Committee on Science and Technology

As in other areas, the first actions of the new Conservative Government with respect to computers were concerned with trimming the apparatus for state assistance constructed over the previous six years. A review of the CADC was announced,[139] while the block funding of APACE was terminated with effect from the end of the 1970/71 financial year.[140] As part of its general policy on investment incentives, computer investment grants were almost immediately withdrawn.[141]

Given its open antipathy toward state intervention and its avowal of cost-effective government, perhaps of more importance was what the incoming administration's positions on ICL and public procurement would be. In evidence to the Select Committee on Science and Technology (SCST), the new Minister of Technology, Sir John Eden, revealed that the Ministry would continue to fund R & D, which would be in the form of specific contracts rather than general grants to ICL. Whilst attaching much importance to a strong British-owned computer manufacturing industry, Sir John did not believe it needed propping up; ICL in particular was "perfectly capable of standing on its own two feet."[142] Before the Election, a spokesman had questioned the future of a public procurement under a Conservative Government,[143] but it was also announced to the SCST that it would remain with minor changes, including the discontinuation of a price preference for British firms.[144] Overall, the changes were "not expected to affect the proportion of Government contracts awarded to ICL."[145]

Sir John's evidence to the SCST was part of a long investigation into the computer industry begun before but interrupted by the General Election. The Committee's report and collection of evidence from ministers and civil servants, various state agencies, trade associations and individual firms constitutes one of the most exhaustive examinations of state policy, relations with industry, and industry prospects ever undertaken in the UK, and is a source of a vast amount of information on these topics. In taking evidence, the SCST also provided a public platform for ICL and the American computer manufacturers with operations in Britain - especially IBM, Honeywell and Burroughs - to argue their respective cases for and against a government computer procurement policy favouring ICL. Not surprisingly, the US companies argued that they were being unfairly discriminated against. They believed themselves parts of the British industry, making valuable contributions to the UK economy. They also believed that a protected public sector market was harmful to effective governmental use of computers. For its part, ICL emphasised the importance of government orders to the company and wanted more, particularly in batches and when far-sighted, as well as development and applications contracts in order to cultivate its applications skills.[146]

The Committee made numerous recommendations covering state support for R & D, government use of computers, and public purchasing. It found it "difficult to describe present Government action regarding computer research and development as a policy",[147] the funding of which it criticised as "derisory."[148] Instead the Committee believed that support for the computer industry should consist mainly of a substantial, market-oriented programme for the development of computer hardware, software and componentry comparable in scale to the support given by the governments of other industrialised nations to their indigenous computer industries. Such a programme would involve not less than £50m. per annum, of which ICL would qualify for a "substantial proportion",[149] and be coordinated through a Computer Research and Development Board, located within the DTI, but independent of existing departmental structures. The Board would also be responsible for matters relating to professional standards, training and education.

Within Government, the Committee recommended that there should be more forward planning in computer use and a greater reliance on external service organisations. Such reliance would strengthen the computer services industry, improve its export potential, and help stimulate standardisation.

The SCST also recommended that the existing, fragmented purchasinig procedures be concentrated within a single Computer Purchasing Board which would assume the functions of the Computer Board, CAS, Civil Service Department, HMSO, DTI and Ministry of Defence. The new Board was intended to be a strong, technically competent agency which would purchase computer equipment and services, except where integrated in weapon systems, and develop and coordinate their use throughout central government. As it believed that single tendering was inimical to the cost-effective use of computers in government, the Committee argued that it should be replaced by a system of preference for firms which contributed "most to the economy and to national objectives in the computer field,"[150] and especially for firms owned and controlled in the UK. Contracts would also be itemised to allow consortium bids, bids from systems houses, and also a more precise and detailed definition of requirements.

The Select Committee was therefore urging vastly increased state support for what it regarded as an important and growing industry. The Economist thought that its Report carried "a bite that is real and expensive, but still not quite deep enough," arguing that while increased R & D funding was welcome ICL did not have "a large enough market base" to be able to compete effectively with IBM.[151] But while exhibiting an intense dislike of single tendering, the alternative criteria the Committee put forward meant that a significant preference would still be shown toward UK firms, which in reality would mean ICL. Implicitly this system would extend over all hardware, peripherals and software purchases rather than be restricted to large mainframe computers. Moreover, by opening up government applications to the services industry, crucial applications expertise would be cultivated.

Before the Government was able to respond to the Select Committee's Report, various adverse changes in the domestic and worldwide computer market reduced ICL's abilities to finance its R & D programme and City confidence in the company,[152] necessitating further DTI support. A statement in July 1971 announcing the continuation of ACTP, the Department's intention to underwrite Computer Leasing Ltd., ICL's associated computer leasing company, and suggesting that ICL should look to cooperation with the European computer industry,[153] did little to allay public fears or stem the company's declining fortunes. Thus a year later, in the middle of the Government's aboutturn on industrial policy, the payment of £14.2m. R & D support to ICL for the period until September 1973 was arranged.[154]

The Government's considered response to the SCST Report appeared a month later in August 1972. Besides the assistance already agreed for ICL, the DTI undertook to place more development contracts and to introduce the Software Products Scheme to encourage the development of software. Altogether the total value of these contracts was to be about £6m. per annum, half of which would be met by the Department. These measures were to be administered by a Computers, Systems and Electronics Requirements Board (CSERB) which, it was said, would closely correspond to the Select Committee's proposed Computer Research and Development Board. Single-tender contracts were, however, to be retained, as was the Computer Board for the Universities. Otherwise governmental purchasing procedures had already been vested in the new Central Computer Agency, which incorporated the CAS, the Central Computer Bureau, and the computer purchasing functions of the Civil Service Department and Stationery Office. In the short-term, any cooperation between ICL and European computer manufacturers was again welcomed, while in the longer term an "outright merger" was considered "absolutely right". Such a merger would help challenge the hegemony enjoyed by US computer firms, as well as being politically desirable given the UK's imminent entry into the Common Market.[156]

The Select Committee was unhappy with this response. It welcomed the establishment of the CCA and the intention to make greater use of external service organisations, but in light of its limited funds the Requirements Board was "at best, an inadequate reply."[157] Moreover, the retention of single-tendering was "bad for the industry and bad for the user."[158] On the whole, the Committee regarded the new level of Government support for the industry as insufficient, and argued that the

Government still appeared "to be content to take isolated decisions" and showed "no sign of formulating a total policy for the industry."[159] It also disliked "the extent of the Government's direct concern with the formulation of international policy" within ICL.[160]

ICL

Just before the SCST's comments were published, the DTI extended its funding of ICL's R&D programme by another £25.8m. to cover the three years from September 1973. Any further financial assistance, of up to £15m., would be met by ICL's other principal shareholders, GEC and Plessey.[161] Repayment of this and the previous tranche of DTI money was to be made up of the amount ICL's profits exceeded 7½% of its turnover, up to a maximum of 25% of profits, in each of the seven financial years, 1977/78 - 1983/84.[162]

ICL's difficulties, as stated earlier, were due to a combination of internal, domestic and international factors. The company was in the middle of the development of the 2900 Series which incorporated a radically new computer architecture and operating system and put a great strain on the company's finances.[163] (Later estimates variously put the total cost of developing the 2900 Series at £125m.[164] and £170m.[165]). New orders slowed in the period 1970-1972, partly because of economic recession and the withdrawal of investment grants,[166] partly because customers were beginning to await the new ranges of ICL, IBM and other manufacturers' machines soon to be introduced, and partly because of increased levels of leasing.[167] Moreover, a declining rate of growth in the American computer market meant an intensification of US competition in European markets.[168] As a result ICL's turnover grew by just 2% between 1971 and 1972, its profits fell from over £10m. to £3.3m., and it shed a quarter of its workforce.[169]

The launch in 1973 of the 2093, the first of its new range, solved many of ICL's immediate cash flow difficulties by recording 750 sales in 18 months[170] but, as it was a small mainframe rather than a minicomputer, it still left ICL excluded from the fastest growing segment of the computer market, a problem it shared with all of the other major mainframe manufacturers. Early in 1976 the company widened its product range and customer base by acquiring for some £19m. the non-American operations of Singer Business Machines Corp., including the rights to Singer's small business computers and its well-received range of point-of-sales terminals.[171] But, again, this move still did not take ICL into the increasingly important area of minicomputers, and in 1977 the company's managing director stated that they were "working hard to develop our posture" at that end of the market. One option was to purchase an established minicomputer maker, although there was no UK manufacturer strong enough to be an attractive prospect. Such was the urgency of the situation that ICL had to have a solution within two years.[172]

In the meantime, toward the end of 1974, ICL introduced the first of its larger machines in the 2900 range in a wave of optimism about the company's future.[173] The company was, perhaps, pressed into making an earlier launch than it wanted to because of the spectre of IBM's System 370, introduced at roughly the same time. Possibly as a consequence, the larger 2900 Series machines suffered from a number of major teething problems, especially concerning its innovative VME operating system.

Later, ICL's managing director agreed that "our early 2900 customers had a rough time. Many things went wrong."[174] ICL's sales of the 2900 Series were likely to have been made more difficult at this time by IBM's 'Project Knock-off' made up of a covert anti-ICL team offering secret cuts in list prices on IBM machines to British customers willing to switch from ICL.[175] Despite this hostile climate a creditable figure of some 560 2900 Series sales, excluding the 2903, had been achieved in June 1979.[176]

As indicated by its statements in 1971 and 1972, the DTI wanted ICL to enter into some kind of merger with one or more European computer firms. (Earlier, in the late 1960s, Harold Wilson had pursued a similar line while on a visit to France.[177]) Such an arrangement was politically attractive to the UK Government. It would, first of all, underline Britain's commitment to the EEC but it would also, because of ICL's then pre-eminence among European computer manufacturers, mean that any such merger would leave a new company largely located in the UK and based on British technology.

ICL had in fact entered a loose collaboration of sorts in 1970 with CDC and CII, the main French computer group, with the aim of dovetailing production and standardising interfaces and architectures.[174] But this grouping split in 1972 in some acrimony as CII left to form a new combine with Philips and Siemens, leaving ICL "shocked" and its relations with CII "strained".[179] Despite efforts by the Minister for Industrial Development and his French counterpart, the two companies remained opposed as ICL reportedly refused to be pushed into any new cooperative effort for essentially political ends.[180] Its name, however, was later linked at different times with the German Nixdorf/Telefunken combine,[181], Burroughs,[182] and Univac[183], but any merger with either of the latter two companies was likely to have been politically unacceptable, given successive British Governments' commitments to either a European link-up or an independent British computer industry. ICL, nonetheless, did take a one-third shareholding in another US company, Computer Peripherals Inc., a peripheral equipment manufacturer previously jointly owned by CDC and NCR.[184] Even after this venture ICL produced only "a relatively small amount of its peripherals requirements, preferring to buy in equipment from outside manufacturers".[185]

Procurement policy

Despite the recommendations of the Select Committee that single tendering for large computers in favour of ICL ought to be replaced by a purchasing policy that would, by implication, extend preference to all British-owned companies over the whole range of computing equipment and services, single tendering was retained by the 1970-74 Conservative Government as the basis of its procurement policy. Although this policy was officially restricted to central government orders some evidence has been presented to indicate that local authorities and public corporations increased their rate of ICL purchases during the late 1960s.

With the return of a Labour Government in 1974 ICL-based procurement was continued, but against a background of reduced public spending central government orders slowed and leasing became more prevalent.[186] In an apparent effort to maintain the level of public sector orders just as the larger 2900 Series machines were being launched the DoI put pressure on other public bodies to buy from ICL.[187] When this pressure was applied to another Government Department to comply with policy a clash with the Treasury ensued.[188] Honeywell and Burroughs complained to the DoI but their approaches were shrugged off by the Department as it "made it clear to them" that it was "not prepared to undermine the position of the only wholly British-owned computer company."[189] Rebuffed by the DoI and incensed by the Anglian Water Authority's decision to buy a computer from ICL contrary to the recommendations of its technical evaluation team, finance and general purpose committees in favour of Honeywell, Honeywell took the Authority to court. Honeywell eventually lost the case but made its point that it wanted access to public sector markets.[190]

American mainframe manufacturers were not the only critics of the Department of Industry's policy at this time. Computer Technology Ltd. called for a long-term policy embracing computers of all sizes,[191] while ICL stated that it would like to see the procurement policy extended across the whole of the public sector.[192] After the DoI had decided to conduct an internal review of its single tender policy, the newly created Electronic Computers SWP also urged the extension of procurement policy to cover not only the whole of the traditional public sector, but also the companies in which the Government and NEB held shareholdings, and to include minicomputers and peripheral equipment. To underline its case, the Working Party pointed out the benefits that American computer manufacturers enjoyed under US military programmes, and those which CII-Honeywell-Bull derived from the French authorities' guarantee of a minimum level of turnover from public orders.[194] Not surprisingly, these recommendations were disowned by the SWP's Honeywell representative who subsequently resigned.[195]

Despite the representations in favour of an extended purchasing policy, the DoI eventually decided that it should remain substantially as it stood until the end of 1980, when it would be abandoned in accordance with an EEC directive on public supplies.[196] Hills argues that the non-extension of procurement policy was mainly due to Honeywell's threat to close its manufacturing operations in Scotland and move them to France.[197] As the 1970s drew on, however, the procurement policy was of decreasing relevance to ICL. By 1977 only 7% of its business came from central government, while its best selling machine, the 2903, was too small to be subject to preference.[198] But had the policy been extended in time to all machine sizes, it would have been of value to both ICL and the British minicomputer industry.

Some official interest in the emergent minicomputer industry appears to have resulted at the end of the 1960s from Mintech's embarrassment of Computer Technology's loss of a Dutch contract due to the Ministry's lack of public support for the company.[199] The Ministry subsequently commissioned a study of the UK minicomputer market which, published under the banner of the DTI, identified it as an area of major growth during the 1970s.[200] Whether or not this report would have led to action if a Labour Government had been returned in 1970 is open to debate, but during the early 1970s the unprotected British market, private and public, was swamped by American imports. Thus, whilst Computer Technology and Digico had sold 127 and 50 machines respectively to central government and public corporations by the end of 1974, DEC had made 338 sales to the same two sectors, and whereas less than half of the minicomputers purchased by universities were of foreign origin in 1973/74, more than three quarters come from abroad in the following year.[201] Once the US minicomputer makers became established in the UK public sector to this extent, the requirements for compatibility and standardisation inherently inhibited the utility of a minicomputer procurement policy.

The DoI and NEB

After taking office in 1974 the Labour Government seems to have been content to let the policies toward the computer industry, built up over the previous few years, continue without major alteration. As noted in the last couple of sections, the emphases upon ICL and procurement policy remained largely as before with the addition of further guarantees to underwrite the leasing of ICL's computers.[202] The Government's shareholding in ICL was, however, transferred to the National Enterprise Board for a consideration of £4.97m. Later the Board increased its stake in the company to just of 25%, mainly through the acquisition of the bulk of GEC's shareholding for about £7m.[203]

By late 1977, however, the DoI was forced to admit that neither the minicomputer, peripheral equipment nor services sector of the industry were in a happy state. With regard to minicomputers it was too late to retrieve any advantage, while peripheral equipment represented both a growing percentage of the value of computer systems and a high proportion of the trade deficit in computing equipment,[204] something which had previously been noted both by the Select Committee in its report and the Electronics EDC. There was also a "growing emphasis on expertise in computer applications and systems" which, the Department implied, required specific action.[205]

In the following year the DoI revealed that the new emphases in policy were to be on improving the balance of payments in the computer field, and on transferring the benefits of developments in computing techniques to industry in general. In the future, policy was to be better coordinated. There was also to be more manpower training, and university research was to be linked more closely to the Department's interests. To that last end, the SRC set up a special panel with representation from the DoI that sought to apply academic research to practical computing projects.[206]

Meanwhile, in 1976, the NEB had taken a 57.4% stake worth £3.14m. in Data Recording Instruments Ltd. (DRI), the main British and European independent manufacturer of peripheral equipment, to allow the company to expand.[207] This investment followed an earlier one by the NRDC to fund DRI's development of a range of disc drives and printers.[208] Further capital was provided in 1978 when the NEB and NRDC subscribed another £1.84m. between them.[209] Then in 1979, presumably in response to the DoI's newly found interest in peripheral equipment, the NEB invested £8m. in a DRI joint venture with a CDC subsidiary, Magnetic Peripherals Inc. in an attempt to enable DRI to compete worldwide.[210] After large losses due, it is said to the start-up costs of this venture, DRI was subsequently sold to CDC.[211]

Despite its shareholdings in ICL and DRI the main thrust of the NEB's policies in the computer field concerned computer services and office automation. According to the Board, the UK service industry's share of an expanding world market was declining because of its fragmentation and lack of resources for adequate product and market development. The NEB thus founded INSAC Data Systrems Ltd. in 1977 to export UK software and systems products, especially those developed by a loose consortium of small companies in which the NEB had or intended to take a shareholding.[212] By 1979 the NEB had taken five such companies under its wing, Computer Analysts and Programmers Ltd. (CAP), Logica Ltd., Systems Designers Inernational Ltd. (SDI), Systems Programming (Holdings) Ltd. (SPH), and Systime Ltd., in which it took varying shareholdings to a total investment of more than £8m., and for which it arranged loan facilities. The idea of a loose consortium was an alternative to outright mergers or takeovers, which might have been resisted by the largely privately owned companies, but one to which some scale benefits could accrue. Once fully established, it was expected that INSAC itself would dispense funds for product development, as well as coordinating overseas marketing strategy for the group as a whole. In 1979 INSAC split into INSAC Products Ltd. and Aregon Group Ltd, and by the end of the year the Board's total investments in INSAC and its collaborative companies amounted to £15.13m.[213]

In 1979, too, the NEB extended its experience of INSAC into electronic office equipment and founded NEXOS Office Systems Ltd. with initial funding of £15m. of which £4.1m. was subscribed by the end of the year. NEXOS was intended to exploit the convergence of computing, telecommunications and office equipment, and like INSAC it was intended to market and specify products which would be developed and manufactured by associated companies. To begin with its product range was supplied by Logica VTS and Muirhead Office Systems Ltd., both companies in which the NEB held equity.[214]

Another Board investment (of £2 m.) in 1979 was a joint venture with the American Q1 Corp. to establish Q1 Europe Ltd. which would develop, manufacture and market advanced microcomputer systems in the UK.[215]

The NRDC, SRC and CSERB

Following the repayment of its loan to ICT, the NRDC once again left mainstream computer activities. But throughout the 1970s the Corporation funded an increasing number of small and medium-sized development projects concerned with peripheral equipment and especially software and applications. However, its interests in Digico and Arcturus, in which it took a 30% shareholding,[216] continued, and in 1979 made an investment in Quest Automation for the development of a microcomputer.[217]

Small investments were made in the development of automated library issue systems, computer animation techniques and, in the latter half of the seventies, a variety of terminals and data capture devices, including in 1977 an intellgent visual display unit with Logica Ltd. The Corporations's largest investment in peripheral equipment development was with DRI in 1973/74, when it took a 23% shareholding and provided loan capital to a total value of nearly £800,000.[218] The NRDC later increased its equity holding to 45% which it later sold to the NEB.

The Corporation's main involvement in the computing field in the 1970s, however, was in funding the development and marketing of software. One of its more important investments was Genesys Ltd., set up in 1974 as a wholly owned subsidiary to develop and market CAD software for civil and structural engineering applications, later including that produced outside of Genesys itself.[219] The success of Genesys led the Corporation to establish a second wholly-owned subsidiary in 1977, Compeda Ltd., with initial funding of £1.8m. Compeda's task was to identify engineering software of commercial potential being written in universities and government research establishments, fund and supervise its future development, and finally market and support it worldwide.[220] By 1980 Compeda had subsidiaries in the USA, Germany, Holland and Japan.[221] In the following year the Corporation contributed £350,000 toward the cost of developing CAP Ltd.'s range of microcomputer software in 1978. Another £650,000 was invested by the NCC under the Software Products Scheme, and the whole project involved an expected outlay of £2m.[222]

From its annual reports it appears that the SRC's computing science budget was concentrated upon supporting research at the universities of Manchester, Oxford, Cambridge, Edinburgh and Newcastle. As noted, its funding of the Manchester team's development of the MU5 had considerable bearing on the design of ICL's 2900 Series. In response to the DoI's desire to increase computer research it began, in 1978, a special programme in distributed computer systems to which £10m. was allocated.[223] Before this programme started the SRC's expenditure in computer science had, after expanding quickly in the previous decade (Table 4.10), levelled off in the 1970s so that by 1978/79 it was still at the same level, in current terms, as in 1970/71. (Table 4.13).

The main institutional initiative of the 1970s with regard to state support of computing research was the formation of the Computers, Systems and Electronics Requirements Board in 1973. This new agency assumed responsibility for the allocation of DoI funding of computing research, other than the direct grants to ICL. It thus acquired the ACTP and the Software Products Scheme, which was administered on a day-to-day basis by the NCC. From 1977/78 it also took over the block funding of NCC's

Table 4.13 SRC Computer Science research grants and studentships, 1970/71 - 1978/79

	Computer Science Commitment (£000s)	% of Total Commitment	Notional[1] Yearly Expenditure (£000s)	No. of Computing Studentships	% of Total No. of Studentships
1970/71	2955	8.1	782	255	3.5
1971/72	2795	6.6	809	282	3.8
1972/73	2213	5.0	758	296	3.9
1973/74	2702	5.6	940	289	3.9
1974/75	2961	5.0	857	258	3.6
1975/76	2545	4.0	851	265	3.6
1976/77	3007	4.5	1198	258	3.5
1977/78	2236	3.0	794	272	3.6
1978/79	2824	3.1	959	291	3.9

Source: SRC. Annual reports, appropriate years.

Note

1. For definition of notional see Table 4.10.

Table 4.14 CSERB expenditures, and NCC, CADC grant-in aid 1970/71 - 1978/79. (£000s)

	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79
Total CSERB exp.	-	-	-	5545	4453	6369	7875	8996	13743
CSERB computing exp.	-	-	-	2000	2171	2869	3311	4046	..[1]
ACTP[2]	630	450	665	575	430	480	640	569	527
SPS[2]	-	-	-	200	150	400	29	150	348
PPDS	-	-	-	-	-	-	-	-	439
DTI extra-mural contracts	360	230	170	140	-	-	-	-	-
NCC[3]	643	606	807	1060	1208	1157	939	-	-
CADC	493	419	668	970	1341	1613	1979	1901	1856

Sources: CSERB expenditures; ACTP, SPS, PPDS, 1973/74 - 1978/79, DoI. Reports of the Research Requirements Boards, appropriate years; ACTP, 1970/71 - 1972-73, DTI extra mural contracts, HoCPD, 887, 292w, 3 March 1975; NCC, CADC, ibid., Civil Appropriation Accounts, appropriate years.

Notes
1. Not identified, but estimated to be £5.5m on the basis of previous yearly expenditures.
2. Both ACTP and Software Products Scheme expenditures are included in CSERB totals from 1973/74 onwards.
3. From 1977/78, subsumed under CSERB total expenditure.

general activities. A breakdown of CSERB's expenditures, showing the amount devoted to computing research is given in Table 4.14. The Table also shows CADC and NCC block funding, and expenditure under the Product and Process Development Scheme in the computer field.

4.6 Discussion

Table 4.15 presents a breakdown of state support in the computer field in the period 1945-1979. The computer industry, it will be remembered, consists of computer hardware, including perpheral equipment, and computer services, but not electronic components. Although the Table is not quite complete, it shows that over £350m. has been spent on supporting the industry, of which about half (£177.6m.) is made up of expenditure on computer investment grants.

These expenditures are gross expenditures and thus do not allow for the repayment of loans, levies, sales of assets, and double counting due to transfer of shareholdings between state agencies. For example, on its creation ICL repaid £6.7m. to the NRDC in respect of monies received 1965-68, leaving the Corporation with a gross profit of £2.76m. and a net surplus of £2.70m. on its investment. Central Government, too, recouped nearly £5m. on transfer of its ICL shareholding to NEB in 1975. On its sale of its shareholding on the open market the Board collected a gross profit of £24.2m. During the intervening years the NEB had in any case been in receipt of dividend payments of about £1m. per year. Therefore of the total Central Government and NEB investments - shareholdings and R & D grants - of £69m. in ICL, dividends and sales of shares returned at least £45m. to the state.

Table 4.15 Summary of state support, 1945-1979 (£000s)

1945-1964	NRDC	2041
	DSIR (universities)	110+
	Ministry of Supply	100
	NPL	250+
	ACTP	?
1965-1970	NRDC	6041
	Mintech (extra-mural contracts)	799
	Computer merger payments	4350
	ACTP	1808
	NCC	1943
	CADC	2188
	APACE	365
	Investment grants	62800
	SRC	2606
1970-79	NRDC	?
	CSERB[1]	22300
	DTI (extra-mural contracts)	900
	DTI (payments to ICL)	40000
	ACTP[2]	1745
	NCC[2]	6420
	CADC	11240
	Computer merger payments	12650
	Investment grants	114726
	SRC	7948
	NEB	52980

Notes

1. Incorporates later NCC and ACTP funding as well as expenditure under PPDS.
2. Later incorporated under CSERB, see Table 4.14.

Apart from investment grants, large expenditures were incurred by the direct Central Government support of ICL, by the NEB, and by CSERB. No amounts are attached to the Government's procurement policy, although an attempt will be made later to assess its effect upon ICL for the years that appropriate data are available. As far as can be established from the Civil Appropiration Accounts no expenditure was involved in the underwriting of leasing companies associated with ICL.

Table 4.16 shows the functional objective of individual measures and instruments: most have been aimed at supporting R & D or diffusion. The analysis is complicated by the inclusion of the computer services industry in this study as software can be regarded either as a product in its own right or as an enabling factor in computer applications, and thus adoption and diffusion. For the sake of simplicity, such measures are placed under the diffusion column where aimed at otherwise hardware manufacturers, or where appropriate if aimed at computer services firms.

Support for prototype production and the manufacture of initial batches of machines was integral to the NRDC's early approaches to the problem of assisting the UK computer industry. At that stage in the industry's development though there would have been little in the way of tooling up costs - computers were largely hand built - but by agreeing to purchase the first batch of production models the Corporation guaranteed an initial market, even if they were not subsequently sold to 'real' customers. Indeed the whole attitude of the NRDC at this time appears to have been that it was willing to absorb losses on its computer development projects so as to build up expertise in the industry while awaiting the domestic computer market to grow. To quote Drath et al on the NRDC's intended support for

Table 4.16 Function of support

	R & D	Prototype	Manufacture	Marketing	Diffusion
1945 - 1964	NRDC DSIR NPL ACTP	NRDC			NRDC
1965 - 1970	NRDC Mintech Computer merger payments ACTP SRC				NRDC Procurement NCC CADC APACE Investment grants
1971 - 1979	NRDC DTI payments to ICL CSERB Computer merger payments ACTP SRC SPS NEB		NEB	NRDC NEB	NRDC NEB NCC CADC Investment grants Procurement Leasing underwriting

the development of a supercomputer, "what was important was not simply the building of a very large machine, but the expansion of research and development in the industry."[224] (Original emphasis). The Corporation's funding of scholarships at Cambridge and Manchester Universities was a further obvious attempt to build up such expertise, while its support for the formation of the British Computer Society and the first computer exhibition at Olympia helped, respectively, to institutionalise computer science as a respectable discipline for research and stimulate the UK computer market. Additionally, the few applications projects the NRDC supported in process control and factory management were attempts to apply computers to fields other than scientific research before they had really broken in the UK.

During the 1950s the DSIR expressed next to no interest in computer R & D. Although university research had a marked impact upon early computer development, all DSIR grants to universities in the 1950s containing a computing component were concerned with the use of computers to solve scientific problems. Even its first major grant in computer science, awarded in 1964, was to "establish" a research group that had been in existence since the 1940s. Moreover, NPL's development of ACE was very much an internal laboratory exercise carried out by its smallest Division.

The twin thrusts of policy in the second half of the 1960s were to concentrate the resources of the industry into a single entity, ICL, while Central Government orders favoured UK-owned firms. Other state assistance was aimed either at funding R & D or increasing the levels and range of computer diffusion. Schemes for both proliferated. R & D support was available from Mintech either as an ACTP or an extra-mural contract; from the NRDC which was responsible to Mintech; or from the SRC which financed university research. Similarly three new organisations - NCC, CADC, and APACE - were set up to extend the range of computer applications. But as this was at a time when "top systems analysts (were) like diamonds and programmers like gold",[225] a further drain was placed on the market for scarce qualified manpower.

The NRDC's support to ICT, clearly in furtherance of Mintech policy, was for the continued development of the 1900 Series rather than for development leading to its launch. This raises the point that innovations may not necessarily be introduced in their final form, and may require modification and enhancement to be ultimately successful.

The emphasis upon ICL bolstered by procurement policy was continued in the 1970s. R & D assistance, other than direct from the DTI and DoI to ICL, remained the province of the NRDC and SRC, while ACTP and extra-mural contracts were subsumed under the CSERB banner. Both market share and large-scale R & D were of critical importance to ICL at this time. This may sound facile but, as argued in Section 4.2, because of the need for compatibility to protect investments in software customers are largely tied to their initial supplier for replacement machines. Furthermore, ICL was not only committed to meeting head-on the challenge of its American competitors, but also to replacing two incompatible ranges of computers with one that would be compatible with both.

Investment grants and APACE were soon terminated, but NCC and CADC continued. During this decade the NRDC's interests switched mainly to supporting the computer services industry, which was also the prime target (other than DRI) of the NEB's own policies. In their respective creations of Genesys and Compeda, and INSAC and NEXOS, both the NRDC and NEB adopted more sophisticated approaches to the support of innovation which embraced both the development and subsequent marketing of software (and office equipment).

By guaranteeing a secure initial market for the larger 2900 Series machines Central Government also provided a customer base within which they could be proved and debugged. Although the DoI and Central Computer Agency may have understood that this might happen, other government departments appear to have been unwittingly involved, giving rise to considerable resentment on the parts of the Ministry of Defence and Treasury at least.[226]

Whereas the other two case studies reveal a pattern of state-funded R & D largely located within state laboratories, the situation with respect to computers has been very different. Between 1968 and 1976, at least £53.5m. of state funding went to ICL. Prior to 1968, the NRDC was the major source of public funds in the computer field and, of course, its funding was entirely located within private firms. During the 1970s, the Corporation and NEB were important benefactors of software development in the computer services industry. ACTP projects were also industry-based. SRC spending on the other hand was entirely within higher education, while most of CSERB's expenditure, other than that on ACTP and the Software Products Scheme, was also to state institutions, such as NPL.

University research has, however, made important contributions to computer development in this country. The first machines introduced by LEO, BTM, and Ferranti were all based on university designs, while Ferranti and latterly ICL continued their close collaboration with Manchester University, whose MU5 was the basis of the 2900 Series. NPL's cooperation with English Electric also produced the Laboratory's Pilot ACE, on which the company's successful DEUCE was based. NPL's second machine, ACE itself, was however built without any industrial involvement, and incorporating outmoved componentry had no identifiable impact upon computer development. Given the early influence of university and state laboratory research upon computer design, the NRDC's establishment of its Patent Pool represented an attempt to open up the resulting patents for wider use. But without the membership of BTM, in particular, the Pool would have been of restricted utility, and decreasingly so once the UK industry began to rationalise itself.

Whilst defence-related R & D is outside the remit of this thesis, it is nonetheless appropriate to make some points about its influence upon computer development in the UK. In Britain relevant mililtary spending was concentrated in electronics companies such as Ferranti and Plessey, rather than business equipment suppliers such as BTM, so that when ICT took over Ferranti's data processing interests, Ferranti retained its military computer activities and military funding. Thus two distinct channels of computer R & D funding - civil and military - began to support two different parts of the industry. This situation was effectively institutionalised under the ICL merger agreement which excluded ICL from competing in purely military (and process control) markets, to which Plessey and English Electric (and therefore later GEC) were confined. As a result, ICL could not benefit from defence contracts while Plessey, which did, developed a range of computers it was unable to market more widely, even if they had been appropriate. Unlike in America, therefore, where military applications were developed under contract by otherwise commercial data processing firms[227], parallel channels of funding in Britain served to fragment rather than concentrate resources.

Turning next to the question of the user-supplier nexus, the Government has obviously had a long-standing relationship with ICL both as sponsor and customer. Together with its procurement policy, the Government's formal influence upon the framing of ICL's R & D programme, allowed for under the company's merger agreement, provided a clearly defined method by which the Ministry of Technology and its successor Departments could make sure that the requirements of Government, as an important customer, would be considered by ICL. Under the terms of the agreement Mintech also promised to make available the Government's expertise in commercial and scientific data processing. How these arrangements worked in practice is difficult to say, but until the Select Committee's recommendations were acted upon the actual procedures for computer purchasing were undeniably complex, involving a variety of agencies and Government Departments. Without a central body to plan, coordinate and develop internal applications and have responsibility for final purchasing decisions, competing interests are likely to have lessened the potential for positive Government influence. In this context, it is noteworthy that ICL complained to the Select Committee that what it wanted from Central Government was not only more orders per se, but also more development and applications contracts to cut its teeth on.

Product-related services cover the range of supplier activities such as systems design and installation, maintenance, training, and, in this context, applications software, provided by the supplier. Thus the NRDC's support for ICT's further development of software for its 1900 Series can be regarded as helping to provide a product-related service, as well as R & D support. Leasing, too, can be regarded as such a service as it extends the ways in which customers can acquire computer equipment. Here, however, the DTI/DoI's underwriting of various ICL-associated leasing companies had less to do with wanting to increase ICL's customer-orientation than wanting to protect the company's fragile cash flow position.

The range of adoption and diffusion schemes, shown in Table 4.16, fall into three categories, those aimed at building up applications expertise, those concerned with reducing the direct financial cost of adoption, and those which guaranteed a market. The NRDC's 1950s applications projects represent attempts to move the locus of computer use from scientific to business data processing, while the NCC, CADC and APACE were later instruments for widening the range of computer applications into, in the latter instances, computer-aided design and engineering.

Of all the schemes and measures described in the course of this chapter, computer investment grants incurred the greatest expenditure. Their intention was, by lessening the cost of adoption, to increase the level of computer diffusion in line with Mintech's stated objectives. Although grants were open to foreign as well as British computer equipment ICL's share of the UK market increased in all market sectors in the late 1960s. (Table 4.8). The introduction of grants coincided with a slight slowing of the rate of computer diffusion, but when they were withdrawn at the end of

1970 the rate immediately fell from 27% in 1970 to 11% in 1971 and 12% in 1972. This drop, however, cannot have been wholly due to the abandonment of grants as they were payable on orders placed rather than deliveries of equipment, and are thus paid on equipment installed after 1970.

The Government's procurement policy provided ICL and its predecessors with a promise of orders for computers of a certain size, which became a guarantee when single tendering was introduced. Its concentration upon ICL and large computers, however, arguably restricted the full effectiveness of the policy. Had it been applied to smaller computers and peripheral equipment at an early enough stage then those segments of the British industry might have fared better, with a consequent improvement of the balance-of-payments in computing equipment.

An estimate of the effect of procurement policy upon ICL can be gauged from comparing levels of purchases in central government and other sectors of the market for the years for which appropriately detailed data are available. If the private sector is assumed to exhibit the 'natural' pattern of market shares, that is what these shares would have been in other market sectors had there been no preferential favouring of ICL, then the difference between the private and public sector markets gives the extent of preferential treatment.

Algebraically this can be represented so

$P = a - b$

where P = Degree of preference for ICL

a = ICL share of public market

b = ICL share of private market

Table 4.17 Public sector preference for ICL, 1964-69, 1972-73.

	P Central Govt. %	Preferential[1] Central Govt. Orders £m	P Local Authorities %	P Public Corps. %	P^2 Public Sector %	Preferential[1] Public Sector Orders £m
1964	34.6	3.2	16.6	1.1	19.2	3.7
1965	8.8	0.7	21.3	6.4	9.9	1.8
1966	11.1	1.4	22.0	25.1	18.9	5.2
1967	13.1	2.4	23.7	6.1	11.7	4.7
1968	17.6	3.3	21.9	25.8	21.7	8.9
1969	29.3	5.8	41.2	35.7	33.3	13.6
1972	26.9	21.6	27.7	21.6	26.5	44.1
1973	25.5	21.8	30.4	16.6	23.9	42.5

Sources: Derived from market share data, 1964-1969, Moonman, E. (ed.) British computers and industrial innovation. London, Allen & Unwin, 1970. p.80; 1972, SCST. Second report on the UK computer industry. (Session 1972/73, HC 97-I). London, HMSO, 1973. pp.183-187; 1973, SCST. Minutes of evidence. (Session 1974, HC 99-i). London, HMSO, 1974. pp.23-26.

Note

1. This is the volume of orders resulting from the degree of preference noted in the previous column

2. Weighted average for the whole of the public sector - central government, local authorities, and public corporations.

Results for the three parts of the public sector - central government, local authorities and public corporations - are given in Table 4.17. The Table shows that the prior constituents of ICL were in fact more favoured before a procurement policy was introduced than afterwards! After falling sharply in 1965, the degree of preference then rose in central government until 1969 when it appears to have levelled off. It is also apparent that ICL found greater preferment in local authorities than in central government even though they were not subject, as such, to a procurement policy. The value of deliveries across the whole of the public sector due to preference was, according to this estimate, nearly £14m. in 1969, equivalent to 12% of ICL's turnover of some £115m. By 1972 and 1973, however, when ICL's turnover was relatively static, the value of preferential ordering is estimated to have been more than £40m. per year, equivalent in 1972 to more than 28% of its total sales, and a very substantial aid to the company.

More generally, there was little govenment interest in computers before 1964 when state policy can be identified with the activities of the NRDC, which devoted much of its resources to the fledgling industry. By 1964 some rationalisation was underway in the industry and further rationalisation to create a single entity was the prime policy objective of the 1964-70 Labour Government. This was accomplished in 1968 with the creation of ICL. Even though the IRC had been established to promote mergers and concentration in British industry, it was Mintech itself under the provision of the Industrial Expansion Act, 1968 that engineered the final merger between ICT and English Electric, thereby ensuring Central Government public support for the new company.

State assistance then became concentrated upon ICL, through public procurement and contributions to its R & D programme. Despite ICL's occasional troubles, it has been an undoubted policy success. While it is generally agreed that Mintech's actions merely speeded up the merger, the longer it was delayed the less likely ICL would have been able to compete with its larger US rivals. Moreover, without the guarantee of Government orders and the £53.5m. contribution towards the development of the 2900 Series it is difficult to believe that ICL would have survived as the main independent computer manufacturer outside the USA in the 1970s, with all the implications that had for the balance of payments and employment levels.

Nonetheless, the ICL merger had some probably unforeseen consequences which have had an unfortunate effect on the subsequent development of the rest of the British industry. The split between civil and defence computer R & D spending, rigidified by the merger agreement, has been noted. GEC, through its takeover of English Electric, and Plessey were also prevented from entering the minicomputer market. Additionally, against the recommendations of the SCST, Government policy then ossified into an inflexible system of support for ICL, thus neglecting the increasingly important areas of minicomputers and peripheral equipment. ICL too was unwilling or unable to respond to the changing patterns of demand in the computer market. (In this, ICL was by no means alone, all the American mainframe manufacturers were similarly caught out by the growth of the minicomputer market.) But the question of wider support for the industry was a thorny one given the political clout of the US multinationals established in the UK.

One of the main initiatives in the 1970s came from the NEB which pursued its own policies to secure the future of the computer services industry. In the light of the subsequent success of the companies it took under its wing, the Board's actions can be judged a success.[228]

Finally, it ought to be noted that despite the worldwide economic and strategic importance of the computer industry, the volume of public financial assistance provided in Britain has been niggardly in comparison to that of other countries. According to the figures presented in Table 4.18 even Sweden, with little in the way of a data processing industry, can claim to have provided more government support than the UK. In the USA, government contracts to computer firms have been a channel of massive development support which according to Freeman amounted to $4.2bn. between 1951 and 1954 alone.[229]

Table 4.18 Foreign Government financial support programmes, 1966-1980 (£m.)

Japan	France	West Germany	Sweden	UK
1220	350	675	139	103

Source: Tysoe, J. & Hickey, P. ICL and the computer industry. London, Laurie, Millbank & Co., 1979, p.19.

Perhaps the whole attitude of British Governments can be characterised by the observations that while the SCST complained of low levels of state funding, the Public Accounts Committee later wanted ICL to make an *ex gratia* payment to the Treasury in recognition of the Government's assistance to the company. Relatively small amounts of public support have been provided against a wider background of distrust as to its necessity and ends.

CHAPTER 5 THE MACHINE TOOL INDUSTRY

5.1 Introduction

Machine tools can be classified into two broad categories, those which remove metal from a workpiece (metal-cutting) and those which change its shape (metal-forming).[1] Traditional metal-cutting machine tools can be futher subdivided into a number of classes depending on the actual and relative motions of the workpiece and tool, and the form of tool itself. Lathes, drills, shapers, planers and boring mills all utilise single point tools, while milling machines, grinders, horizontal boring machines and saws are typified by multipoint tools. Size constitutes another difference between machine types. Drilling machines are usually used for small bore holes and with small or medium-sized workpieces. Vertical boring machines on the other hand are often large enough to bore a hole several feet in diameter in a workpiece weighing several tons.

Metal-forming machine tools comprise a similarly diverse range of machines, including presses, forging machines, spinning, and wire and rod drawing machines.

A further distinction is frequently made between general and special-purpose machine tools. General-purpose machines are defined as being flexible enough to deal with a wide variety of workpieces. In contrast, special-purpose machines are designed for the dedicated machining of a single workpiece or family of workpieces. They are thus much less flexible and generally more expensive than general-purpose machines, but are capable of much higher production rates.

On the whole the main thrust behind post-war machine tool innovation has been to reduce labour costs in machining.[2] However, other factors were vitally important to the two dominant innovations of the period. Physico-chemical metal removal techniques, the main classes of which are electrochemical, electron beam, electrodischarge (spark erosion), laser, chemical (etching) and ultrasonic machining, have yet to diffuse widely, but as they are unaffected by the hardness of metals they have found particular niches where that is a prime consideration.

In numerical control (NC)[3], the most important post-war development, the sequential operation of the machine tool is achieved through the use of digital information to define the relative positions and/or movement of the workpiece and tool.[3] Two distinct forms of control exist. Point-to-point (PTP) systems describe tool and workpiece interaction only in terms of particular positions, so that movement between them is along a straight line. With continuous path (or contouring) systems workpiece and tool move along pre-determined paths. Although such systems are more expensive, they are inherently more suitable for three dimensional machining, such as turning (lathes) or milling. Point-to-point systems are, however, perfectly satisfactory where simpler movements will suffice, as for instance in drilling. The bulk of the development of NC took place outside the machine tool industry, particularly within electronics companies. Nonetheless, the first NC machine tool was developed at the Massachusetts Institute of Technology under sponsorship from the U.S. Air Force, and indeed subsequent USAF development and procurement contracts meant that at least 150 of the 173 NC machines sold in the USA between 1954 and 1958 were bought for use in the aerospace industry.[4]

Athough this very first machine consisted of a 3-axis contouring system, adapted from a remote gun placement control system developed during the War, retrofitted to a large vertical milling machine, most of the diffusion of NC over the next fifteen years was made up of PTP drilling and boring machines. However, the early application of NC in the aircraft industry had less to do with a need to reduce costs than the requirement for the very precise machining of complex components.

While NC machine tools are obviously more expensive and complicated than traditional ones, they can offer cost advantages in a number of circumstances. As they obviate the need for operator intervention, they reduce the need for skilled manpower over multi-shift use. Moreover their accurate repetitive abilities can improve and standardise quality. As they reduce setting up times NC machines are also particularly suitable for one-off or small-batch production.

The full benefits of NC have nonetheless been conditional upon other machine tool developments. To remove the need for human intervention to correct, or allow for, minor changes in machine behaviour between operations, NC machines needed greater rigidity and the use of moving parts with low and constant frictional characteristics. Automatic measuring techniques and cutting tool monitoring and changing systems have also had to be developed and refined. In addition, multi-shift working has stressed the need for greater reliability, while widespread diffusion has been consequent upon the development of simpler and standardised programming languages, specifically designed for NC use.

The first generation of NC systems were hardwired in that changes in operational sequence were effected through physical changes to the connections in the control system. Later, the use of punched cards, or more commonly paper tape, to introduce digital information made true programming possible. More recently, the major developments have been computer numerical control (CNC), in which a machine tool is controlled by its own mini or micro computer, and direct numerical control (DNC), whereby a number of NC or CNC machines are under the overall control of a central computer system.

By virtue of its greater programming and memory powers, CNC has brought with it a capability for adaptive control, so that individual workpiece and tool characteristics can be allowed for in machining, and the development of multifunctional machine tools (machining centres). With DNC, machine tools can be linked to the operation of other machinery, such as transfer machines and robots, leading to a greater integration of the whole production system (computer-integrated manufacture), and to other factory functions such as design (computer sided design and manufacture).

5.2 The UK machine tool industry

In 1979 the UK machine tool industry had an output of£570m. and employed some 50,000 people. Output had then declined by about 30% in real terms since peaking in 1970 when employment stood at roughly 70,000. (Table 5.1). Deliveries of NC machine tools rose as a percentage of total value from 7.8% in 1968 to 14.1% in 1980, although there was a marked dip in the middle 1970s. Following a similar pattern, output of physico-chemical machine tools reached 2.1% by value of the total in 1979. In an international context, Britain's share of world production fell from more than 8% in 1960 to 4.5% in 1979. (Figure 5.1).

Th machine tool industry is made up of mainly small and medium-sized firms, although many are subsidiaries of much larger engineering groups. Very few firms have more than 1,000 employees, and currently only one company outside Japan and the Communist bloc has more than 5,000 employees. At one time, however, Alfred Herbert Ltd. was the largest machine tool manufacturer in the world with a workforce well in excess of 10,000.

The historical development of the industry's structure is given in Table 5.2, but the Table requires careful interpretation because of the inclusion of welding equipment suppliers.[5] (Employment in the welding industry was approximately 10,000 in 1976). Although the Table shows the existence of a large number of firms, the Machine Tool Trades' Association (MTTA) prefers a working figure of 200.[6] Two apparent trends are the decrease in large establishments between 1958 and 1978, and a substantial increase in the number of very small firms. This last trend is largely accounted for by official reclassifications, and the use of better survey techniques.

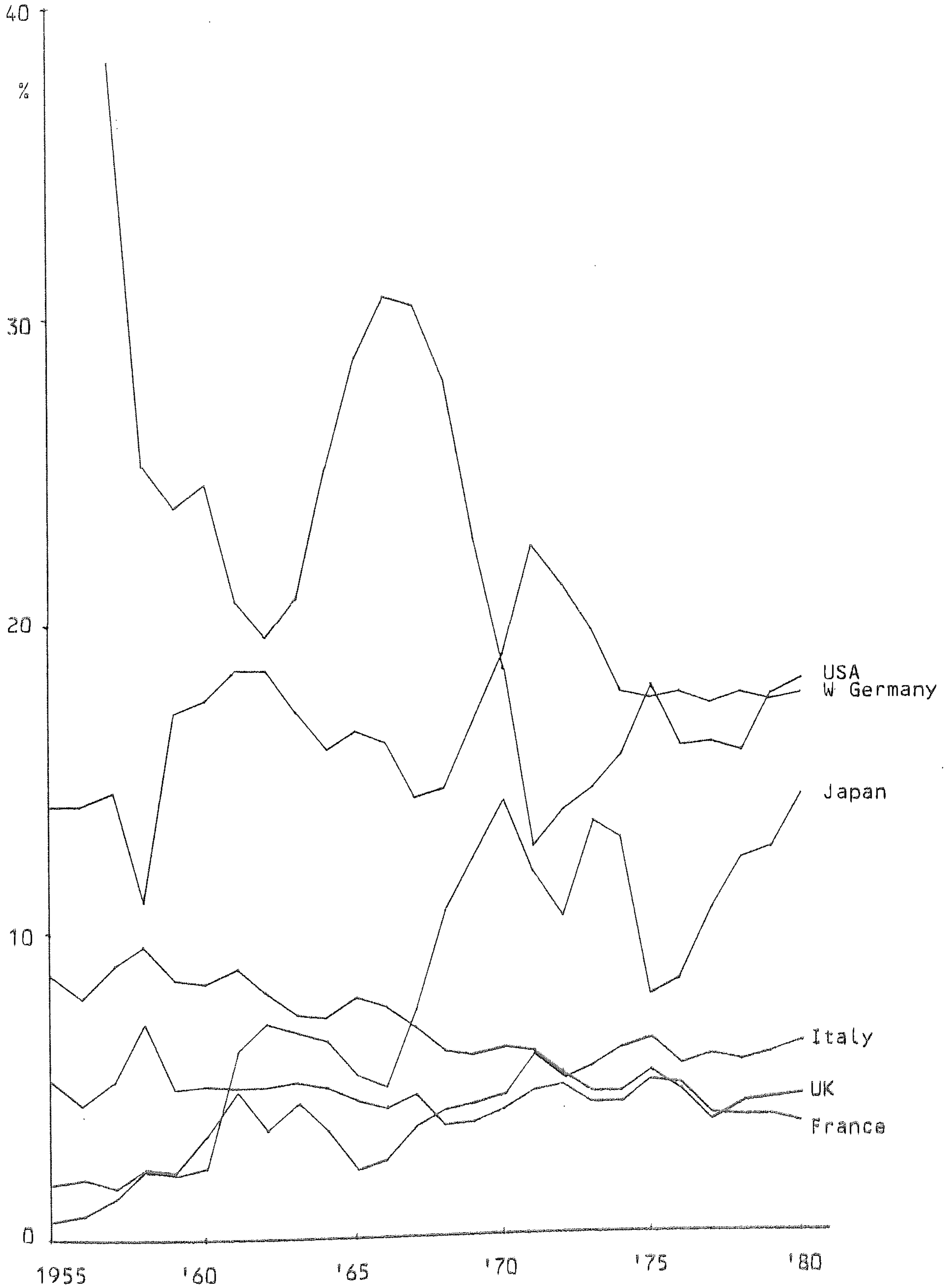
In the absence of large firms the industry appears to be relatively unconcentrated. In 1958, for instance, the eleven largest companies produced just over 40% of the industry's output, while in 1976 the five largest were responsible for 24% of its net output. But as one firm may own a number of subsidiaries the true degree of concentration is hidden rather than revealed by these official figures. After the spate of mergers and takeovers in the 1960s it was estimated that just seven firms controlled

Table 5.1 The UK machine tool industry: deliveries and employment, 1948-1980

Year	Employment (000s)	Deliveries (£m.)	Deliveries (1970£m.)	NC % by value	Physico-chemical % by value
1948	79.0	32.8			
1949	79.4	37.0			
1950	81.4	40.1			
1951	89.4	48.6			
1952	103.7	62.0			
1953	100.1	66.2			
1954	97.7	65.6	132.3		
1955	95.2	75.4	142.0		
1956	100.2	85.5	148.7		
1957	103.6	95.2	157.4		
1958	62.3	83.9	134.2		
1963	74.4	114.2	152.5		
1968	72.1	153.1	177.6	7.8	-
1970	70.7	198.7	198.7	7.9	-
1971	64.8	189.0	170.7	10.0	-
1972	54.1	188.3	159.6	6.0	1.9
1973	53.0	221.3	173.8	6.0	3.2
1974	53.7	259.7	158.4	6.2	2.0
1975	52.8	329.3	153.2	7.2	1.4
1977	51.5	409.1	136.4	8.2	1.7
1978	52.1	512.9	164.4	10.4	2.0
1979	51.1	568.3	147.5	11.5	2.1
1980	50.5	589.2	130.6	14.1	-

Sources: Employment: 1948-1969, Census of Production, appropriate years; 1970-1979, MTTA. Machine tool statistics. London 1980. Until 1957 includes engineers small tools and welding equipment, 1958-1969 includes welding equipment. Deliveries: 1948-1971, Annual abstract of statistics; Business Monitor (PQ 322) thereafter. Deflators, 1954-1964 supplied by MTTA,; 1965-1967 Mechanical Engineering Wholesale Price Index; 1968 - Machine Tools Wholesale Price Index.

Figure 5.1 Shares of world production, 1955-1980



Source *American Machinist*, appropriate years.

Table 5.2 UK machine tool industry[1]: structure

		SIZE OF ESTABLISHMENT				
		1-24	25-99	100-499	500-999	> 1000
1958	No. of ests.	148	99	110	17	42
1968	No. of ests.	302	136	128	24	9
	No. of firms	296	..	..	..	8
1978[2]	No. of ests.	767	172	105	11	7
	No. of firms	..	..	..	..	7

Source: Census of Production, appropriate years.

Notes

1. This table gives the structure of MLH 332, which includes welding equipment as well as machine tools.

2. Size categories for this year, 1-19, 20-99, 100-499, 500-999, > 1000.

half of the UK machine tool output,[7] a level of concentration believed to have continued.[8]

Another factor affecting concentration is the sheet variety of machine tools. A manufacturer will generally specialise in a limited range of machine types: even at its largest Alfred Herbert competed in just half of the machine tool sub-classes.[9] It is thus possible for specific markets to be much more concentrated, so that the Way Committee found that in 1969 75% of the deliveries of centre lathes, for example, was accounted for by only three firms.[10]

Table 5.3 gives estimates for the numbers and ages of machine tools in manufacturing industry as a whole and a couple of specimen industries including motor vehicles, the largest customer for machine tools. Each census has found that about 40% of the national machine tool stock was less than ten years old, and about a quarter more than twenty years of age, although this proportion rose in 1982 to about 32% at the expense of the middle age category. Otherwise the main feature of the Table is the decline in the size of the national machine tool stock by about a third in the twenty years before 1982. This means that while the average annual consumption of machine tools has remained at about 4% of stock per year, total consumption has fallen from about 50,000 per year in the decade before 1961 to about 33,000 per year during the 1970s. Similar purchasing patterns are also evident in the data relating to individual industries.

Another way of viewing the domestic market is in terms of worldwide consumption figures. Figure 5.2 shows that of the six countries examined machine tool purchases by value fell most in the UK. Other countries, with

Table 5.3 UK machine tool populations

		Total	M' cutting	M' forming	NC	Age (years) <5	6-9	10-20	>20
1961	TOTAL	1233757	1034536	199221		41		37	22
	Motor vehicles	204762	-	-		43		40	17
	Machine tools	32333	-	-		37		34	29
1966	TOTAL	1140660	968256	172404		38		36	26
	Motor vehicles	181795	-	-		41		37	22
	Machine tools	35473	-	-		37		31	32
1971	TOTAL	856682	727856	128826		19	22	37	22
	Motor vehicles	-	-	-		19	23	31	27
	Machine tools	-	-	-		22	25	37	16
1976	TOTAL	891404	733086	158318	9725	39		37	24
	Motor vehicles	112839	-	-		15	19	39	27
	Machine tools	22887	-	-		18	22	35	25
1982	TOTAL	833422	682625	150797	25802	26	13	29	32
	Motor vehicles [1]	136171	-	-		21	18	29	32
	Machine tools [1]	22931	-	-		24	19	30	27

Sources: Metalworking Production, 105, Dec. 1961; 110, 27 July 1966; Metalworking Production. Third survey of machine tools and production equipment in Britain. London, 1971; - Fourth survey of machine tools and production equipment in Britain London, 1977; - Fifth survey of machine tools and production equipment in Britain. London, 1983.

Notes
1. Percentages includes other production equipment.

The exception of the USA, have also exhibited falls but this is within the context of increasing worldwide industrialisation, with such countries as Brazil, Korea and Taiwan also becoming important machine tool markets.

A shrinking domestic market is not necessarily a sign that manufacturing industry as a whole is contracting. Newer machines are usually far more productive than older ones, and indeed the UK total of NC machine tools rose from just under 10,000 in 1976 (1.1% of total) to nearly 26,000 in 1982 (3.1% of total). Nonetheless an increasingly small home market places a greater competitive pressure upon machine tool suppliers, and means that to preserve capacity they have to turn to export markets.

Over the years there has generally been a small but positive trade balance in machine tools, although in 1979 there was a remarkably large deficit of more than £60m. (Table 5.4). Exports have typically made up 40% of total production, but have consistently been of lower unit value than imports, although the margin of difference was less in the 1970s than in the 1960s, which in turn was less than in the 1950s. Import penetration reached 45% in 1979, as compared with 33% in 1970, 25% in 1960, and 32% in 1950. (This figure was high due to the Korean War rearmament programme). Until the middle 1960s the main UK export markets were Commonwealth countries, but they have since diversified considerably. Imports, in contrast, have been predominately from West Germany, USA and Switzerland, and in very recent years, Japan. (Table 5.5). In international terms, Britain's share of world trade has declined from about 8% in the early 1960s to 5% in 1979. Over the same period only the USA has fared worse, while Japan has risen from nowhere to become the world's second largest exporter. (Figure 5.3).

Figure 5.2 Shares of world consumption, 1962-1980

Source American Machinist, appropriate years.

Table 5.4 Machine tools: trade data, 1948-1979

	Imports			Exports			Balance	Relative Unit Value
Year	£m.	000 tons	£/ton	£m.	000 tons	£/ton	£m.	
1948	14.1			4.5			9.6	
1953	22.8	44	518	46.9	45	1032	-24.1	0.50
1958	23.3	36	642	17.3	16	1075	6.0	0.60
1960	28.2	39	714	22.3	21	1075	5.9	0.66
1961	34.2	42	816	31.7	28	1120	2.5	0.73
1962	41.2	48	853	31.3	27	1156	9.9	0.74
1963	43.7	51	855	26.3	22	1177	17.4	0.73
1964	43.2	49	879	33.2	25	1306	10.0	0.67
1965	48.8	54	908	33.6	27	1230	15.2	0.74
1966	41.1	43	955	38.3	31	1225	2.8	0.78
1967	43.8	43	1018	53.3	38	1384	-9.5	0.74
1968	56.4	50	1138	45.2	31	1476	11.2	0.77
1970	84.6	67	1257	55.4	33	1649	29.2	0.76
1971	94.1	68	1381	47.0	27	1709	47.1	0.81
1972	80.5	53	1532	48.0	27	1781	32.5	0.86
1973	84.2	52	1629	65.8	33	1975	18.4	0.82
1974	97.9	52	1882	94.3	39	2429	3.6	0.77
1975	155.2	65	2398	109.4	38	2915	45.8	0.82
1976	176.7	68	2605	142.4	40	3551	34.3	0.73
1977	184.9	69	2679	144.4	38	3786	40.5	0.71
1978	222.0	68	3258	212.1	52	4043	9.9	0.81
1979	222.9	69	3216	285.0	60	4712	-62.1	0.68

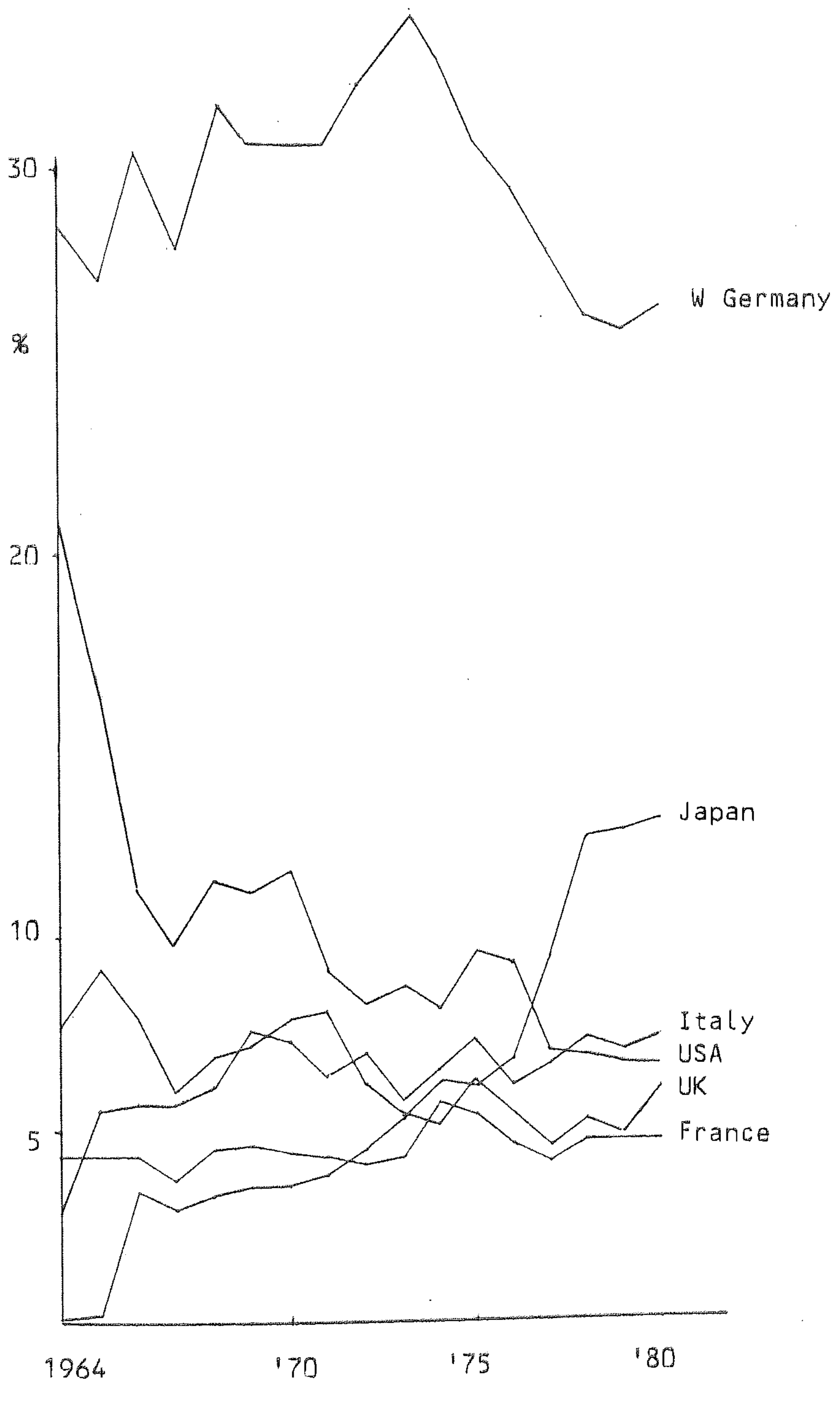
Sources: 1948, MTTA. Machine tool statistics. London, 1980; 1953-1970, Overseas Trade Statistics is analysed in Machinery; 1971- Overseas Trade Statistics of the United Kingdom, appropriate years.

Since the Second World War then, the British machine tool industry has been in decline. Britain's share of world production, consumption and exports have all fallen, and its home market has become increasingly invaded by imports. Employment in the industry has contracted and production in real terms has dropped since its peak in 1970.

Commentators have generally argued that the industry's lacklustre record has been due to a poor innovative performance,[11] insufficient attention to marketing,[12] and incompetent management[13]. Certaintly, R & D expenditure has fallen away dramatically since the late 1960s (Table 5.6), but before that UK firms were quickly involved in NC development, and in the 1960s made the first design of what a decade later became a flexible manufacturing system. However since 1967, when the UK was the world's second largest manufacturer of NC machine tools after the USA, it has been overtaken by Japan, France, Italy and West Germany.[14] Moreover, as noted earlier, imports have been consistently more expensive, and by inference, of greater technical quality than exports, which until the mid 1960s at least, were aimed primarily at Commonwealth markets.

At another level one survey has shown that while technical attitributes, such as accuracy and reliability, were rated as the most important factors in machine tool purchasing decisions taken by British and West German users, many British machine tool makers have based their marketing strategies on price competitiveness.[14] It has also been found that users have preferred foreign machines because of their superior technology, and better performance and delivery dates.[16] Poor salesmanship and sales service, lack of exporting nous, and unappealing styling have also been identified as particular failings of the industry.[17]

Figure 5.3 Shares of world trade, 1964-1980



Source American Machinist, appropriate years.

Table 5.5 Machine tools: pattern of UK trade, selected years

Main export markets (£m.)

1955		1965		1975	
Australia	3.6	India	6.6	USA	17.8
India	2.4	Australia	5.6	S. Africa	13.5
France	1.5	S. Africa	4.6	Poland	11.1
S. Africa	1.5	Spain	3.0	France	8.6
Canada	1.2	Canada	2.9	Spain	8.4

Main sources of imports (£m.)

1955		1965		1975	
USA	6.4	W. Germany	12.5	W. Germany	38.5
W. Germany	5.0	USA	9.1	USA	15.0
Switzerland	2.5	Switzerland	4.0	Switzerland	11.5
France	0.9	Italy	1.9	France	8.3
Belgium	0.4	France	1.9	Italy	7.2

Source: Machinery; Overseas Trade Statistics, appropriate years.

Table 5.6 Machine tool industry: R & D expenditure, 1964–1978

	1964	1966	1967	1968	1969	1972	1975	1978
Current£m.	3.5	5.4	5.4	5.2	4.2	1.6	4.3	8.8
1975 prices£m.	10.0	14.0	13.5	12.3	9.3	2.7	4.3	5.9

Sources: Central Statistical Office. Research and development expenditure. (Official Studies in Statistics, 21) London, HMSO, 1973; Trade and Industry, 27, 638-695, 24 June 1973; Central Statistical Office. Annual Abstract of Statistics. London, HMSO, 1982. Deflators taken from Bowles, J.R. Research and Development: expenditure and employment in the seventies. Economic Trends, 334, 94-111, August 1981. Table 12.

5.3 State Policy, 1945-1964

Initial developments

Following the Second World War the Government's immediate interest in the machine tool industry was in its position as an important exporter and thus earner of foreign currency. With wartime controls still in existence, particularly those over building and steel allocation, the Government possessed considerable if indirect influence over machine tool production and consumption, and was able to divide output between export and domestic markets. This policy, the industry believed, was damaging to manufacturing industry as a whole. An editorial in Machinery complained that:

> it is time that the Government gave greater consideration to this aspect of our affairs (domestic expenditure on machine tools) and ceased to regard machine tools, except in special cirucmstances, primarily as a direct means of earning foreign currency. The state of our economy still demands the all round use of more productive equipment, and from every point of view it is highly desirable that the volume of new machine tools supplied to factories in this country should be substantially and permanently increased[18]

while another protested that:

> unfortunately those in authority still speak with two voices, simultaneously demanding machine tool exports on a substantial scale and greater output and higher efficiency from the engineering factories at home, which are handicapped for lack of modern equipment.[19]

One unexpected outcome of the Government's concentration upon exports was that much of the demand for machine tools to re-equip ordinance factories caused by the Korean War had to be filled by an influx of imports on an unprecedented and never-to-be-repeated scale (See Table 5.4). In 1951 it was estimated that some 35,000 extra tools were required by the defence programme, of which 8,000 had already been specifically ordered from British machine tool manufacturers. The leeway was to be made up by diverting 7-8,000 machine tools from domestic industry orders and placing orders abroad for the remaining 19-20,000 machines.[20] As it turned out, these imported machines were noted to be of high unit value.[21]

Another effect of the Korean War was that subsequent Budgets were deflationary and aimed to cut back already low levels of capital investment still further. Machinery again complained that the Government's approach was "pawning our tools to pay the rent".[22]

At this time the DSIR was funding two organisations that were conducting machine tool research, the Production Engineering Research Association (PERA), and the Mechanical Engineering Research Laboratory (MERL), later the National Engineering Laboratory (NEL). Established in 1946, PERA's main machine tool interests was in their use, but it is worth noting that PERA received about $ 350,000 (£125,000) worth of equipment and publications, including some "outstanding examples of American machine tool design and manufacture" via the Economic Cooperation Administration and the DSIR, which were used for demonstrations of machining techniques and machine performance to machine tool manufacturers and users alike.

By 1950 two out of MERL's seven divisions, Division E (Mechanisms and Engineering Metrology) and Division F (Mechanics of Formation and Machine Shaping of Materials) were directly concerned with machine tool studies.[24] Much of Division E's research was concerned with gears and gear performance, and in 1952 it began work on the application of 'electronic methods' to charting the errors of alignment of a gear cutting machine. This experience led to this Division, rather than Division F, taking on in 1955 the development of Moire fringe techniques as a method for error-checking applicable to NC machine tools.

Diffraction grating research had in fact started at NPL in 1948 but by 1952 the sideline of Moire fringes had come to be regarded as having considerable potential in numerical control.[25] According to one study Ferranti, the electronics company, was instrumental in this realisation. "Close collaboration" was established between the two organisations, with NPL developing the gratings on Ferranti's behalf.[26] Research on machine tool control continued at NPL until 1959 when it decided to withdraw because the research groups at NEL and the Manchester College of Technology were then well established in the area.

Other NEL research from the early 1950s, on air bearings, led to the design ten years later of BSA-Churchill's range of air-lubricated grinding machines which sold heavily, and won for their manufacturer Queen's Awards for both Technological Innovation and Export Achievement.[27]

In 1956 the framework of technology policy toward the machine tool industry expanded when, in January, the NRDC placed its first machine tool development contract. This was with Dr., later Professor, Koenigsberger at the Manchester College of Technology. The project was an investigation of the performance of the mechanical elements of a machine tool operating under electronic control. Later the Corporation was to state that the investigation "appeared to be needed but the organisation of the machine tool industry was such that it could not readily mount such a project. However, the matter appeared urgent because of the promise of increased productivity from the successful application of the new control methods and the threat of competition from overseas."[28] The NRDC did not expect to recover its complete outlay on the project, but believed that the work was "clearly in the public interest".[29] At the end of 1958 the NRDC withdrew its support, but the project continued under a research grant from the DSIR of £ 33,100 over two years from August 1959. This was the DSIR's first direct involvement in machine tool research.

The NRDC's intervention is interesting on two accounts. Firstly, it was a rebuttal of a statement made the previous year by the President of the MTTA, Mr. Potts, in which he claimed that his industry was "a virile one, willing to spend money freely on research".[30] Secondly, the Corporation poached on territory - the sponsorship of academic research - that was the DSIR's normal responsibility. This was one of a number of such incidents that led in 1958 to the setting up of a Joint Committee to oversee the allocation of research contracts of common interest.

The DSIR, Melman, and Mitchell Reports

The DSIR's assumption of responsibility for NC research at what had then become the Manchester College of Science and Technology was the first part of a wider programme of support agreed with the MTTA following a survey of the industry's R & D requirements by the Department's Economics Committee. Its report was never published but a joint statement referring to its contents was released by the DSIR and MTTA,[31] and its recommendations were appended to the later Mitchell Report.[32] From these sources it would appear that the main conclusion of the DSIR report was that the industry "would benefit from being able to recruit much larger numbers of designers and engineers specially trained in the technologies appropriate to the industry ", while commenting that "at the present time, facilities for training such specialists appear to be inadequate in the United Kingdom." To achieve this aim the principal recommendations were that, because of the shortage of specialist teachers in the appropriate subjects the industry should help itself in all appropriate ways; that research schools in machine tool technology should be established with Government help; that the machine tool industry should make greater use of existing government funded research institutions; that the industry should consider establishing a research or design organisation of its own; and that the DSIR should consider what it could do to make more effective use of its resources to help the industry.

Actions to meet these recommmendations were also announced in the DSIR/MTTA Joint Statement. Schools of research and higher training in machine tool technology were to be developed at the Manchester College of Science and Technology (as noted), the University of Birmingham, the Royal Technical College, Salford, and the College of Aeronautics, Cranfield, with research grants totalling more than£100,000 from the DSIR over the next two to three years.[33] These centres were to be further bolstered by research contracts from private machine tool builders. Machine tool research at NEL was to be increased and the DSIR announced that it was considering several propósals for civil development contracts for advanced machine tool designs. On its part, the industry through the

MTTA agreed to provide for ten scholarships per year and specialist lecturers for a two-year advanced course on machine tool design at Manchester, and to inaugurate an annual Machine Tool Design and Research Conference.[34] It also agreed to set up a Machine Tool Industry Research Association with grant-in-aid from the DSIR. (This was in spite of the fact that the industry's overtures to the DSIR during the War regarding the establishment of a research association had received a cold response[35]).

In line with the Department's promise machine tool research expanded at NEL from 1959. In the following year it was estimated that a quarter of the Laboratory's total budget was devoted to machine tool investigations,[36] while some success of their earlier researches was witnessed in the exhibition of two NEL developed machine tools, an error-correcting gear hobbing machine and a vertical boring machine with hydrostatic drive, at the 1960 International Machine Tool Exhibition at Olympia.[37]

The DSIR, however, was not the only critic of the machine tool industry during this period. Early in 1960, Austen Albu, M.P., circulated a damning memorandum advocating that greater support for R & D, prototype production and marketing should come from government.[38] The Observer complained that only the Staveley Company had a "real research department", and that in 1958 the industry took on only two graduates compared to the five hundred taken on by the West German industry.[39]

But the most publicised yet, strangely, unpublished criticisms came from an American, Professor Seymour Melman, in a report made for the European Productivity Agency on the machine tool industries of Western Europe.[40] His thesis, that in order to counteract the threat of cheap, mass-produced machine tools from the Communist bloc countries the industries of Western Europe had to adopt the same mass production methods, was however rejected all round. Metalworking Production thought that Melman "went too far in his interpretation",[41] and argued that the market in the United Kingdom was not big enough to warrant the mass production of machine tools by domestic manufacturers. Instead the industry's problems lay in

> convincing potential customers to dip their hands more deeply into their profits before distributing their earnings in other directions, and really get down to the job of continually - not spasmodically - equipping their plants for greater efficiency and higher output of goods which can be sold at lower prices.
>
> Surely there is no good sense in manufacturers, in general, complaining that machine tool makers do not devote enough effort or money to research and development work or for expansion or improvement of their productive capacity if, when the makers do go to town in that way and 'produce the goods' in the form of more productive, and possibly more expensive, equipment the potential user complacently gives them the cold shoulder - content once again to get by with out-of-date plant.[42] (original emphasis).

The real importance of the Melman Report, however, lies in that it led directly to the setting up a sub-committee, chaired by Sir Stuart Mitchell, of the Board of Trade's Machine Tool Advisory Council "to consider the report by Professor Melman ... and to report ... what action could usefully be taken by the United Kingdom machine tool industry on his recommendations".[43] It too rejected Melman's proposition, but in doing so used the opportunity to carry out a wider ranging study of the industry. In contrast to Melman the Mitchell Committee argued that the industry

> suffers from over-concentration on the production of standard machine tools and that this accounts for its shrinking share of increased world trade and for the high proportion of machines imported into this country.

Basically this over-concentration on standard types springs in our view from the lack of a sufficiently intense development effort.[44]

This lack of effort the Committee found evident from the low number of qualified engineers and drawing office staff employed in the industry. It stated that "in 1958, 90 machine tool firms employing 30,000 people had a total of only 25 graduate engineers",[45] while the percentage of draughtsmen was less than half of that existing in West Germany or Switzerland. In addition, the Committee also argued that the £3m per annum it understood to be spent on R & D was "insufficient for an industry of its size and national importance".[46] Having decided that the machine tool industry's problems stemmed from a lack of research effort, it urged the industry to greatly increase its R & D expenditure to the equivalent of 10% of turnover by the end of 1964, and to take on an additional 250-300 qualified scientists and engineers. It also endorsed the proposals contained in the DSIR/MTTA Joint Statement, with the additional comments that the research association should be linked, if possible, to a teaching centre, and that the DSIR should place some R & D contracts with firms outside the machine tool industry but in relevant adjacent fields, such as electronics, control engineering, automatic gauging, and new metal removal techniques. On the other hand the Committee held that machine tool firms should stay out of electronics manufacture, but rather keep close contacts with electronics firms and, to that end, recruit suitably qualified electronics engineers. Moreover, it urged the industry to rationalise itself and suggested that MTTA should undertake surveys of the age of the national machine tool stock, and of likely future demand patterns.

Despite offering what is on the whole a reasoned and reasonable analysis of the industry's internal problems, the Mitchell Report failed to address the question raised earlier by one of the industry's defenders, of whether or not low and conservative investment among customers restricted upon innovative effort. If it was, then many of the Reports recommendations would have been in vain. The Report is also probably inaccurate in its estimates of R & D expenditure and employment, although that does not necessarily fault its analysis. Indeed, its quoted rate of R & D spending of £3m per annum is quite possibly double what it actually was,[47] while its estimate of 120 qualified scientists and engineers engaged in R & D is probably on the low side.[48]

But perhaps the greatest criticism that can be made of the Report is that, beyond its welcome for the DSIR's initiatives, it makes few concrete suggestions as to how its recommended targets for increases in research personnel and R & D spending could be attained. As such the Report remains exhortative rather than a platform for action.

Reaction to the Report from the machine tool industry itself was generally favourable. Metalworking Production called it "a penetrating and objective study", while Mr. E.W. Field, President of the MTTA, thought it "a very fair appraisal of the industry's circumstances", and Mr. J. Gabriel, Chairman of Charles Churchill & Co. Ltd., said that the Report "comes as a breath of fresh air and sanity, and generally speaking, I would endorse everything that it contains."[51] Moreover, its rhetoric may have encouraged the machine tool industry to view research more positively as during the early 1960s "many more companies established R & D departments and many of those with only a nominal interest expanded considerably."[52]

Even before the Mitchell Sub-Committee began its enquiry the DSIR was committed to bolstering the national machine tool R & D effort and, as noted, agreed to expand relevant work at NEL and establish four academic entres of research. The Machine Tool Industry Research Association (MTIRA) was quickly established by the industry and the DSIR provided grant-in-aid of £50,200 in 1961, and a total of nearly £260,000 over its first four years of existence. Presumably because of the Department's support for four academic centres, and because it would not have fitted the usual Research Association model, MTIRA did not become the teaching centre suggested by the Mitchell Report.

Placing civil R & D contracts proved much more difficult, and even though the Department set aside a fairly large sum for this purpose, it only entered into two machine tool contracts. The first, announced in December 1961, was awarded to Craven Bros. (Manchester) Ltd. for the development of a gear grinding machine which would "incorporate entirely novel mechanised principles and embody some of the latest techniques developed at NEL".[53] Worth about £200,000 the contract was due to last three or four years, but because of problems in its basic design concept it was terminated in 1963.[54] The second contract, worth £ 330,000, was placed with Staveley Industries in 1962 for the development of a large tape-controlled multi-purpose machine tool. This project was technically successful and the prototype was unveiled at the International Machine Tool Exhibition at Olympia in July 1964.[55] Technical supervision for both contracts was exercised on behalf of DSIR by NEL.

In an effort to increase its contractual support of industrial R & D the Department also released broad specifications for two types of machine tool, an electro-chemical machining unit and a turning machine, for which it was willing to place development contracts. Five proposals were recieved for the former and two for the latter. At the same time the Department also received applications for support for the development of an advanced gear grinding machine and a complete gear manufacturing machine tool system. After some consideration both applications were recommended to the NRDC for support.[56]

But despite the DSIR's interventions and the industry's own initiatives in the wake of the Mitchell Report criticisms of the machine tool industry continued unabated. Use of NEL's services by machine tool manufacturers, reported to be "reluctant", was a source of complaint by the Laboratory.[57] The Chairman of the Electronic Engineering Association thought that machine tool builders did not help their customers in choosing control systems,[58] while at a joint conference of the Institute of Mechanical Engineers and the National Council for Quality and Reliability the industry was strongly criticized for its record of poor designs and unreliable machines.[59] Machine tools were also cited by the Amalgamated Engineering Union as an example where "the innovations of design have mostly come from other countries."[60]

Meanwhile the publication of the first machine tool census, carried out at the behest of the Mitchell Committee not by the MTTA but by the industry's trade journal Metalworking Production (Table 5.3), provided machine tool manufacturers with some apparent ammunition with which to defend themselves. Although the findings that 59% of the British machine tool stock was more than ten years old, and 22% more than twenty years of age, no longer looks so startling, it provoked the submission of a memorandum to the Chancellor of the Exchequer, Mr. Selwyn Lloyd, by the National Association of British Manufacturers calling for measures to induce the re-equipment of industry through accelerating the rate at which existing machinery could be written off.[61] Its appeal was joined by a TUC statement to the same effect.[62] No immediate changes were made but in the November Budget of 1962 investment and writing down allowances were both increased.

In the meantime the opposition Labour Party had, as part of its general formulation of an alternative policy for science and technology, considered the position of the machine tool industry. At the 1955 General Election it had proposed the nationalisation of sections of the industry,[63] but early in 1961 its new policy, propounded by Harold Wilson, was that rather "than a sweeping programme of expropriation and nationalisation for the industry, there is a strong case for state-owned machine tool plants, specialising particularly in the types of machine tool where the existing industry is deficient."[64] Such factories would act as a spur to the rest of the industry as well as supplementing machine tool production. Two years later, as the next General Election approached, the industry entered the political fray and complained, in its own policy document, that "unfortunately some of those who might invested in the UK machine tool industry have been deterred by rumours and suggestions of nationalisation. This negative attitude has done nothing but harm to the industry."[65]

5.4 State Policy, 1964-70

Initial developments

The Labour Party thus come to power in October 1964 with some notion of state-owned machine tool plants hanging in the air. A rumour that parts of Short Bros., the troubled 60% state-owned Belfast aircraft builders were to be converted to this purpose was soon circulating,[66] but questions in Parliament on possible public ownership in the industry received only non-commital answers.[67] Instead, the government's first actions of substance toward the industry were Mintech's takeover of its sponsorship from the Board of Trade, and the formation of the Machine Tools Economic Development Committee at NEDO under the chairmanship of Sir Stuart Mitchell, late of the Mitchell Report. Mintech's eventual announcement of its policy for the industry in June 1965 awaited and adopted various measures put forward in an action plan drawn up by the EDC.[68] Despite Frank Cousin's expressed intention to "pick up the machine tool industry and shake it",[69] his announcement contained no reference to any form of state ownership, and was probably much less radical than many expected.[70]

The principal aim of Mintech's policy was to raise machine tool R & D spending by increases in the number of civil R & D contracts, expanding the various contributions of the NRDC and academic funding bodies - the UGC was urged to make funds available for a new machine tool technology university department - and building up NEL's work still further with a major effort on the application of numerical control. Furthermore, Mintech announced an important new initiative, the Pre-Production Order Scheme (PPOS), to encourage "promising ideas which, because of lack of finance or firm orders, companies have felt unable to exploit". Under PPOS, to which £ lm. was initially allocated, advanced machine tool prototypes, especially NC machines, were bought by the Ministry and loaned for a period of one to two years to a user who, in exchange for free usage, provided detailed technical and economic reports on the machine. The user was under no obligation to buy the machine tool but had the option to do so at a second hand price if it turned out to suit his needs. On the basis of reports received from the user the machine tool was then made ready for production. The Ministry, which bore the difference between new and second price, also made an allowance for development costs in its initial purchasing price. The award of PPOS and development contracts, Cousins promised, would also take into account the need to encourage concentration in the industry, although it was hoped that the industry itself would take the lead in any rationalisation.

Other Mintech actions were to include the setting up of an expert machine tool unit to coordinate machine tool research and provide technical advice to govenment and other public users of machine tools, and a working party to study the cyclical nature of investment on machine tools. A review of the government's own machine tool holdings was also promised with the idea that older machines would be replaced, and lastly, Mintech was to examine the EDC's recommendation that it should encourage the use of advanced machine tools through stipulating their use in appropriate cases.

No mention was made at this time of the EDC's other proposals for preferential tax relief on current machine tool R & D expenditure; a change in the fiscal incentives for plant investment; information sources to guide machine tool purchasers; or for the need for a national exhibition centre in or around London. However, all except the first of these recommendations were subject to later developments. A National Exhibition Centre was eventually built on the outskirts of Birmingham and, in 1966, following various investigations, tax allowances on investments were replaced by grants. Advisory services of various sorts became an important strand of Mintech's machine tool policy and will be discussed in due course.

By the following April, the Ministry had placed half a dozen development contracts[71] and a NC division had been created at NEL.[72] The NRDC too had entered into a joint venture with BSA Tools Ltd. for the development of an NC lathe. This project, which was one of the two passed on to the Corporation by the DSIR, was continued by Alfred Herbert on its takeover of BSA in 1966. The first sale of the Batchmatic 50, as it was then called, took place in 1970 and by 1982 over 300 machines had been sold.[73]

Progress was thus "lamentably slow" in the light of the expectations raised by Cousin's announcement[74] but activity increased from the end of April 1966 when the first of the long awaited pre-production orders were announced, two with Ferranti, one with Churchill-Redman Ltd., for another NC lathe, and one with Molins Machine Co. Ltd. for a revolutionary NC machine tool system, the Molins System 24 which, although ultimately a commercial failure, was the forerunner of the FMS concept.[75] At the same time the NC Trial Period Scheme administered by the NRDC on the behalf of Mintech with an allocation of £lm., was opened with the purpose of enabling inexperienced customers to try out an NC machine tool in production for a trial period of upto two years. For a small premium paid to the NRDC, a user would purchase a machine from a supplier registered with the Corporation, but retain the right to return the machine anytime between 6 and 24 months after installation for a guaranteed high repurchase price.[76]

News of this scheme was welcomed by the MTTA "as an indication of the Minister's appreciation of the importance of promoting the development of numerical control",[77] while Metalworking Production believed that its announcement, together with the start of PPOS, "may well be recorded as a turning point in British industry's acceptance of NC; it will certainly be noted as a rapproachement between the Ministry and the MTTA".[78] Certainly the intention of the two schemes was to further strengthen NC diffusion in Britain which, gathering speed, was second only to the USA in the number of recorded deliveries. In Frank Cousin's words, Mintech's position was that "NC is necessary, inevitable, and desirable ... We must become involved in its use on a big scale".[79]

Three months later Mintech underlined its commitment to NC by setting up the Institute of Advanced Machine Tool and Control Technology (IAMTCT) in the grounds of NEL. Intended as a "national centre for study of the design and development of advanced types of machine tools, associated numerical control systems and equipment, computer-aided design technqiues and so on", it was also to serve as a training ground for potential machine tool technologists with a throughput of 50-100 students per year when fully established. Altogether about £500,000 was set aside for the formation of the Institute, the idea for which came from the Mitchell Report.[80] Despite the blaze of publicity that launched the Institute it was thereafter quietly forgotten and in 1970 it merged with NEL.[81]

By the end of 1966, therefore, the Ministry of Technology had introduced a range of measures to aid the generation and diffusion of advanced machine tools, especially those incorporating NC, with some apparent success. The industry had had two good years and R & D expenditure had risen by over 50% in current terms (Table 5.6). Moreover, in line with the Ministry's wishes, the industry had engaged in a series of mergers and takeovers which continued into 1967, then leaving 12 major groups or companies in charge of nearly three quarters of machine tool output.[82] However, from 1967 a number of important changes in direction and structure of Mintech's machine tool policy occured.

Policy development

The first main new initiative was in the area of NC awareness schemes. At the beginning of 1967 the Royal Aircraft Establishment, Farnborough (RAE) and NEL both instituted courses in NC programming while later in the year NEL organised two conferences on NC programming languages, the first of NEL itself and the second at the University of Aston. Mintech also supported the establishment of an NC machine tool demonstration centre by Airmec Ltd., an NC system manufacturer.

Early the next year, Mintech brought the RAE and Airmec-AEI activities - Airmec had since taken over AEI's numerical control interests - with PERA's parallel interests together under a single umbrella scheme, the Numerical Control Advisory and Demonstration Service (NCADS), to offer impartial advice on the adoption and use of NC equipment. All told £750,000 was committed over three years to the work of PERA and RAE, including £ 350,000 for NC machines and associated equipment. A further undisclosed sum was given over to the Ministry's joint venture with Airmec-AEI. Under NCADS the activities of the various bodies were rationalised so that PERA concentrated on offering free or highly subsidised advice on the selection and investment appraisal of NC machine tools, RAE on organising courses and offering specialist advice on NC programming, and Airmec-AEI on providing a full demonstration service of machines fitted with its own control systems.[83] By the end of 1969, the PERA branch of NCADS had recommended the purchase of NC equipment to the value of more than £3½m., of which more than £1m. had been ordered.[84]

NCADS was specifically aimed at providing and disseminating information about NC. Other sources of more general machine tool advice included, MTIRA and PERA, especially through its Production Engineering Advisory Service.[85] In 1969 two other relevant specialist information services were set up with pump-priming grants from Mintech: the Industrial Centre for Design and Manufacturing Engineering, located at Salford University, received £96,000[86] while the Group Technology Centre was established at Aldermaston with Ministry funds of £300,000 over three years.[87]

NCADS came at a time when the NRDC Trial Period Scheme was experiencing difficulties in getting off the ground. Delays in putting the scheme into operation due to legal and contract-drafting problems meant that the first two machines were not placed until August 1967, fifteen months after the schemes inception.[88] More importantly, however, the Corporation was having problems in getting suppliers to join the scheme and users to make use of it. Of 39 manufacturers invited to take part only 15 agreed, including the subsidiaries of two American companies, some of whom later withdrew.[89] User participation was poor for a number of reasons. Some companies were hesitant because of their lack of knowledge about NC, while others were unable to raise the necessary cash to make the initial purchase. The sterling crisis and the devaluation of the £ in 1967 led to the raising of the bank rate and a tightening of credit regulations, while investment grants were being paid upto 18 months late. Another reason was that many NC machine tool manufacturers, including some that had joined the scheme decided, in the face of credit restrictions, to start their own facilities for the cheap credit purchase of their machines.[90] The scheme continued to disappoint and was eventually terminated in 1970 after 11 machines had been purchased.[91] The Corporation's final outlay on the scheme amounted to just £28,500 of the £1m. originally allocated.[92]

To get round the problems posed by the late payment of investment grants the NRDC devised a method by which banks would provide an equivalent sum, minus an appropriate interest prepayment, to customers when they placed machine tool orders. The scheme however was rejected by the Treasury "on the extraordinary grounds that it would favour machine tool buyers over other applicants", although the Economist thought it was more likely to be due to the precarious state of the Government's finances. The idea was reconsidered but never taken up.[93]

1967 was proving to be a hard year for machine tool makers as orders fell dramatically. In order to maintain production levels Mintech hurriedly introduced a stockbuilding scheme which had been one of two specifically rejected the previous year by the Ministrys own working party on the industry's cyclical problems. Very briefly, the working party found that the cyclical pattern of orders for machine tools was no worse than that experienced in other industries and countries, and argued that stockbuilding schemes proposed by the MTTA and Staveley Industries, a major machine tool manufacturer, were not justified. Rather, it recommended that the industry cope with the cycle by concentrating into stronger, more modern units; by diversification and increased exports; by introducing its own leasing schemes and by lessening its reliance on skilled labour through the greater use of NC. It also suggested that customer industries should plan their machine tool purchases better, and that the Government itself should set an example in this respect.[94]

Despite this advice Mintech decided to adopt the Staveley scheme whereby, for a premium of 1% of total value, it undertook to underwrite 50% of any losses incurred when machines built for stock under the scheme were eventually sold, or not, as the case might be. A ceiling of £5m. total stock value was placed on the scheme, applications had to be made by the end of March 1968, and stockpiling finished by the end of 1968.[95] In the event, only one company, strangely enough Staveley Industries, joined the scheme, and no final Mintech expenditure was incurred.[96]

Meanwhile, a £5m. second phase to the Pre-Production Order Scheme had been introduced in April 1967. About a half of the original £1m. had been spent on six orders involving 40 machines or systems. As this second phase was intended "not merely to speed the introduction of efficient modern machines, but also help the machine tool industry at this time, when orders are needed", conditions were eased so that new machine tool models would be considered even if they did not incorporate any novel features.[97] Two years later in 1969 a further commitment of £2m. marked the return of the PPOS to its initial innovation-based format.[98]

Table 5.7 MTIRA and central government expenditures, 1965-1970.

(£000)

	MTIRA		Central[1] Government R & D
	Total income	Mintech grant	
1965-66	175	71	..
1966-67	180	68	121
1967-68	217	70	685
1968-69	216	83	..
1969-70	239	83	..
Total	1027	364	

Sources: MTIRA. Annual reports, appropriate years; Central Statistical Office. Research and development expenditure, op.cit.

Notes

1. R & D funded by central government performed within the machine tool industry. SRC support for machine tool research was put at £139,000 for 1968, while in the same year NEL machine tool research expenditure was £673,000.[99]

In addition to the activities described so far, centres of machine tool research included MTIRA, PERA and NEL, while the SRC supported research conducted at universities and polytechnics. Moreover, Mintech provided further funds for industry-based research by way of civil development contracts. The amount of R & D financed by central government performed within the machine tool industry, together with details of MTIRA and PERA expenditures, are given in Table 5.7.

The Industrial Reorganisation Corporation

The last major set of state initiatives during this period concern the IRC's interventions to rationalise the NC supply industry, its support for the expansion of higher technology machine tool companies, and a loan to BLMC to finance its machine tool purchases.

Although sales of British-made NC machine tools continued to grow strongly in the late sixties, rising from 323 in 1966 to 558 in 1968, representing 2.8% and 7.8% of the total value of machine tool deliveries repectively, concern was rising over the supply of NC equipment itself. From an early strength in this field British manufacturers were no longer offering the range of systems required, especially the more advanced types. Of the NC machine tools ordered under PPOS by October 1968 only about half incorporated control systems of UK design and manufacture,[100] while in 1969 it was estimated that the American company, International General Electric, had 80% of the NC lathe control system market,[101] and that NC system R & D in the USA was ten times what it was in the UK.[102] Moreover, Plessey one of the main UK system suppliers was manufacturing designs under license from another American company, Bunker-Ramo.[103]

Mintech's belief was that a strong UK presence could only be achieved by the merging of the competing interests of the principal British suppliers.[104] Already Airmec had recently taken over AEI's NC department but its systems were at the cheaper and less-sophisticated end of the market. Mintech's concern was indicated to the IRC,[105] and in 1969 the Corporation entered into discussions with the three major UK NC system makers Airmec-AEI, Ferranti, and Plessey. After "prolonged" negotiations Plessey acquired Airmec-AEI in October 1969 for £2.2m, and two months later the Corporation engineered "a strong UK presence" in numerical control when Plessey bought out Ferranti's NC interests for some £ 2.5m. To enable the new company, Plessey Numerical Controls, to accelerate its development plans the IRC subsequently provided a dowry of a £3m. loan.[106]

Following its NC activities, the Corporation went on to provide funds for the expansion of three leading high technology machine tool companies. In March 1970 it made a loan of £750,000 to Marwin "to enable the company to continue its expansion of the production of numerically controlled machine tools."[107] A further £750,000 was made available, and this was taken up in January 1971. £1 million was supplied to Herbert-Ingersoll in May 1970, £525,000 as equity and £475,000 as a loan, to finance the expansion of the company's Daventry factory.[108] Herbert-Ingersoll was a new joint venture between Alfred Herbert and the US Ingersoll Corp. for the manufacture of advanced transfer machinery intended for the car industry. Another £1.5m. was allocated for the firm's future needs but this was not taken up, possibly because by the time Herbert-Ingersoll needed it the IRC had been abolished and its commitments passed to the less interventionist Department of

Trade and Industry. The IRC's third machine tool investment, a £300,000 shareholding taken in December 1970, in Kearney & Trecker, was this time tied to a similar investment by the Midland Bank Finance Corporation. Again the Corporation's objective was to enable the company, another leading NC machine tool manufacturer, to expand capacity.[109] Unlike its previous two interventions, this investment was made after a Conservative Government was returned at the June 1970 General Election, but like the one in Herbert-Ingersoll at the pre-election request of the former Minister of Technology.

The IRC's last remaining involvement with machine tools marked a major departure from previous practice, either by the Corporation or by any other state agency or government department. It took the form of a £10m. revolving loan in June 1970 to British Leyland Motor Co. (BLMC) specifically for the purchase of machine tools. Although an obvious aid to the car company's own investment plans, the main intention was that BLMC would inform the Corporation of its machine tool requirements which, once vetted, the IRC could dangle as a carrot before "particular" machine tool companies in discussions concerning "expansion schemes, the development of new metalforming techniques and the manufacture of machine tool ranges not current produced in the UK, but where the domestic market affords a sufficient base from which to promote export sales."[110] As a second carrot there was also the possibility that the IRC would fund any necessary expansions or development plans of cooperative machine tool firms.

The rationale of the loan to BLMC was, as the then Minister of Technology was to explain later, "to break the vicious circle that if you haven't produced it nobody will buy it and if you haven't got a customer nobody will produce it".[111] However, neither the MTTA nor Lord Stokes, the Chairman of BLMC, liked the idea of the IRC controlling BLMC's machine tool purchasing policy,[112] and with the return of a Conservative Government in the same month as the loan was made, and the abolition of the IRC in the next year, it is very probably that the Corporation exercised little influence over final purchases.

5.5 State policy, 1970-1979

The Way Report

A year or so before the Labour Government lost the 1970 General Election, Mintech had appointed a committee to review the position of the machine tool industry and its existing R & D arrangements, and to "advise on the adequacy or otherwise for these purposes of the present arrangements for Government/Industry interaction and of the finances available for the machine tool industry from its own resources or other existing sources of finance."[113] While this committee, the Way Committee, noted that "the present (Conservative) Government have .... made clear their intention to create a suitable climate for industry to operate in, rather than interfere directly in the affairs of industry",[114] it nonetheless believed that the machine tool industry was "so important to the health of industry generally that continued attention by the Government will be simply repaid."[115]

The Committee's Report centred its arguments and recommendations on four main points, the needs to strengthen and expand the industry, increase domestic demand, simplify the lines of communication between the

Government and industry, and rationalise and improve the form of public support for research and development.

As a target, the Report argued that the industry should aim for deliveries of £300m. (at 1969 prices) by 1975, an increase in production of 80%, which would require substantial increases in both home demand and exports. Such a large rise in capacity would necessitate a major programme of investment of some £60m. to modernise and expand production facilities, and a greater recruitment of technologists and technicians. To achieve this objective the Committee recommended that the Government should encourage the further rationalisation of the industry and make capital available for its expansion. It also urged that the Government should support collective market research, and include a special responsibility for machine tool trade in the commercial departments of various embassies.

A major hindrance to the prospects of the machine tool industry, however, was the low level of domestic demand. International comparisons suggested that capital investment in British industry was "seriously inadequate" and that the "allocation of a larger slice of the national cake to capital investment (was) essential if industry was to prosper."[116] The Report suggested that the Government should continue schemes for the application of NC machines and, to increase machine tool demand generally, that investment grants should be replaced by a system of free depreciation and investment reserve certificates. It also argued that the Government itself should take steps to make sure that its own direct and indirect consumption of machine tools optimally helped the industry. It therefore recommended that the Government should centralise machine tool purchases of educational institutions, for which funds and advice should also be made available for the greater use of NC equipment, ensure that its establishments bought British rather than foreign machines, and encourage its contractors to use advanced British equipment.

Lines of communication between Government and the industry, the Report argued, were too complex, and it thus recommended that apart from education, all Government involvement should be through the Machine Tool Sponsorship Division of the reponsible Department, and that a Machine Tool Advisory Committee be created to replace all existing committees, including the Machine Tools EDC.

Lastly, the Committee found that although research and development were in a better position that at the time of the Mitchell Report ten years before, state-funded R & D was too institution-based. While it attached some blame for this to the industry for not making requests for available funds, it nonetheless recommended that priorities for Government-funded R & D should be decided with the greater involvement of the machine tool and user industries, and that such funds should be committed to applied R & D projects only if there was a realistic industrial contribution. As such it advocated that the Pre-Production Order Scheme be continued. Within the state sector it also argued that R & D was spread too thinly between competing institutions, especially in higher education, and needed to be concentrated into fewer centres of excellence.

The Way Committee's Report reiterated many of the arguments rehearsed in the various reports of previous committees and working parties, but rather than concentrating just on R & D or cyclical demand it produced the most complete analysis to date. But because it saw the expansion of the industry dependent on a variety of state action centred on a large scale investment programme, the new Government took little notice of its recommendations other than where they coincided with accepted policy. Thus investment grants were soon replaced by tax allowances in line with the Conservative's election promise. The SRC had already stated its commitment to a policy of selectivity and concentration, while the greater involvement of industry in the setting of research priorities was later to be institutionalised in the Requirements Boards.

One scheme criticised in the Way Report was soon terminated. Response to NCADS had been "disappointing"[117] and it was disbanded at the end of 1970, although the PERA component was to be maintained at least until its future was reviewed in June 1971.[118] However, the popular PPOS was also reassessed[119] and, following the DTI's decision to exact a levy on sales resulting from future projects, fell into virtual disuse.[120] Civil R & D contracts too were run down in the Government's attempt to redraw the boundaries of the state.[121] Overall the Government's attitude toward the industry at this time was that although "very conscious" of the difficulties it faced, it looked to the changes in investment relief to "stimulate an increased demand for machine tools."[122] But far from increased demand, orders for machine tools collapsed both in domestic and export markets and employment fell in the industry by about 16,000 (23%). R & D spending, too, which had begun to fall at the end of the 1960s, came under greater pressure still and fell away even more steeply, so that in 1972 it was less than a third of what it was four years before (Table 5.6).

Prompted more perhaps by the problems of Rolls Royce and the shipbuilding industry, the Government changed the tack of its industrial policies and placed responsibility to the machine tool industry under the DTI's newly created Industrial Development Executive. Its first action, proposed by the Machine Tools EDC but reflecting some of the recommendations of the Way Report, was the Accelerated Orders Scheme by which the Government promised an extra £9-10m. in March 1972 for its own purchases in the following few months.[123] This was increased to £16m. in July,[124] and by January 1973 the total sum had been allocated as orders.[125] Under the scheme some orders from ordnance factories, technical colleges etc. were brought forward while others were additional to normal requirements. Although there was no compulsion to order British machines, the Government had "every hope and expectation" that the bulk of the money would go to UK manufacturers,[126] and indeed imported machines turned out to account for less than 1% of eventual purchases.[127]

KTM and Alfred Herbert

While the Accelerated Order Scheme was intended as a counter-cyclical measure to help the industry as a whole the DTI's next move was far more interventionist. During this period orders for NC machine tools had fallen more precipitately than for machine tools in general (Table 5.1), and with excess capacity Kearney & Trecker applied to the DTI for assistance under Section 8 of the Industry Act, 1972 to enable it to take over Marwin and its longer order book. In order to create "a viable machine tool manufacturing unit possessing some of the most advanced numerically controlled technology outside the United States", the DTI agreed a grant of £1.25m. to Kearney & Trecker in December 1972 to pay off Marwin's outstanding loan from the IRC. The merger was concluded in March 1973 and the formal transaction took place in July with the simultaneous repayment of the IRC loan. An additional loan of £200,000 was subsequently soon made to the new company Kearney & Trecker - Marwin (KTM).[128]

The merger however failed to produce a strong new company immediately and an expected small profit in 1973/74 turned into an expected loss of more than £1m. KTM was "regarded by the British Government as something of a 'showpiece' in the British machine tool industry"[129] and the new Labour Government's Department of Industry concluded "that grave doubts about KTM's viability as judged by normal commercial and financial criteria, were outweighed by considerations of national interest arising from the need to preserve the advanced industrial technology involved and to protect the balance of payments."[130] The DoI thus provided £3.5m. fresh capital in June 1974 in exchange for a 50% shareholding[131], and in the next month appointed Vickers Ltd. to take management control with the option of taking a controlling interest by July 1976. A guarantee of up to a further £250,000 was later given to KTM's bankers[132] but that was expected to be the end of public support.[133] However, when Vickers decided to take up its option in 1976 KTM's existing share capital was written down, 86% of the new voting stock was bought by Vickers for £773,000, the remainder by Kearney & Trecker (USA) for £127,000, and the DoI provided an extra £1.9m. capital, £1m. as a loan.[134]

Over two years, therefore, KTM was half-nationalised and then returned to the private sector by a Labour Government which, just over a decade before, had been thinking of nationalising parts of the machine tool industry. £5.4m. was pumped into KTM in what one senior civil servant called "a straightforward rescue of a firm in the national interest."[135] Including the previous commitments by the DTI and the IRC to the pre-merger companies, and allowing for double-counting and the repayment of some loans in 1976,[136] a total of about £6.5m. was committed to KTM between 1970 and 1976 to preserve what was considered an important part of the industry.

Just before Kearney & Trecker first approached the DTI Herbert-Ingersoll Ltd., the other advanced machine tool company supported by the IRC, had gone into receivership. The company failed because "the volume of business available in the United Kingdom (had) been consistently disappointing." Needing a turnover of £6m. per year to make a profit, orders in 1970/71 were worth £2m. of which £1.9m. were for export.[137] Assistance for Herbert-Ingersoll was ruled out by the DTI[138] not, as suggested because of its relatively small workforce,[139] but because the company did not apply for and would have been excluded from selective aid in any case, because it had gone into receivership before the new Industry Act came into force in August 1972.[140] Prior to going into receivership £237,500 of the IRC loan to the company had been repaid, but the remainder had to be written off.[141]

The failure of Herbert-Ingersoll was in some ways indicative of the problems posed by a dwindling home market. In particular, the car industry, the largest single market for machine tools, was entering a period of contraction and fewer machine tool purchases that has continued into the 1980s. However, with its modern factory and advanced product line Herbert-Ingersoll's problems were different to those of its parent Alfred Herbert, when it went to the Labour Government in 1974 for assistance.

Alfred Herbert had grown considerably during the 1960s when it took over several smaller machine tool companies. But profitability was low, and despite efforts to reorganise from 23 into 7 separate operating units,[142] it was left with a wide and overlapping range of standard and mainly outdated products. It built NC machines, for instance the Batchmatic acquired with its takeover of BSA Tools, and manufactured its own NC systems, but the latter were expensive and difficult to use, and because they came from a competitor other machine tool builders would not use them.[143]

Despite an apparently adverse report on the company by a firm of consultants,[144] and a recommendation from the Industrial Development Advisory Board that Alfred Herbert should be allowed to go into receivership, the DoI decided to offer support in the form of an initial guarantee of £2m. under Section 8 of the Industry Act, 1972.[145] This was later raised to £5m., and then in July 1975 changed to long-term finance of upto £ 25m. to "enable the company to reduce its overdraft, and consequently its heavy burden of interest", and to "provide working capital and capital for expenditure on new plant and equipment."[146] About a half of the £25m. was in fact used to extinguish accumulated liabilities.[147] In addition nearly £1.2m. was paid to acquire the company's total equity,[148] and then the whole amount of £26.2m. converted into new equity, leaving Alfred Herbert state-owned and without debts. About this time too pressure was put on British Leyland to buy Alfred Herbert machine tools.[149]

In due course the equity in what was now called Herbert Ltd. was passed to the NEB, whose policy was "to support a rationalised company with fewer but more up-to-date products."[150] Poor profits and the need to invest in new plant and product development meant that the Board had to provide Herbert with loans of £5.69m. during 1976 and 1977,[151] but a loss of £3m. in 1978 required that Herbert's share capital had to be extended by a further £10m.,[152] most of which was used to pay off the company's new overdraft and other bills.[153]

Further NEB aid to Herbert came from the Machine Tool Loan Scheme administered by the Board at the behest of the DoI. Introduced in 1976, loans were offered to machine tool makers to build for stock during their current slump in orders so that capacity and employment could be maintained. £5m. was advanced to Herbert under the scheme and a further £906,000 to 8 much smaller companies.[154] The scheme, however, backfired. When trade eased in 1978/79 Herbert was "saddled with large stocks .... of old-fashioned standard machines" it had to sell at considerable discounts, and interest charges were said to amount to £1.2m.[155] The same problem plagued the other companies of which 5 repaid their loans in full, but 3 went into liquidation with the NEB recovering approximately half of the outstanding debts.[156]

By the end of 1978 then, taking into account a new small loan, and some minor repayments, total direct state assistance to Herbert Ltd. amounted to £46.62m. But despite any misgivings on the part of the NEB, the Labour Government's position was that it had been an "important move ... to rescue Alfred Herbert" because if one took away the company, one took away "a significant proportion of the machine tool industry, thereby weakening the British machine tool industry as a whole."[157]

Apart from Herbert Ltd. the NEB also supported three small specialised machine tool companies. Power Dynamics Ltd., manufacturing tube bending machines, soon went into receivership. Agmaspark Ltd, which had previously designed a series of spark erosion machines with NRDC support, and doubled its sales after the NEB had invested £410,000 in 1976, was eventually sold into receivership in 1981. The NEB also took a 71% interest in Mollart Engineering (deep hole drilling machines) in 1977 for £380,000, but that company too was closed in 1981.[158]

MEMTRB, SRC and NRDC

During the early 1970s the most important change in the technology policy framework was the creation of the Research Requirements Boards, including the Mechanical Engineering and Machine Tool Requirements Board (MEMTRB). MEMTRB's budget, and its allocation to machine tools, is shown in Table 5.8. MEMTRB Reports unfortunately do not reveal the amount spent on projects based in industry, except for 1978/79 when, included under the "other" category, it came to £1,089,000. In that year MEMTRB also began funding of the Automated Small-Batch Production Project under which the Board was intent upon funding flexible manufacturing system research and pilot systems to the tune of £14m. over five years. £520,000 was committed to various research projects at NEL, PERA and MRIEA, and £70,000 to a one-year design study in the modular design of machine tools by Butler Machine Tools, but the centrepiece of the project to date has been a £3m. contract with the 600 Group for the development of a system of robot-serviced machine tools for the manufacture of lathe components.[159] In addition to the amounts shown in Table 5.8, MTIRA received grant-in-aid of £293,000 out of total income of £973,000 between 1970 and 1974.[160]

Table 5.8 MEMTRB expenditures, 1973/74 - 1978/79

	1973/4	1974/5	1975/6	1976/7	1977/8	1978/9
Research establishments	3866	4134	5868	5257	4693	4361
UKAEA	385	564	870	1125	1424	1460
Research associations	-	797	1038	1817	1708	2067
Other	-	-	71	410	848	1532
Total	4231	5495	7849	8609	8673[1]	2063[1]
Machine tools	814	741	657	1124	2153[2]	2063[2]

Sources: DTI/DoI. Research and Development Requirements Boards Reports, appropriate years. Machine tool expenditures from House of Commons Select Committee on Science and Technology. Second report: A case study of a machine tool development at the Cranfield Institute of Technology. London, HMSO, 1977, p.26.

Notes

1. Does not include expenditure on 'related' work of £291,000 in 1977/78 and £1,269,000 in 1978/79.
2. Machining, forming and fabrication programmes.

Notable developments at the SRC in this period included the formation of its Manufacturing Technology Committee in 1972 which thereafter concentrated its resources into four specific programmes concerned with machine tools. Starting in 1974, £0.8m. had been spent on the Coordinated Grinding Programme by 1979, including an industrial contribution of some £250,000,[161] and a further £ 0.5m. committed. Research under this programme was concentrated at the Universities of Birmingham and Bristol.[162] EDM research was especially supported under a second programme on dies and moulds to which £1.2m. was budgeted by 1981 after starting in 1976.[163] A third programme on the efficiency of batch manufacture began in 1977. In 1978 a fourth programme on the application of NC began and by the following session grants of £ 250,000 had been announced,[164] reaching £690,000 in 1981.[165] Previous SRC support for NC had not been very great - expenditure in 1977/78 amounted to just £6,000[166] - while this new programme was to be coordinated with and part funded under MEMTRB's ASP project.[167]

During the early 1970s the NRDC made efforts to publicise and promote its services to the machine tool industry. A number of features, for instance, appeared in the trade press advertising the Corporation's willingness to support suitable projects.[168] As a result its investments in this field increased dramatically in number. Apart from the Trial Period Scheme administered on behalf of Mintech the NRDC had, prior to 1970, supported only three machine tool ventures but by the end of the 1978/79 financial year it had entered into a further seventeen.[169] Four involved universities or polytechnics while the rest were with mainly small specialist companies. Examples include the joint ventures FormFlo Ltd and Sperik Machine Tool Co. Ltd., established in 1971 and 1973 to develop and manufacture specialised rolling machines and ball processing machines respectively. In 1972 the Corporation also began to finance the development of a range of spark erosion machines with a company, Agemaspark, which later received NEB support. Possibly the most important project concluded in this period, and the only one with a major established manufacturer, was with Alfred Herbert Ltd. Following the introduction of the Batchmatic 50 in 1970 which had received earlier Corporation funding, a new agreement was signed to cover the development of two new NC turning machines, the Batchmatic 250 and 350. No information is available concerning individual project costs although it was stated that machine tool investments amounted to £375,000 in 1971/72, equivalent to about 8% of the Corporation's total development expenditure in that year.[170]

Machine Tool Industry Scheme (MTIS) and other initiatives

Apart from the rescues of KTM and Alfred Herbert, the main initiative toward the machine tool industry undertaken by the DoI, prompted by the Machine Tools EDC, was the establishment of the Machine Tool Industry Scheme, again under Section 8 of the Industry Act, 1972. Announced in August 1975 with an allocation of £20m. and a closing date of December 31 1976, MTIS offered support for capital investment, new buildings, rationalisation and product development additional to existing plans and on a selective basis. Interest relief grants were initially provided toward product development but were replaced by straight 25% grants in July 1976.[171]

After a slow start the scheme "eventually attracted a stronger response than had been expected,"[172] and it was extended to the end of 1977 with an extra allocation of £10m. 438 applications were finally received,[173] and by April 1980 312 offers had been made for assistance totalling £34.4m. toward projects costing £168.2m., and payments came to £15.8m.[174] Because of the more difficult trading conditions existing after 1980 it was later estimated that no more than £8m. of the £13.25m. offered toward product development would actually be taken up. Nevertheless, 38 exhibitors at the MACH 80 machine tool exhibition showed products developed under MTIS support.[175]

During the post-1974 period machine tool makers were also eligible for state support under more general investment and development schemes introduced during this time. No details of support offered under APS and MAP[176] are available but two machine tool projects were assisted under SIS,[177] while by May 1981 £453,000 was allocated to 26 development projects in 20 machine tool companies under PPDS of which £338,000 had been paid. In addition, pre-production orders to the value of £2,239,000 had been placed with 7 companies of which £1,573,000 had been paid.[178]

5.6 Discussion

The volume of state support to the machine tool industry over the period under review is given in Table 5.9. Although the Table is incomplete in that the machine tool budgets of important agencies such as NEL, NRDC and SRC are not included through lack of full data (but see the notes to the Table), it shows that a minimum of £115m was committed to assisting the industry, almost all in the years 1964-1979. To put that figure into some kind of context, it is equivalent to about 20% of the industry's 1980 turnover, or the whole of its 1963 turnover in current terms (Table 5.1).

It should be noted, however, that all figures given are for gross expenditure and thus do not allow for the repayment of loans, especially to the IRC, NEB and NEDC. The total also includes the £16m. paid under the Accelerated Order Scheme for additional and accelerated state machine tool purchases. Apart from this scheme major expenditures or investments were made by the IRC, NEB and under the Industry Act, 1972 for the rescues of KTM and Alfred Herbert, and for the Machine Tool Industry Scheme. The main beneficiary of state support was Alfred Herbert, whose abortive rescue in the 1970s took up nearly £47m., including £5m. committed under the NEB's Machine Tool Loan Scheme.

Table 5.10 indicates the function of particular measures and instruments. Neither the stockpiling schemes of Mintech and the NEB nor the Accelerated Order Scheme are included as their purpose was to maintain capacity in the industry. The Table shows that although the variety of state support expanded after the 1950s most instruments and measures still incorporated provisions for supporting research and development. The activities of the NEB and those carried out under the Industry Act, 1972 are shown as extending across the range of activities from R & D to marketing because of their general support for KTM, Alfred Herbert and some smaller companies. The IRC on the other hand is restricted to three categories; R & D because its assistance to Plessey Numerical Controls was for the company's development plans; manufacture because its investments in Marwin, Kearney & Trecker, and Herbert-Ingersoll were to expand capacity; and diffusion because its loan to BLMC was specifically for the purchase of machine tools.

Table 5.9 Summary of state support, 1945-1979 (£000s)

		Value	
1945-1964	MTIRA block grant	260	
	NRDC[1]	?	
	DSIR (R & D contracts)	530	(2 contracts, amount committed)
	DSIR (universities)[2]	121+	
	NEL/NPL[3]	?	
1965-1970	MTIRA block grants	442	
	NRDC[1] (devpt. projects)	?	
	NRDC NC Trial Period Scheme	28	
	Mintech R & D contracts[4]	1077+	
	Mintech stockbuilding scheme	0	
	IAMTCT	500	
	NCADS	750	
	PPOS[5]	5520	
	NEL[5]	?	
	IRC	15800	(4 projects)
	SRC[6]	?	

1970-1979	MTIRA block grants	973	
	MEMTRB[7]	7552	
	NRDC[1]	?	
	Accelerated Order Scheme	16000	
	NEL[3]	?	
	Industry Act, 1972	6900	(KTM)
	Industry Act, 1972	26180	(Alfred Herbert)
	NEB, Herbert	15690	
	NEB, Loan Scheme	5906	
	NEB, Other	790	
	MTIS[8]	34400	
	SIS	?	(2 projects)
	PPDS[9]	3192	
	SRC[6]	?	

Notes

1. Total NRDC expenditure 1955-1982 on 24 machine tool projects, including 4 begun after 1979 was£4.8m.
2. This relates to grants noted in text, and ref. 33.
3. NEL expenditures on machine tool research cannot be isolated from other NEL commitments but for 1968 it was put at £673,000. After 1974 included in MEMTRB expenditures.
4. This is equivalent to central government funded R & D performed in the machine tool industry, see Table 5.7.
5. Expenditure under whole scheme until 1974, includes some minor expenditures on other technologies supported such as textile machinery, see Chapter 7.
6. No explicit SRC figures available but for 1968 put at£139,000.
7. Includes MTIRA and NEL expenditures from 1973/74 onwards.
8. This is the sum committed, eventual expenditure possibly much smaller.
9. Sum committed.

Table 5.10 Form of support

	R & D	Prototype	Manufacture	Marketing	Diffusion
1945 - 1964	MTIRA				
	DSIR				
	NRDC				
1964 - 1970	MTIRA				
	NRDC				Trial Period Scheme
	IAMTCT				
	Mintech				
	NEL				
	SRC				
		PPOS			
	IRC		IRC		IRC
					NCADS
1970 - 1979	MTIRA				
	NRDC				
	NEL				
	MEMTRB				
	SRC				
	MTIS		MTIS		
			NEB		
			Industry Act, 1972		
	PPDS	PPDS			
			SIS		

Support for prototype production and trials was otherwise limited to the Pre-Production Order Scheme, the Product and Process Development Scheme, and MEMTRB's funding of pilot FMS installations under the APS Project. Other support for capital investment in the machine tool industry is known to have been provided under the general Selective Investment Scheme and the Machine Tool Industry Scheme. While any provision for capital investment is likely to affect the demand for machine tools in general, specific measures to encourage diffusion were restricted to the 1960s. Two of the three such measures, the NRDC's NC Trial Period Scheme and NCADS were moreover oriented toward NC machine tools in particular.

Even though full figures for NEL and SRC machine tool budgets are not available, the notes to Table 10 strongly suggest that their total expenditures on machine tool research have amounted to several million pounds over the years.[176] That being so, it is clear that the bulk of state funds for R & D have been expended in public institutions, particularly MTIRA, NEL and academia. Industry-based R & D has been supported mainly by civil development contracts from DSIR, Mintech, and MEMTRB, by the NRDC, and under MTIS and PPDS. Apart from contacts between MTIRA and industry, which included in the Association's early years the siting of some research projects within firms because of its initial lack of laboratory facilities, technology transfer has otherwise been occasioned by the collaboration enjoyed by the SRC in its various 1970s machine tool programmes. In addition, the involvement of NEL and RAE in the NC Advisory and Demonstration Service can be viewed as attempts to harness the expertise otherwise locked up within state laboratories to the problems faced by industrial users.

A few measures have promoted, or at least allowed for, direct contacts between suppliers and users. PPOS and the prototype ordering provisions of PPDS have involved contact at the prototype stage rather than during development, while the poorly received NRDC NC Trial Period Scheme was essentially to provide customers with extended production trials. The IRC's loan to BLMC was the most interesting initiative here. Although its intent was less to encourage user-supplier contact during development than to ensure an initial market for new machine tools, such contact was likely to have ensued had not the whole purpose of the loan been subverted. Another, but much later, instance of user-supplier contact in its extreme form was MEMTRB's funding of a pilot FMS installation at the 600 Group's machine tool factory at Colchester. Here the intention was to give a potential FMS supplier first hand intense experience of installing and using such a system. The pilot system has only recently been completed and it is not known whether the company has taken any orders for similar systems.

There have been no measures which have tried to encourage product-related services.

Measures which have specifically aided the adoption and diffusion of machine tools are the IRC's BLMC loan, NCADS, and the NRDC's NC Trial Period Scheme. This last scheme was intended to overcome barriers to adoption by allowing users to gain experience of NC with the safety net that, if they were not satisfied with their equipment, or if it was unsuitable for their purpose, they could return it for a guaranteed high repurchase price. However, the initial financial commitment was increased slightly rather than reduced under the scheme, and although the margin of increase is unlikely to have deterred any potential users, the overall commitment might have done.

NCADS, on the other hand, offered a variety of technical and economic advice and demonstration services to potential and existing NC users. While its disbandment coincided with a large fall in orders for NC machine tools, it would be facile to associate the two given that the scheme was found to be disappointing. Nonetheless, the poor response the whole scheme elicited might not have been repeated when the rate of NC diffusion again increased in the second half of the seventies.

More generally the machine tool industry has been the subject of a number of official reports and the focus of wideranging state attention since the late 1950s. Concerted action by the DSIR followed its own internal report and that of the Mitchell Committee, both of which identified a lack of research and development effort as the main reason for the industry's poor performance. As the Department put aside more money for civil R & D contracting than it spent, it is very likely that it wished to place more than the two such contracts with machine tool firms than it actually did. Otherwise most of the DSIR's actions had the objective of increasing the amount of research in state laboratories. A new research association, MTIRA, was established but many machine tool manufacturers did not, at least immediately, become members. Alfred Herbert, for instance, delayed its membership until 1968.[177]

Under Mintech, whose initial policy was based on recommendations from the Machine Tools EDC, the variety and volume of state support, with an emphasis upon NC machines, increased. While PPOS was the only scheme which, according to the MTTA "commanded many real success" only a handful of the 36 machines so supported and exhibited at the 1968 Olympia International Machine Tool Exhibition attracted more than 6 orders. Wolff argues that the low sales were due to "over-ambitious technological specifications and inadequate market assessment."[179] Certainly other 1960s schemes met with less, even if equivocal, success. Neither the NRDC's Trial Period Schem, undertaken at Mintech's request, nor Mintech's own stockpiling scheme, attracted much support. The formation of the stockpiling scheme, it will be remembered, was in the face of advice from one of Mintech's own working parties.

In the wake of the establishment of MTIRA and the building up of research within academia and NEL, IAMTCT appears to have been an unnecessary additional institutional centre of machine tool research. A contemporary critic of its formation is reported to have said "we can't get trained staff now and the position will be even worse when the Institute gets going."[180] These criticisms can be taken to have been vindicated by the Institute's later quiet incorporation within NEL.

Right at the end of the Mintech era the IRC's machine tool activities represented a different and far more interventionist approach to the problems of the industry. Its investments were in order to strengthen the position of specific machine tool manufacturers at the advanced technology end of the industry, and to encourage rationalisation among NC system supplies.

Some form of procurement policy was hinted at in Mintech's initial policy statement and advocated in the later Way Report but apart from the

Accelerated Order Scheme, the IRC's loan to BLMC for machine tool purchases remains the only attempt to pursue such a policy. This is even though the state's annual machine tool purchases, if not considerable, are probably large enough to positively influence the plans of machine tool makers.[181]

One success of Mintech's early reign was a considerable rise in the amount of machine tool R & D performed in the industry, although it began to fall away again by 1970 and catastrophically thereafter. What final effect this rise may have had is hard to disentangle from trade and production data although it is noticeable that the UK's share of machine tool trade rose from 6% in 1967 to 8.1% in 1971. Perhaps the most that can be said is that its full benefits would have been contingent on long term higher rates of research expenditure to further improve innovations arising in this period.

The Way Report of 1970 presented perhaps the most thoughtful and constructive official analysis of the machine tool industry yet to appear. It criticised some previous practice, particularly the proliferation of research centres, the evolution of the overlapping complex system of support, and communication between state and the industry, and recommended that they be rationalised and simplified, not to reduce state support but rather to make it more effective. With the change of government, and unlike the DSIR and Mitchell reports of a decade earlier, its proposals were largely ignored. Possibly as a result, deliveries in 1975 were 50% lower than the target believed attainable by the Report. (Table 5.1).

Policy in the mid-1970s was dominated by the rescues of KTM and Alfred Herbert. A comparison of the two shows that different issues, strategies and outcomes were involved in each case. KTM was a showpiece company with an existing range of advanced machine tools whose problems stemmed from a lack of proper financial controls and a less than competent management. Immediately after its initial rescue the DoI introduced new private sector management in the shape of Vickers Ltd. and KTM has since prospered. Although the DoI's actions drew some criticism from the Public Accounts Committee at the time, there was a successful outcome.

Alfred Herbert's difficulties were different. It was a much bigger and unwieldly company, accounting for about 10% of the industry's output and employment in 1977, with a wide range of mainly outdated products and a large overdraft. Putting Alfred Herbert back on its feet required paying off its debts and investing in the development of a complete new product range. Overall control was placed with the NEB, rather than with private management, presumably partly because no private company would have undertaken the task. Despite attracting nearly £50m. public support over four years Herbert was eventually broken up and its constituent parts sold off. As greater concentration in the machine tool industry has been urged many times, the lessons of Alfred Herbert should not go unremarked. Already large by machine tool company standards at the beginning of the 1960s Alfred Herbert grew still further by a series of takeovers through the rest of the decade. Without any consequent product rationalisation or new investment, except in Herbert-Ingersoll, resources were too thinly spread and the economies of scale that might have emerged were never realised.

CHAPTER 6 THE TEXTILE MACHINERY INDUSTRY

6.1 Introduction

Although the different characteristics of different fibres means that particular textile machinery types are usually only suitable for one fibre or fibre mix, textile production can nonetheless be broken down into three common stages : (i) the manufacture of yarn from fibres; (ii) fabric manufacture from yarns; and, (iii) finishing, during which fabrics are processed (dyed, etc) ready for end use[1]

Yarns are generally manufactured by spinning, that is by drawing and then twisting together cleaned short fibres. Traditionally, as in the case of cotton, opened bales of fibres are initially cleaned by fans and beaters to form a lap, which is further cleaned and processed in a carding engine to align the fibres into ropelike slivers. A drawframe then produces a much finer rope of uniform density, known as a roving, ready for spinning. During spinning a twist is inserted, giving the yarn greater strength, after which it is wound onto cones ready for fabric manufacture. Because of its greasiness wool has to be further washed (or scoured) before carding. Originally manmade fibre filaments were cut into suitable lengths and treated as above.

Weaving and knitting are the two main methods of fabric manufacture. In weaving, previously lubricated (sized) longitudinal yarns (the warp) are run from a beam onto which they have been wound, through a loom where latitudinal yarns (the weft) are interwoven at right angles to form a cloth which is then taken up on a roller. Conventional looms employ a shuttle to carry the weft to and fro through the warp. Knitting on the other hand consists of connecting together loops of yarn. If a single yarn is used, the resulting fabric is said to be weft knitted, while in warp knitting several longitudinal yarns are linked together. Tufting, in which tufts of fibres are inserted into another fabric base, is another form of fabric construction use extensively in carpet and terry cloth production.

Finishing includes cleaning and purifying, drying or printing, and the application of any finishes, such as crease or water resistant chemicals.

Whilst textile manufacture was long regarded a craft the greater pace of technical development since the Second World War[2] has meant that "technology rather than craft has become the guiding force in the textile industry[3]. The overall thrust of innovation has mainly been toward reducing labour requirements through increasing productivity and reducing the number of machine operations,[4] and coping with (as well as promoting) the greater usage of synthetic fibres. In this last regard a new class of texturing or bulking machinery has been developed which, by permanently deforming synthetic fibre filaments to give them some properties associated with spun yarns, bypass the previous need to cut and spin man-made fibres.

The main innovation in spinning as such has been the introduction in Czechoslovakia in 1967 of open-end rotor, or break, spinning. In this system the yarn twist is imparted aeromechanically on the inside of a rotor or drum, thus combining spinning and winding operations as well as having a faster production rate. By 1979 an open-ended spinning system was estimated to use 60% less labour and be 25% faster than a conventional ring spinning one, even though mills using the latest conventional techniques were said to be three times as productive as mills of twenty years earlier.[5]

Similarly in weaving, while greater production rates on looms have been achieved through increases in weaving width and shuttle speed, and by automating the weft replenishment system, greatest progress has been due to the development of a variety of shuttleless looms. The first shuttleless loom, using a small gripper to carry the weft, was introduced by the Swiss firm SulzeR Brothers soon after the War. Since then, other shuttleless looms utilising air or water jets have been developed principally in Czechoslovakia, while rapier looms which use long needles to carry the weft have been developed by the Draper Corporation in the United States. Recent attention has been concentrated on multiphase weaving in which a numbers of synchronised weft carriers operate simultaneously. The relative rates of production of different types of loom are given in Table 6.1.

Considerable increases in knitting production rates have also been achieved, promoted partly because knitting is particularly suitable for use with synthetic fibres. From 450 courses per minute in 1939, warp knitting speeds reached 1400-1500 c.p.m. in 1968, largely as the result of advances made by two West German companies, Mayer and Liba.[6] In circular weft knitting production rates too have been greatly increased by the doubling of rotation speeds and the use of more feeds. Their patterning ability has been ehanced moreover by the use of electronic and computer control systems.

Table 6.1 Maximum working limits of various loom types

	Cloth width (in)	Speed (picks per min)	Weft insertion rate (yds per min)
High speed conventional	74	180	370
Gripper	153	220	935
Double rigid rapier	81	190	428
Water jet	69	350	670
Air jet	79	215	470
Multi-phase, circular	95	320	850
Multi-phase, flat	130	500	1700

Source : Rothwell, R. Innovation in textile machinery (SPRU Occasional Paper Series, 2), Brighton, 1976, pp 56-57.

Other innovations have included the development of novel forms of fabric construction. Stitch binding, originating in Czechoslovakia and East Germany, consists of sewing together webs of fibres or slivers of weft fibres, thus utilising the output of carding machines. Used mainly for the production of upholstery, a further advantages of this system is its high rate of production determined by sewing machine speeds. Another new form of fabric construction, typically used in making clothes and linings, is adhesive bonding in which webs of fibres are literally glued together.

6.2 The UK textile machinery industry

The UK textile machinery industry is made up of firms making a wide ranges of equipment and accessories of the kind just described.[7] An analysis of available data shows that about 21% of the industry's output in 1979 was accounted for by equipment used in pre-spinning processes, 36%

by equipment used in spinning, twisting and subsequent yarn manufacture operations, 31% by fabric production machinery (including 11% in the special area of carpet production), and 12% by finishing equipment.[8] The industry's contraction and decline is evident from Table 6.2. Employment in 1979 at 24,000 was a third of what it was thirty years before, while gross output in real prices had in the six years since 1973. The industry is typically composed of small and medium-sized firms, almost all British owned. An examination of the historical development of the structure shows that contraction has meant a steady decline in the number and size of firms and establishments (Table 6.3). According to official statistics, however, there has been little change in degree of concentration, with the five largest companies (11 establishments) responsible for 60% of gross output in 1978, as against 53% of net output in 1958 (23 establishments).[9]

Although the industry has consistently exported more than 70% of its output (Table 6.4) the UK has slipped from being the world's second largest exporter of textile machinery after West Germany in 1963, with 18-19% of total exports, to being the OECD's fourth equal largest exporter in 1979 after Germany, Switzerland and Japan, with some 8% of total OECD exports. The picture however varies according to type of machinery. In 1978 the UK's share of OECD exports of weaving machinery and knitting machinery were 2% and 12% respectively.[10] Exports, once principally to protected Empire markets, continue to be mainly to developing nations, now increasingly penetrated by European competition.[11] This pattern is reflected by data on relative unit values of exports and imports (Table 6.4), which shows that although the gap had almost disappeared by the end of the 1970s, Britain's trade has been characterised by exporting cheap and importing dearer and by implication, more sophisticated machinery.[12]

Table 6.2 UK textile machinery industry : employment and output, 1948-1980

Year	Employment (000's)	Gross Output (£m)	Gross output (1970£m)
1948	74.4	65.8	
1949	76.0	73.7	
1950	74.6	76.0	
1951	75.2	84.2	
1953	67.6	73.5	
1954	62.0	78.2	129.2
1955	66.0	89.1	
1956	61.1	88.8	
1957	60.6	90.4	
1958	49.1	76.7	
1963	51.4	125.0	117.3
1968	49.2	179.3	144.8
1970	46.8	195.1	144.5
1971	43.6	212.1	137.4
1972	39.9	216.8	147.2
1973	40.4	270.2	160.1
1974	41.5	334.5	152.8
1975	37.1	357.8	132.6
1976	33.5	337.7	111.4
1977	29.9	328.1	90.3
1978	26.8	329.9	86.5
1979	24.1	326.4	85.4
1980	21.0	298.7	78.1

Source: Historical record of the Census of Production, 1907-1970 and Business Monitor (MLH 335) for year thereafter. Deflated gross output constructed Engineering and Allied Industries Wholesale Price Index until 1965, and the Mechanical Engineering Wholesale Price Index for years thereafter.

The Table also shows that while a favourable balance of trade continued, import penetration had increased from about 20% in 1960 to 48% in 1970 and 76% in 1980.

Table 6.3 UK textile machinery industry : structure

		SIZE OF ESTABLISHMENT				
		1-24	25-99	100-499	500-999	> 1000
1948	No of ests.	..	210	97	16	14
	No of firms	..	..	..	..	..
1958	No of ests.	484	115	68	11	8
	No of firms	..	..	..	..	..
1968	No of ests.	396	112	66	15	6
	No of firms	..	106	55	10	4
1978[1]	No of ests.	322	113	38	6	5
	No of firms	316	111	37	6	3

Source Census of Production, appropriate years

Note

1 Size categories for this year are 1-19, 20-99, 100-399, 400-749, 750.

A survey of UK textile machinery buyers revealed that their reasons for foreign equipment were primarily to do with quality and technical attributes rather than cost.[13] However, a wealth of evidence argues that the textile industry has itself hampered the domestic development of innovative machinery. Rothwell has noted that European textile manufacturers have been more willing to experiment with novel machinery than their UK counterparts.[14] Moreover, studies of the diffusion of shuttleless looms,[15] shortened processing arrangement in cotton spinning,[16] sizing equipment,[17] and synthetic fibre processing techniques[18] have, between them, demonstrated that the fragmented and horizontal structure of the UK textile industry and its low degree of shift working have been inimical to the adoption of innovations. Another study has shown that a great deal of superannuated machinery, especially looms, was in use in the Lancashire cotton industry in the 1950s,[19] while recent statistics reveal that the purchase of more advanced textile machinery is at a lower relative level in the UK than in most other EEC countries.[20]

TABLE 6.4 UK Textile machinery industry : trade data 1948-1979

Year	EXPORTS £m	EXPORTS 000 tons	EXPORTS unit value	IMPORTS £m	IMPORTS 000 tons	IMPORTS unit value	Balance £m	Export/ Import relative unit value
1948		111			9			
1953		113			7			
1956	45.0	80	563	7.0	7	1000	38.0	0.56
1957	43.2	70	617	7.4	7	1057	35.8	0.58
1958	39.6	56	707	7.4	7	1057	32.2	0.67
1959	41.1	56	734	7.9	8	988	33.2	0.74
1960	51.8	67	773	11.9	11	1082	39.9	0.71
1961	62.1	77	806	17.8	16	1113	40.3	0.72
1962	62.5	78	801	16.9	16	1056	45.6	0.76
1963	63.9	76	841	20.4	18	1133	43.5	0.74
1964	64.1	79	811	26.3	21	1252	37.8	0.65
1965	67.8	76	969	28.7	22	1305	39.1	0.74
1966	78.7	79	996	30.1	23	1309	48.6	0.76
1967	76.1	69	1103	32.8	25	1312	43.3	0.84
1968	96.3	75	1284	48.4	31	1561	47.9	0.82
1969	106.9	77	1388	51.0	29	1759	55.9	0.79
1970	116.8	76	1537	53.3	28	1904	63.5	0.81
1971	141.6	81	1748	53.8	25	2152	87.8	0.81
1972	146.6	73	2008	57.8	26	2223	88.8	0.90
1973	166.2	86	2078	87.8	34	2582	78.4	0.80
1974	210.2	84	2502	101.6	36	2822	108.6	0.89
1975	239.4	87	2752	91.7	28	3275	147.7	0.84
1976	252.3	70	3604	107.7	24	4488	144.6	0.80
1977	211.3	51	4143	112.1	23	4874	99.2	0.85
1978	220.1	44	5002	134.3	27	4974	85.8	1.01
1979	239.7	47	5100	147.0	28	5250	92.7	0.97

Source Overseas Trade Statistics of the United Kingdom, appropriate years

On the basis of this and similar evidence, Rothwell argues that the UK textile machinery industry's decline since the War has been due to its poor innovative performance, born out of a complacency stemming from a reliance on large, but unsophisticated, Empire and developing country markets and a conservative domestic textile industry.[21] The lack of major innovations orginating in the UK since the last war was implied in the last section. As another indicator of innovative effort R & D data are presented in Table 6.5. After peaking in the late 1960s R & D expenditure in the industry fell by 37% in terms between 1968 and 1975. As for research and technical personnel, Rothwell points out that they accounted for 5.6% of total employment in the industry in 1974 as against 16.4% in West Germany.[22]

Table 6.5 Textile machinery industry : R & D expenditure, 1964-1978

	1964	1966	1967	1968	1969	1972	1975	1978
Current prices (£m)	1.0	1.8	1.9	2.3	2.1	2.4	3.4	5.8
1975 prices (£m)	2.9	4.7	4.8	5.4	4.7	4.1	3.4	3.9

Sources Central Statistical Office. Research and development expenditure (Official Studies in Statistics, 21) London, HMSO, 1973; Trade and Industry, 638-695, 24 June 1977; C.S.O. Annual abstract of Statistics, 1982, London, HMSO, 1982. Deflators taken from Bowles, J.R. Research and development: expenditure and employment in the seventies, Economic Trends, 334, 94-111, August 1981, Table 12.

6.3 State Policy, 1945 - 1964

The Evershed Reports

Around the end of the Second World War a number of official reports were published as the British textile industry came under official scrutiny. These reports were, in the main, critical of the industry's past performance and future prospects. In comparing labour productivity in the British and US cotton industries, the Platt Mission reported that productivity per man hour in Britain was between 18% and 89% below that found in the USA, depending on type of mill and particular process.[23] The main reason for this difference was the greater American use of higher-speed automatic plant and their better mill organisation. Only 5% of looms in British mills were believed to be automatic as against 95% in the USA, while ring spindles accounted for 99% of cotton spindleage in the USA as compared with about 50% in the UK. More generally, the Mission also commended the American industry's greater degrees of vertical organisation, product standarisation, and shift working.[24]

Following the "very disturing"[25] findings of the Platt Mission, the Board of Trade appointed a working party in 1945 to consider the cotton industry's prospects, with the underlying assumption that it should be maintained as a major national industry. Stressing the need for the more intensive use of labour saving machinery, the working party's final report constituted a framework for a programme of planned re-equipment, which became the basis of the Cotton Industry Act, 1949, and a controlled expansion of the textile machinery industry. To this latter end it proposed that an independent investigation of the textile machinery industry should be undertaken, particularly as it felt that because of lack of demand and a monopoly in spinning equipment supply, the design of British textile machinery had lagged behind that of other countries. Towards the makers of weaving equipments the report was especially scathing, stating that :

> the main point which stands out from our investigation is the inadequacy of British makers of automatic looms to cope with the requirements of the British weaving industry. This inadequacy exists both in regard to the volume and type of available supplies.[26]

In response the Ministry of Supply established the Evershed Committee which made two reports, the first concerning the manufacture of spinning equipment and the second the weaving and precision winding machinery sectors.

The main cause of concern regarding spinning machinery was the near monopoly held by Textile Machinery Makers Ltd (TMM), which had emerged in the early 1930s as a result of a series of mergers between all of the major manufacturers of spinning equipment. However, the Committee found that while a sour relationship had developed between TMM and its domestic customers, it was not due to any abuse by TMM of its monopolistic position, but rather to some textile firms' resentment that TMM was also supplying their foreign competitors. The relationship was further strained on the one hand, by the exclusion of machinery manufacturers from membership of the textile research associations, most importantly the British Cotton Industry R.A. (BCIRA, or the Shirley Institute as it is more commonly known), and on the other by TMM's loss of technical supremacy to foreign manufacturers.

Although the interim report's conciliatory tone represented a transparent attempt to repair damaged relations, the Committee nonetheless found that TMM's management structure, adopted in the wake of its orginal mergers, was over-complex, and that the company failed to comply with modern standards of costing. Moreover, the company "lacked adequate means or policy for research and development beyond that required for day-to-day technical investigation and mechanial modification".[27]

The report also emphasised the textile industry's own responsibility with regard to the development ot textile machinery. It had "not been conspicuous (with notable exceptions) in encouraging progressiveness"[28], while the - recently reversed - policy of exclusion of machinery makers from BCIRA had placed them at a disadvantage with regard to R & D. Thus the Committee urged the textile industry to capitalise on the advantages of a local supply industry, but cautioned, somewhat prophetically that:

> if through undue conservatism on the part of home customers or in the absence of encouragement from them the machinery workers are thrown back for a market for their products on the less advanced industries of the world, much of the incentive for technical development will disappear.[29]

The Evershed Committee's second report examined the postion of the weaving and precision winding machinery sectors. The Cotton Industry Working Party (CIWP), it will be remembered, was particularly concerned about the ability of British loom manufacturers to supply enough automatic looms of the right type to re-equip the cotton industry. As a matter of urgency, it estimated that 120,000 automatic looms needed to be installed over five years if the cotton industry was to compete efficiently.

Although the Evershed Committee decided that British looms were not inferior to foreign designs it found that the industry, as presently composed, was quite incapable of supplying even half the looms required, even over ten years. No criticism was contained in this finding as the order books of loom manufactures were filled for some years ahead. There was also little hope that the number of looms required could be provided by imports, even if the effect on the balance of payments could be ignored. To achieve the target set by the CIWP, the Committee concluded that as well as the full cooperation of existing loom manufacturers, far reaching government action would be required in providing factories and plant and releasing labour. It would also need the adoption of a single or limited range of standard loom designs, which demanded immediate research cooperation between makers and customers. Manufacturers membership of the Shirley Institute would help in this respect.

Impressed "by the number of new and progressive elements"[30] it contained, the Committee felt less anxious about the winding equipment sector and, in contrast, believed it largely capable of supplying envisaged demand. Any temporary deficiency in supply could be made up with imports from Switzerland or the USA without severely affecting the balance of payments. It did, however,emphasise the necessity of continued research, and noted that Swiss manufacturers had a justly deserved and long standing reputation for this kind of machinery.

While the Evershed Committee, in general, praised the work of textile machinery manufacturers it had no long term view of how the industry should develop, but then it was restricted by its terms of reference to report merely on those matters recommended for immediate attention by the CIWP. Some stress was laid on the need for research and development and some concrete recommendations were made with regard to the spinning sector. Unless the production of automatic looms was to be expanded, no active role was envisaged for the state other than the greater involvement of the research associations.

The most positive response to the Evershed Committee's reports came from TMM itself which had been the butt of most criticism. The company, following the Committee's recommendation, rationalised and changed its management, instituted a new costing system, and opened a central research laboratory at Helmshore. For its efforts TMM was thanked by the Minister of Supply in the House of Commons.[31]

The Government's, own reactions were to open discussions with the cotton industry on the supply of automatic looms, and to congratulate itself for having its policy with regard to winding equipment - "of encouraging new technical developments while permitting imports essential to fill gaps in the equipment of the textile industry" - confirmed.[32] What new technical developments it was encouraging is not known. Nor is it clear that anything came of an earlier statement that "all possible encouragement will be given to developments of promise in this (shuttless looms) and other fields of (textile) machinery production".[33]

Even though there was mention of a Bill on the textile machinery industry being presented to Parliament no such Bill emerged.[34] Nonetheless, the Government held considerable influence over the industry during this immediate post-war period through its retention of a variety of wartime controls. Using these controls it was able to allocate textile machinery production to domestic and export markets, balancing the needs of the UK textile industry with the national need for export earnings.[35]

The pressing problems of the balance of payments may have had some bearing on the final framing of the scheme for re-equipment contained in the Cotton Industry Act, 1949.[36] Despite the great need to re-equip weaving firms identified by the Platt Mission, the scheme was restricted to the spinning section of the industry. The official argument for this restriction was that weaving firms were producing all the automatic looms they could, so that "the order books of Northrop's for weaving machinery are filled up with orders from the home market for years ahead",[37] but perhaps more pertinently, it obviated the need either for action to expand the production of automatic looms, which it will be remembered would have caused most problems for domestic suppliers, or to import many thousands looms.

The Textile Research Associations

In the late 1940s, therefore, state attention was focussed on the textile machinery industry largely because of its role as supplier to the textile industry. Following the Cotton Industry Act, 1949 such attention subsided until the late 1950's when the whole question of the future of the cotton industry, and machinery manufacturers, rearose. Meanwhile the main form of state involvement with the textile machinery industry was through the textile research associations whose work was loosely coordinated through the Standing Consultative Conference on Textile Research which set up a Spinning and Weaving Machinery Panel in 1948. Although the Associations were under the wing of the DSIR, there is no evidence that the Department had any special interest in textile machinery. No relevant research contracts were placed until 1959, and only the Manchester College for Science and Technology had a textile post-graduate course supported by the DSIR. Moreover, the Department's main engineering research centre, NEL, had no specific programme for textile machinery, although some general research involving, for instance, hydrodynamic bearings, was of relevance.[38]

By 1950 there were nine textile research associations. Four - BCIRA, the British Launderers' R.A. (BLRA), the Linen R.A. (LIRA), and the Wool Industry R.A. (WIRA) - had been established during the first flush of research association formation after the First World War, while the remaining five - the British Hat and Allied Feltmakers R.A. (BHAFRA), the British Jute Trade R.A. (BJTRA), the Hosiery and Allied Trades R.A. (HATRA), and the Lace R.A. (LARA) - came in the second wave which followed World War II. Under the provisions of the Industrial Organisation Act, 1947 two, BCIRA and WIRA, arranged to be funded by levies on their respective industries rather than by the usual method of individual subscriptions.

Table 6.6 Textile research associations : incomes, 1950-1964 (£000s)

	BCIRA[1]	BHAFRA	BJTRA	BLRA	BRRA[1]	HAIRA	LARA	LIRA	WIRA
Date of formation	**1919**	**1947**	**1946**	**1920**	**1949**	**1946**	**1946**	**1919**	**1981**
Total income[2] 1950-1951	220	19	32	31	196	62	18	71	133
DSIR grant	80	8	11	10	53	22	8	22	52
Total income 1964-1965	587	14	68	91	-	107	35	84	352
DSIR grant	117	3	23	26	-	28	12	19	83
Total income 1950/51-1964/65	5942	244	707	842	3511	1074	359	1041	3504
DSIR grant	1322	91	255	253	653	347	145	285	966

Source DSIR Annual reports, appropriate years

Notes

1 BCIRA and BRRA merged in 1961.
2 Data prior to 1950-51

Table 6.6 shows that the income of the various research association varied considerably with BCIRA by far the largest and BHARA and LARA the two smallest. Indeed, the activities of these two were restricted to little more than offering a library-based information service to members. In the following paragraphs the textile machinery related work of the four largest research associations, BCIRA, BRRA, WIRA and HATRA is briefly reviewed.

Following World War II BCIRA reversed its previous policy to allow the membership of textile machinery makers. Nonetheless, even before the War the Association had been involved in the development of new machinery and techniques, as well as their evaluation for textile firms. In particular, its work on the sizing process had been fruitful and had led to the introduction of an electric hydrometer in 1935, an accelerated drying hood in 1948, and the Shirley Automatic Size Regulator in 1951. It is impossible to determine the actual effort devoted to machinery development but as an indicator 22 of the 104 papers published by Institute staff between 1953-54 and 1955-56 were concerned with textile equipment rather than textiles.[39]

In 1951 the Institute established a separate company, Shirley Developments Ltd, to exploit its inventions either by selling or licensing them for manufacture, or alternatively by selling products made either under contract or by the research association itself. Later the company expanded its activities to include inventions originating from elsewhere, especially other textile reseach associations.[40] It was therefore in competition with, and even duplicating, the work of the recently formed NRDC.

In 1958 the Institute embarked on a major R & D programme aimed at automating the cardroom sequence in cotton yarn production.[41] Mainly financed from the Institute's own funds the project also received nearly £200,000 support from the NRDC over the next six years.[42] Like many of the Corporation's interests in the computer field this project was intended to result in, rather than exploit, an invention.[43] Discussions with British firms failed to lead to commercial exploitation and in 1966 a license agreement was signed with Roberts Co. of America. Although technically successful, substantial increases in operating speeds of individual items of cardroom machinery achieved in the meantime made the system economically unviable and Roberts soon decided not to proceed.[44]

While the Shirley Institute had established a rayon section in 1928, the "special need for research on machinery specifically designed for manipulating rayon fibres" led to the formation of the BRRA in 1946[45] with its own Textile Machinery Advisory Panel, later split into two, Looms and Chemical Plant. In practice, however, only two of the Association's four departments were concerned with machinery development and testing - the other two dealt with the physics and chemistry of rayon - so that in 1957 it estimated that about a quarter of its programme was devoted to machinery development. Initially the BRRA's two main machinery projects were concerned with converting rayon filment into sliver - this was carried out in conjunction with TMM - and with adapting ordinary non-automatic looms for rayon weaving. Later work included the development of a false twist unit (licensed to Ernest Scragg in 1963); investigating the possibility of using pneumatic shuttle propulsion for a loom, again with the cooperation of loom manufactures; and research in high speed warp knitting. A further instance of BRRA's links with textile machine firms was a machine devised for pnenmatically stripping yarn residues from exhausted pirns and bobbins that was manufactured and sold under license. It also developed a range of instrumentation which was similarly manufactured and sold by instrument firms. By 1958 its two main projects were investigations of the effects of machinery vibration on yarn quality and the application of fluid-bed techniques to textile finishing, principally dyeing.

From 1959 much effort was redirected into machine testing to help address the more immediate problems of the Lancashire textile industry as it ran into trading difficulties, and also began to re-equip under the Cotton Industry Act, 1959. However, the increasing use of blended fibres meant that the distinction between cotton and synthetic textile manufacture had largely disappeared, so that in 1961 BRRA formally merged with BCIRA to form the Cotton, Silk and Man-Made Fibres Research Association (CSMMFRA), thankfully still to be known as the Shirley Instititute. This amalgamation though resulted in a reduction of the total number of research projects from 213 to 125 and a 30% fall in the joint staff complement.[46]

WIRA's main form of involvement with textile machinery was initially through its extensive equipment testing facilities. These activities were typified by the investigation, begun in 1953/54, of the relative merits of automatic and non-automatic looms.[47] By then, however, it had also become involved in the co-development of some machinery, particularly involving automatic control, most improtant of which were the Rapier Autoleveller Drawing System and the WIRA Autocount, which automatically tested the uniformity of carding engine output.[48]

The work of HATRA covers the manufacture of all knitted goods. Early investigations into the control of knitting machines were a feature of its activities, resulting in the development of a Yarn Speed Counter and a Yarn Length Counter. As the knitting of synthetic fibres became more important it was included in HATRA's research programme, and in 1964 the Association reached an agreement with a manufacturer of false twist machinery for the worldwide exploitation of a method if had devised.[49]

The Cotton Industry Act, 1959

During the late 1950s large increases of cheap imports from Commonwealth countries led to a fall in demand for domestically produced cotton textiles. The knock-on effect of depressed orders for textile machinery can be seen in Table 6.2, as gross output and employment fell by 15% and 19% respectively in 1958. Although the Government was pressed to intervene on behalf of textile machinery manufacturers[50] its response, hastily constructed for an impending General Election, was a second scheme in ten years for the reorganisation and re-equipment of the cotton industry, with no specific action aimed at textile machinery manufacture. Debates on the Cotton Industry Bill revealed the continued backward state of the industry. Productivity increases achieved during the 1950s were small compared to those of other countries, while spindle usage rates - an indicator of the amount of shift working - were barely half of those averaged in West Germany and France.[51]

While the Cotton Industry Act, 1959 can be critisied for failing to address the industry's deep structural problems,[52] its immediate effect on textile machinery firms can be seen in Tables 6.2 and 6.4. Although production data for the years 1959-1962 are missing, gross output in 1963 was 63% up in current terms on 1958. More importantly for the domestic industry, the re-equipment scheme provided an opportunity for foreign machine workers to become better established in the UK market. As state-subsidised investment got into full swing, the volume and value of imports doubled between 1959 and 1961, and the share of the domestic market taken by imports rose from 17% in 1958 to 25% in 1963 by value.

Another effect of the Cotton Industry Act, 1959 was that it brought the textile machinery industry back to the political spotlight. One analysis of its problems was put forward by Barbara Castle, MP, with reference to a company based in her Blackburn constituency.

> Since the War, British Northrop Limited has faced a tremendous slackening off in the demand for automatic looms. It has been increasingly unable to sell these looms abroad because of the development of competition in textile machinery there, and its inability to sell them to the British manufacturer who has increasingly got into the doldrums (sic).[53]

This view, that one of the inhibiting factors for loom builders was its domestic market, received support a couple of years later when a commentator reported that the trend in British design was toward looms with a "minimum of complexity" because that was what was demanded by Lancashire weavers.[54]

An alternative analysis, which laid the problems facing the textile machinery industry at its own door, was put forward when the Minister for Science was asked to consider instituting a DSIR enquiry into the industry because of the view:

> commonly held, that this industry is another of those that is losing ground today to overseas competitors because of an inadequate use of research and development departments and of graduate scientists and engineers, with the result that most of the inventions in textile machinery are coming from abroad.[55]

Duly, but some two years later in 1961, the DSIR announced that in conjunction with the Board of Trade, it was to make a survey of the R & D requirements of the industry, similar to those already conducted for the shipbuilding and machine tool industries. Whether or not this survey was completed is not certain,[56] but the DSIR nonetheless quickly placed three research contracts all with UMIST, showing perhaps some concern about the state of textile machinery research and development.[57]

But disquiet with the industry's innovative capability continued and was raised again in the 1963 Feilden Report.[58] In the same year the DSIR, as a part of its 'earmarked' grants scheme for the research associations, made a grant of upto £57,350 to the Shirley Institute, later revised upwards to £74,600 out of £114,700, for an investigation of novel methods of spinning, particularly open-ended or break spinning.[59]

6.4 State Policy, 1964-1970

In contrast to what happened to the computer and machine tool industries, the return of a Labour Government and the advent of the Ministry of Technology in 1964 brought little initial change to the structure and conduct of technology policy toward textile machinery. Although responsibility for both the DSIR breakspinning grant to the Shirley Institute and the textile machinery industry were transferred to Mintech in 1965, until the Ministry began go show more concern in about 1968 the state's main involvement with the industry remained through the research associations.

Details of the incomes of the three main research associations, the Shirley Institute, HATRA and WIRA, are given in Table 6.7 for the years under review. As before it is difficult to ascertain with some precision the amounts allocated to machinery rather than textile projects although official statistics offer some clues. According to these statistics, the research associations performed textile machinery R & D to the value of £346,000 in 1966/67 and £244,000 in 1969/70,[60] amounting to 19% and 12% of the totals in these two years. (See also Table 6.5) These figures are roughly in accord with the Shirley Institutes's own estimate that in 1967/68 at least 60% (£240,000) of its research budget of approximately £400,000 was devoted to research on machinery operation.[61] In the following year 6% of its expenditure (about £45,000) came from contracts placed by machinery makers.[62]

In parallel to the decreasing role of the research associations in textile machinery research in the late 1960s the state's structure of support for the textile machinery industry widened. Prior to 1964 the NRDC and the DSIR had supported major projects at the Shirley Institute. The latter break-spinning programme continued under Mintech sponsorship until 1969, during which time it was one of the Institute's three largest projects. Following the end of funding, discussions were held with the Ministry and a machinery manufacturer about the best way to utilise the expertise built up, but they did not lead to any concrete proposals.[63]

Table 6.7 Selected textile research associations : incomes 1965-1970 (£000s)

	CSMMFRA	HATRA	WIRA
Total income, 1965-66	716	110	370
Mintech grant[1]	116	26	82
Total income, 1969-70	854	205	464
Mintech grant	97	32	94
Total income, 1965-70	3767	749	1698
Total Mintech grant	541	136	372

Source Annual reports of the research associations

Note

1 The Mintech grant is the block grant-in-aid. It does not include other Mintech monies disbursed differently.

Reduced levels of block grant support also stimulated WIRA to argue that it needed greater state funding to enable it to establish "its potential contribution to textile machinery R & D in collaboration with the machinery manufacturers."[64] In contrast to the absence of cooperative R & D between machinery builders and machinery users, more than three quarters of the Association's projects involved active collaboration, particularly with other research associations and universities.[65] HATRA, alternatively, appears to have failed to interest the NRDC in taking up the further development of an electronic yarn length counter it had designed.[66] It did, however, have its industrial income organised into a levy from 1969[67] to mirror arrangements existing at the Shirley Institute and WIRA.

One further factor affecting the textile research associations at this time were calls for their rationalisation. It was claimed that while the increasing use of synthetics, mixed fibres blends, and novel methods of fabric constructions had blurred many of the orginal distinctions between them there was, in spite of the Standing Consultative Conference on Textile Research, too little coordination and too much duplication of research.[68] In an effort to increase cooperation the DSIR had initiated a scheme in 1963 by which the associations put aside 2% of their respective incomes into a fund for collaborative projects, [69] but during the late 1960s both WIRA and the Shirley Institute began their own independent programmes of research into stitch binding. However, the merger of BCIRA and BRRA in 1961 was seen as a step in the right direction and in 1969 HATRA took over responsibility for the Lace RA.

From 1968 onwards the direct support of textile machinery machinery manufacturers began to increase, and showed some coordination particularly between the activities of NRDC and Mintech. In that year Mintech placed two contracts for textile machinery under its Pre-Production Order Scheme, the first other than for machine tools. The contract with Stone-Platt was for six open-ended (break) cotton spinning machines and technical support from its subsidiary, Howard and Bullough, worth approximately £80,000.[70] At the same time the NRDC entered into a joint venture with TMM (Research) Ltd, another Stone-Platt subsidiary, for the further development of break spinning machinery and their extension for use with long staple yarns,such as wool.[71] NRDC funding continued until 1972 by which time Stone-Platt was said to have devoted £½ million to the whole project over six years.[72]

The second of Mintech's pre-production orders, worth £66,000, was for 48 British Northrop (BNL) Sensamatic looms for installation in Courtauld's Leigh factory.[73] This followed the NRDC's support for the manufacture and trial of 96 BNL M model filament looms installed in Courtauld's Norwich mills.[74] Altogether about 500 Sensamatics were delivered, and without Minitech's support it has been argued that BNL, previously in deep decline, would not have survived.[75] Despite a call by one of the Ministers at Mintech asking for more proposals for pre-production support from textile machinery manufactures[76] the two examples above remained the only instances of such support.

Even with NRDC's and Mintech's coordinated support for BNL, loom development and manufacture in the UK continued to be in a sorry state. The 'M' model and Sensamatic were of conventional design, while greatest growth was in the market for shuttleless looms, which were all developed and supplied from aboard. In spite of its BNL purchases, Courtauld's weaving sheds were largely equipped with Swiss and Czechoslovakian gripper-shuttle looms. Through its own Technical Development Unit Courtaulds had tested, developed and modified many advanced machines for its own use, including, as well as shuttleless looms, a Czechoslovak break spinning system designed by Kova and Czech Arachne stitch bonding machinery. It had also acquired its own circular weft knitting machinery manufacturer, A. Kirkland.[77]

Besides its support for Stone-Platt and BNL, the NRDC also began the funding of two rather more speculative loom developments and two carpet machinery joint ventures during the late 1960s. Beginning in 1967, the Corporation provided two years sponsorship to Professor Vincent of UMIST for a project aimed at producing a revolutionary type of shuttleless loom in which the weft was 'spat' across and through the warp.[78] Between 1968 and 1977 the Corporation also helped to finance the development of a linear motor driven loom invented by Mr N. H. Smith, together with additional research conducted at the University of Bradford.[79]

One of the Corporation's two carpet machinery joint ventures, starting in 1969, was with Wilson & Longbottom for the development of a high speed Wilton carpet loom. The first loom began weaving trials in 1975.[80] The second joint venture involved the formation of Durcam R & D Co. Ltd. with Metal Box Ltd. and Hugh Mackay & Co. Ltd., an established maker of high quality carpets. Durcam, in which the Corporation held a 26% shareholding, was intended to develop and manufacture a machine to produce patterned carpets at similar speeds to carpet tufting machines.[81]

One area of textile machinery in which Britain was doing well at this time was in the growth market of yarn texturing. Three firms dominated the British scene, the U.S.-owned Leesona, Klinger Manufacturing and especially Ernest Scragg & Son which, in 1967/68, doubled its turnover to £13m, and with profits of over £3m was fifth in the 1968 Management Today profitability league, also winning the Queen's Award to Industry for

Export Achievement. But because of the "ferocious" over-capacity in this sector and licensing difficulties, Scragg suffered losses in 1969/70.[82] Thus the IRC, which had been looking for opportunities to reorganise the textile machinery industry to aid the development of "more sophisticated product ranges aimed at the advanced markets of Western Europe and North America",[83] supported the merger of Klinger and Qualitex in January 1970, with the accompanying sale of Klinger's textile machinery interests to Scragg. To ease the merger the Corporation made a loan of £2m to Qualitex with the option at a later date, never exercised, to convert £1.75m of its loan into a maximum of 2.5m of the Scragg shares held by Qualitex.

During 1969 and 1970 two other policy sections aimed at the textile industry are likely to have affected the machinery industry, if only indirectly. Both stemmed from a report of the newly formed Textile Council which was concerned with the continued decline of the cotton and allied textiles industry. The report reiterated the accepted criticism of the industry that it was too fragmented, had excess capacity, and lacked confidence. Labour productivity was low, shift-working rare, and despite the Cotton Industry Acts of 1949 and 1959, there had been insufficient re-equipment and modernisation.[84] One independent estimate was that little more than half of all looms installed were automatic.[85] The first response was the Textile Re-equipment Scheme operated at the government's request by the IRC.[86] The second, in line with one of the Textile Council's recommendations, was the raising to 25% of the annual tax allowance on new machinery purchases worked for three shifts by cotton firms.[87] Overall, its effect on investment was expected "to be positive, though small and unquantifiable".[88] Later the allowance was extended to the wool textile industry.[89]

6.5 State Policy, 1970-79

Following the return of a Conservative Government in 1970 much of the interventionist impetus toward the textile machinery industry built up in the last years of the 1960s was dissipated with the abolition of the IRC, the replacement of the Ministry of Technology by the DTI, and the general contraction of support offered by the NRDC. The formation of the Research Requirements Boards in 1972 nonetheless marked an important change in how public funds for the support of R & D were disbursed. Initially, responsibility for textile machinery projects was given to the Mechanical Engineering and Machine Tool Requirements Board (MEMTRB) while textiles was placed with the Chief Scientist's Requirements Board.

This was an helpful split of responsibilities as the research associations were to return to their previous pre-eminent location of publicly-funded textile machinery R & D as other forms of support were run down. Furthermore, while MEMTRB did not inherit any textile machinery R & D contracts from the DTI, its main funding obligations were to NEL, CADC and UKAEA, institutions which had no real traditions of textile machinery related research.[90] The Board though did place a contract with Cambridge Consultants Ltd. (CCL) in 1974 for a feasibility study of a novel form of multi-phase loom, and its expenditure on textile machinery research in 1974/75 came to £117,000.

Table 6.8 GARB expenditure, 1975/76 - 1979/80 (£000s)

	1975/76	1976/77	1977/78	1978/79	1979/80
Textile Research Council	453	539			
SATRA[1]	322	237	1051	1198	1642
BLMRA[2]	105	143			
NEL	22	-			
RCA[3]	10	-			
UKAEA	-	63	163	100	14
Other	-	-			
Private industry	-	34		140	431
Total	912	1016	1214	1438	2087

Source GARB Annual reports, appropriate years.

Notes

1. Shoe and Allied Trades Research Association.
2. British Leather Manufacturers Research Association.
3. Royal College of Art.

In the following year the creation of the Garment and Allied Industries Requirements Board (GARB) brought textile and textile machinery R & D together again under one umbrella. The CCL project initially remained with MEMTRB but was later transferred to GARB. Unfortunately, GARB annual reports do not include details of projects supported or specify the amount of funds devoted to machinery research. Details of overall GARB expenditure given in Table 6.8. It shows that the bulk of expenditure was taken up by support for the research associations although this fell as a proportion of the total from 96% in 1975/76 to 79% in 1979/80 as the percentage of funds spent in private industry rose from 3% in 1976/77 to 21% in 1979/80. The individual incomes of the three main textile research associations is given in Table 6.9.

Table 6.9 Selected textile research associations : incomes, 1970/71 - 1978/79 (£000s)

	CSMMFRA	HATRA	WIRA
Total income, 1970-71	794	205	503
DTI grant	102	25	103
Total income, 1978-79	1672	534	1536
GARB grant	206	180	368
Total income, 1970-79	10001	3277	7783
Total state grant	1104	851	1641

Source *Annual reports* of the research associations

A significant change in the way in which the associations were funded occured in 1974 with the formation of the Textile Research Council (TRC). By presenting a joint programme to the Requirements Boards the TRC's purpose was to ensure a greater measure of coordination between the research activities of the individual RAs. Greater rationalisation still was the point of merger talks between the Shirley Institute and WIRA in 1977 and 1978 but these failed to the latter's disappointment. WIRA believe "that a pan-textile Research Association (was) what (was) required to meet the needs of the texile industry in the 1980s".[92]

While non-wovens continued to be a major research interest at WIRA during the early 1970s, the Association also made a "major policy decision" in 1970 to work with the Stone-Platt group in the NRDC supported project for the development of break spinning machinery suitable for wool and wool fibre blends. This it believed was the "most effective way of pooling expertise and knowhow in this field and at the same time being sure of engineering and production facilities when the project is successfully completed",[93] a problem, noted earlier, that had presented itself to the Shirley Institute at the end of its research on break spinning in 1969. Remarkably, the Institute took up research on break-spinning again in 1975 after a lapse of five years.[94]

The NRDC's support for Stone-Platt's continued development of its break spinning machinery terminated in 1972. Its sponsorship of the linear motor loom which started in 1968 appeared to be vindicated in 1974 when a license was granted to Standing Electronics Ltd. of Blackburn for the loom's manufacture and sale.[95] However, the loom was found to be unsatisfactory and Standing stopped manufacture in 1977. The

Corporation's total investment in this project was £28,5000.[96] Support also continued for Wilson & Longbottom's carpet weaving rapier loom, but the Corporation turned down the company's request for assistance for another rapier loom for weaving heavy industrial fabrics, which subsequently won the Queen's Award for Technological Innovation in 1976.[97] During this period, however, the Corporation only entered into one new development project, a joint venture with Petrie & McNaught Ltd. starting in 1973, for the development and the production of the first batch of seven gilling machines.[98]

It did though also act as a broker between a university department and a textile machinery company. At some point in the 1960s the SRC had supported research at Loughborough University aimed at producing pile fabric by a novel locked-loop stitch method. Patents arising were assigned to the NRDC, and following some further developments with Edward Pickering (Blackburn) Ltd., the Corporation signed an exclusive license in 1971 for the invention's exploitation by a new company, Pickering (Locstitch) Ltd. The SRC continued to support relevant research at the university which it claimed led to design improvements.[99] In 1980 it was reported that the system was finally coming to be accepted.[100]

Details of other SRC supported textile machinery research at universities are difficult to trace until the very late 1970s when some research project titles were published by its various committees. During 1977/78 two of the 56 new projects selected for support by the Manufacturing Technology Committee were concerned with textile machinery,[101] while in the following year the equivalent figures were 4 out of 61.[102] The total amount of funding involved, over different time periods depending on the project, were approximatley £40,000 and £92,000 respectively.

However, the main new initiative taken toward the textile machinery industry during the 1970s was the setting up of the Textile Machinery Industry Scheme (TMIS) in 1976 under Section 8 of the Industry Act, 1972. The first such scheme had in fact been aimed at rationalising and reequiping the wool textile industry following the recommendations of the Atkins Report,[103] in a similar manner in many ways to the provisions of the Cotton Industry Act, 1959.[104]

The establishment of TMIS came in the wake of proposals from the Textile Machinery SWP set up to aid in the formation of industrial policy after the return of the Labour Government in 1974. Particular concern was expressed about the industry's low levels of capital investment and R & D spending which, it was believed, had resulted in low productivity, falling profitability, and a share of world trade that had declined from 16% in 1964 to 10% ten years later. Capital investment averaged 2.5% of sales in 1972, which was less than half of the levels of the West German and French industries, and a third of that achieved in Italy. Falling R & D expenditures (Table 6.5) meant that British firms, even the leading companies, spending on average the equivalent of 3.7% of turnover on research, were well behind their major foreign competitiors where a level of 6% of sales was thought to be common.[105]

Against this background £ 20m was allocated to TMIS in an attempt to stimulate the industry to "at least recover" its 1964 percentage of world trade.[106] Under the scheme support was initially available in the form of concessionary loans or equivalent interest relief grants for upto 50% of the cost of new product development, 20% grants for new plant and machinery, 15% grants toward new buildings, concessionary loans or interest relief payments for restructuring or rationalisation projects, and for smaller companies, half the cost of necessary consultancy fees. Later, in the cause of easier administration, straight 20% grants toward the costs of design and development replaced the previous support for new products. Unlike most of its sister schemes TMIS thus had explicit provision for product development, but it is interesting that it did not incorporate the Textile Machinery SWP's specific suggestion that pre-production ordering be re-introduced.[107]

The scheme closed for application at the end of 1977 but processing went on until 1979. Although only £13m of the £20m was authorised to be taken up, it was still reckoned that about three-quarters of the industry had applied for support. Altogether 55 projects involving a total expenditure of £ 67m were offered aid. 53% of the support was to go towards development projects, which it was hoped would lead to a threefold increase in R & D spending over the next three years.[108] Two years later, however, it was reported that the amount actually taken up under the scheme came to only £ 6m, reflecting the continued contraction of the industry and its attempts to cut operating costs.[109]

In the meantime the Textile Machinery SWP had undertaken a number of investigations of export markets, market trends, and product gaps in the range of available British machinery.[110] But inevitably the value of its work was hampered by a number of bankruptcies both among textile and textile machinery manufactures. Perhaps the most surprising failure among machine makers was that of Platt-Saco-Lowell (previously Stone-Platt) which had acquired Ernest Scragg in 1975. Platt, one of the most profitable machine builders during the middle seventies, was eventually sold off to John D. Hollingsworth on Wheels Inc. of the USA, while the Swiss company Rieter took over what had been Ernest Scragg. On the other hand the collaspe of many textile mills released in many cases good second-hand equipment which was then available to compete with new machinery. A particular problem appeared to be in regard to woollens machinery, often acquired with state help under the Wool Industry Textile Scheme.[111]

6.6 Discussion

Much of the state's interest in the fortunes of the textile machinery industry has been the consequence of greater concern about the textile industry, its only market. For instance, the Evershed Committee, which produced the only published official reports specifically dealing with the industry until the establishment of the Textile Machinery SWP nearly thirty years later, was set up to investigate whether machinery makers could cope with the demands of re-equipment following the Cotton Industry Act, 1949. Similarly, further debates on the cotton industry in the late 1950s led to the DSIR's unpublished, and perhaps uncompleted, enquiry into the R & D requirements of textile machinery manufactures. Only from the late 1960s onwards has some public attention been focused on the industry for its own sake.

For most of the period under review the bulk of technology policy has been based on the textile research associations. Even when the DSIR and NRDC offered their first direct support to textile machinery projects they were located at the largest textile R.A., the Shirley Institute. Indeed it was not until 1968 that a machinery manufacturer received direct state support. During the next two years a greater variety of interventionist support emerged as the NRDC, IRC, and Mintech through the Pre-Production Order Scheme, became involved in the activities of individual firms. In particular, the initiatives of the NRDC and PPOS showed some rare coordination of objectives. With the return of a Conservative Government in 1970 interventionist behaviour tailed off and, despite isolated NRDC investments, the institutional focus of state aid, if only by default, returned to the research associations now supported through the Requirements Boards. The formation of the Textile Machinery SWP in 1974 provided a valuable, but arguably long overdue, forum for discussion and debate about the industry. Its advice was one factor in the setting up of the Textile Machinery Industry Scheme through which a variety of grants became available to the industry. The full potential of the scheme, however, appears to have been restricted by the economic recession of the late 1970s and early 1980s.

One feature of TMIS was the number of firms that it supported. Previously, state policies had only offered a small number of companies: the names of Ernest Scragg, Platt-Saco-Lowell (including under its guises as TMM and Stone-Platt), and BNL have occured most often, while Wilson & Longbottom, Durcam (Hugh Mackay & Co.) Petrie & McNaught, and Pickering have been mentioned in terms of their contacts with the NRDC. Throughout this case study, and in common with the the other two, disentangling the amount of relevant research conducted in academic institutions has proved a problem. The first DSIR research contracts were placed at the end of the 1950s but details of subsequent funding, other than odd examples financed by the NRDC and SRC, have been difficult to trace.

Identifying the volume of state support is complicated by the dual responsibilities of the research associations towards their textile and textile machinery members. GARB expenditure, too, is undifferentiated. By its own estimates, a quarter of the Shirley Institutes total programme in 1957 was concerned with textile machinery, while in 1968 at least 60% of its research expenditure was devoted to machine operations. Going by official and research association statistics, the proportion of textile machinery R & D to total RA expenditure has varied on a downward trend from 29% in 1966/67, 16% in 1969/70, 18% in 1972/73, to 10% in 1974/75. Rather than attempting then to distinguish between textile and textile machinery expenditures, and between R & D and other expenditures, at the textile research associations, Table 6.10 merely presents total block grants disbursed to the RAs.

Table 6.11 presents the operational object of particular measures or instruments. It shows that although the range of state policy has broadened over time, most measures have concentrated upon R & D. The research associations could be considered to have helped in the diffusion of textile machinery in the sense that they have run examinations and equipment trials, and provided technical information and advisory services for their principal group of clients, the textile firms.

During the Mintech period the Pre-Production Order Scheme subsidised and arranged the trial of two machines one, the BNL Sensamatic loom, on a relatively large scale. NRDC undertook the installation and manufacture of another BNL loom. In the 1970s the NRDC turned to mainly investing in development projects, but it also supported the manufacture of the first batch of machines produced by Petrie & McNaught.

The establishment of the Textile Machinery SWP brought with it various marketing services, but that has been the only example of such support.

Under the umbrella of TMIS separate measures were included with the emphasis upon the first phases of innovation - design and development - and capital investment. It is not known whether individual firms were in receipt of more than one type of grant, covering both development and re-equipment.

With regard to the location of state-funded R & D it is clear that, despite the lack of some data, most had been conducted within state laboratories rather than within private industry. Other than that supported by the DSIR and SRC at academic institutions, most had been carried out within the textile research associations as a part of their own programmes, while some extra funding was provided for specific projects by the DSIR, Mintech and NRDC to the Shirley Institute. State support for industry-based R & D on the other hand began with the NRDC's part-funding for Stone-Platt's break spinning development project in 1968. Until the advent of TMIS eight years later, the NRDC remained the main source of such state involvement through its occasional investment, although the Requirements Board supported the development of a weaving machine, and perhaps a small number of other unspecified research contracts.

Table 6.10 Summary of state support, 1950-1979 (£000s)

		Value	
1950-1964	RA block grants	4317	
	NRDC[1]	195	(1 project, Shirley Inst)
	DSIR (universitites)	9	(3 grants)
1965-1970	RA block grants[2]	1049	
	DSIR R & D contract[3]	75	(Shirley Inst)
	PPOS	146	(2 projects)
	NRDC[4]	?	(6 projects)
	SRC	?	
	IRC	0	(1 project)
1970-1979	RA block grants	3596	
	Other GARB[5]	977	
	MEMTRB	117	
	NRDC	?	(4 projects, 3 continued)
	TMIS[6]	6000	
	SRC[7]	?	

Notes

1. £1,750 actually paid 1965/67;
2. Shirley Institute, HATRA and WIRA only;
3. Although placed in 1963, the bulk of expenditure occured from 1965;
4. One project, 1968/1977 incurred an NRDC investment of £28,500;
5. Does not inclue MRMTRB expenditure;
6. As processing went on until 1979 much of this expenditure would have been made after that date. About half of this would have been on development projects;
7. Six grants agreed 1977/79 involved a total allocation of £132,000.

For the full benefit of institutional industrially relevant R & D to be achieved it is necessary that private companies have their own active R & D departments, and that there is some form of mechanism for the transfer of results. The main such method has been the collaboration of research associations and textile machinery manufacturers in joint projects. Stone-Platt has been the company most involved both with the Shirley Institute and with WIRA.

Table 6.11 Function of support

	R & D	Prototype	Manufacture	Marketing	Diffusion
1945	RAs				RAs
1964	NRDC				
	DSIR				
1964	RAs				RAs
	DSIR				
1970	NRDC		NRDC		NRDC
	SRC				
		PPOS			PPOS
1970	RAs				RAs
	NRDC	NRDC		NRDC	
1979	RRBs				
	SRC				
	TMIS		TMIS		
				NEDC	

On another tack the parallel involvement of these two research associations in break spinning research, not to mention the gap of five years between the Shirley Institutes' two phases of relevant development, can have done little for either Association's aims to conserve expertise in that area.

The user-supplier nexus was predominantly enouraged through the Pre-Production Order Scheme but it did not actually promote user-supplier contacts during development when the identification and understanding of user needs is so important. It could be argued that with both textile and machine manufacturers as members, the textile RAs were in a position to ensure that user needs were well-articulated in their machinery projects. There is, however, little documentary evidence that any such consideration was regularly involved. WIRA, for instance, has since been criticised for its lack of a commerical approach and tendency toward academic-type research.[112] On the other hand, an account of the Shirley Institute's development of an automated card room sequence shows that although users were represented on the project steering committee, the mandate to pursue a defined technical goal meant that other considerations were excluded, resulting in a technical success but comercial failure.[113] Similarly, while GARB, like other Requirements Boards, had industrial representation intended to ensure a market orientation in its deliberations, its inability to fund or attract industry-based projects, ensured that the problems of technology transfer remained.

Apart from NRDC and Pre-Production underwriting of sizable numbers of BNL looms to Courtaulds, state support for the diffusion of textile machinery has been by way of subsidised re-equipment schemes for the textile industry. These, as noted, were arranged for the benefit of textile manufacturers rather than machine builders. All such schemes have been open to imports and have not been coordinated with any support to domestic suppliers, thus restricting their full beneficial effects. For example, TMIS is likely to have achieved more of its potential had it coincided with, or even better, preceded a scheme such as WTIS. Then the new investments of woollens firms would have provided a market for machinery manufacturers to innovate for. But as anecdotal evidence about WTIS, and import/export data following the Cotton Industry Act, 1959 reveal, these schemes appear to have sucked in imports. In contrast weaving was presumably excluded from the Cotton Industry Act, 1949 because it would have called for a greater than acceptable level of loom imports.

CHAPTER 7 CONCLUSIONS

It was argued in the Introduction that studies of the effectiveness of single technology policy measures or the success of individual projects needed to be complemented by historical studies of policy. This has been the intent behind the three preceeding case studies that have described and discussed policy toward the computer, machine tool and textile machinery industries in the period 1945 - 1979. The development of policy has been traced in relation to the institutional framework of policy and the specific circumstances of the three industries. Following the discussion of the innovation literature in Chapter 2 the emphasis has been on how the state has affected innovation, the process through which technical change occurs. The purpose of this last Chapter is to review the findings of the case studies, to draw out some more general points about the conduct of policy, and finally suggest some lines of possible future research.

Although it has not been possible to define exactly the volume of state support, it was found that gross expenditures toward the computer, machine tool and textile machinery industries totalled more than £350m., £115m. and £13m. respectively. About a half of the computers total was made up of investment grants. Such grants were available for machine tool and textile machinery purchases but are not included for the reason that they were part of a non-specific policy for industrial investment, whereas computer grants were provisions expressly to speed the diffusion of computing equipment. On the other hand the computer total does not take note of the effect of public procurement policies athough an attempt was made to quantify their influence in terms of extra orders for the firms involved for the years that appropriate data was available (Chapter 4.6).

Another qualification is attached to the textile machinery figure which includes total grants to the textile research associations whose constituencies cover both textile machinery and textile firms. Finally, each total is a gross figure and does not make allowance for any double accounting, share sales or repayments to state agencies. As was shown in Chapter 4.6 net expenditures may be considerably less than gross totals.

Despite these qualifications the varied volumes of state assistance clearly demonstrates that computers and machine tools have been the focus of far greater state attention than has textile machinery. Machine tools has been regarded as a key industrial sector whose relatively small size has belied its importance as a key supplier to the rest of manufacturing industry. Alternatively computers has been perceived as a strategic industry in that reliance upon foreign manufacturers could have serious consequencies in terms of disrupted supply or restricted access to latest technologies. In contrast state interest in textile machinery has largely been a by-product of a greater concern for the declining textile industry.

While this thesis has concentrated on the influence of state policies upon promoting innovation this has necessarily been the immediate objective of many of the measures and interventions discussed. In many cases state action has been motivated by a desire to retain employment, increase levels of investment, or because of anxiety about the balance of payments, or a mixture of these and other reasons. For example, a number of machine tool schemes were introduced to maintain capacity and employment during investment cycle tronghs. Moreover, policy toward the industry in the 1970s was dominated by the abortive rescue of one company, Alfred Herbert, whose collapse it was believed would have untoward consequences for local levels of unemployment in the West Midlands and the national balance of payments. Much of the near £47m. specific aid to the company was to pay off its debts and acquire its equity, and not in the first run to improve the technological level of its products.

If the ultimate aim of policy has been to strengthen industrial performance then it can be argued that those toward the machine tool and textile machinery industries have failed. By almost every measure both industries have suffered real decline during the period considered. Changes in classification make long time-base comparison or the machine tool industry difficult, but between 1970 and 1979 when comparable data is available deliveries fell from nearly £200m. to less than £150m. at 1970 prices, and employment from some 70,000 to 50,000. Over longer time periods UK shares of world production, trade and consumption have all decreased. Similarly, employment in textile machinery manufacture more than halved between 1954 and 1979 to just over 24,000 while in the same period gross output dropped from £129m. to £78m. at 1970 prices.

Assessing policy toward the computer industry in these terms poses more problems because it has only existed since the end of the Second World War. Nonetheless, the UK industry's output has grown from less than £10 m. in 1960 to more than £1000m. in current terms in 1979 at which time billings to the computer services industry reached £400m. Employment in the manufacturing industry rose by about a third between 1966 and 1979 to nearly 48,000 and in the service industry from 14,000 in 1971 to nearly 24,000 (full time) in 1979. However, the relation between these figures, especially those regarding the manufacturing industry, and the focus of this thesis the domestically-owned industry is complicated by the significant presence of American computer firms in the UK economy. Perhaps a better overall indicator of the success of otherwise of policy is that in a world market for mainframe computers dominated by US firms only in the UK and Japan have indigenous industries capable of effective competition survived.

Of course this is a somewhat superficial kind of assessment. It does not address the questions of whether these industries would have performed better in the absence of specific policies, if different measures had been employed, or if policy had involved greater sums of state support. Answering questions such as these that concern the absolute efficacy of policy involves a myriad of methodological problems and is outside the scope of this thesis. Rather it has addressed the question of whether policies have been appropriate to the objective, explicit or otherwise, of increasing innovation and thereby industrial performance. There is no comprehensive theory of innovation, but Chapter 2 concluded with some general guidelines for the assessment of policy content.

It was argued that policies should be appropriate to an industry's structure, technological base and products. Both the machine tool and textile machinery industries are segmented and composed in the main of small and medium-sized businesses conducting relatively small amounts of R & D. Conversely the computer hardware industry has been marked by the emergence of large companies with intensive R & D programmes, although the computer services industry is characterised again by smaller firms.

Policy toward the computer industry has concentrated on support for ICL, the result of a series of mergers and takeovers the last of which were engineered by the IRC and Ministry of Technology. It has often been claimed that their interventions merely served to hasten the end of a process of rationalisation that would have occurred in any case. Given that the firms involved were operating in the same barely differentiated market with the burden of high R & D expenditures state strategy would appear to have been appropriate. Any delay in the final merger is likely to have lengthened the time incurred in the development of ICL's next generation of computers. However, the subsequent near-total emphasis upon ICL and mainframe computers with the relative neglect of the microcomputer and peripheral equipment markets was, with hindsight, a serious shortcoming of policy. As suggested in Chapter 2.8 even in industries composed of large firms smaller ones can still make a significant contribution to innovation.

The NEB's activities in the computer services industry during the latter half of the 1970s marked an interesting departure in policy. By taking a number of software houses under its INSAC umbrella it was in a position not only to develop an overall policy but also, even if it was not its main intent, take advantage of some economies of scale without dissipating the entrepreneurial talent or will of the individual firms. Recent newspaper reports suggest that the companies engaged in INSAC have since prospered.

Policies toward the machine tool and textile machinery industries have also shown signs of concentration upon particular firms but for different reasons. Before the Textile Machinery Industry Scheme very few firms from that industry had received state assistance. The company most involved was Stone-Platt but that appears to be because it was one of the machinery builders most committed to conducting R & D. In comparision many more machine tool companies attracted state support before the similar Machine Tool Industry Scheme was launched, but it is noticeable that three, Alfred Herbert, Kearney & Trecker,and Marwin, in particular received substantial support. While the merged Kearney & Trecker - Marwin was eventually successfully, the very large sums of money invested in Alfread Herbert were lost. A number of question marks remain against the wisdom of such a large scale commitment to one company with the large opportunity cost that involved, and the strategy subsequently pursued to right the ailing company. From the evidence put forward in Chapter 2 it was argued that economies of scale in innovation related activities would be harder to achieve in highly differentiated industries, such as machine tools, where the expertise involved is specific to one machine tool type rather than to machine tools in general. Alfred Herbert had grown during the 1960s from a large to the world's largest manufacturer through a series of acquisitions which left it with a diverse array of mainly outdated products. An alternative rescue plan therefore might have involved breaking the company down more directly into particular product groups and concentrating on those with some future potential.

The next point concerns the distribution of costs in the process of innovation and the proposition that technology policies should recognise the importance and costs of all activities involved. In the discussion at the end of each case study policy measures were categorised according to their function. Of course those functions carried on outside a firm bear no direct influence upon the process of innovation within it unless it is intimately involved. Neither is all direct industrial assistance intended to specifically stimulate innovation : far from it, as already stated, the objective of some state support has been, for instance, to increase productive capacity. The effect of such an investment upon innovation is impossible to determine without investigating the behaviour of the firm itself. It might enhance the quality or reduce the price of recent innovations, or even present an opportunity to allow innovations to proceed that would otherwise have been prevented by the cost of tooling up, etc. In addition, state assistance toward my activity any serve either to supplement or replace the firm's own investments.

Notwithstanding these conceptual difficulties the case study discussions demonstrate that much state activity impinging directly upon the firm has been aimed at funding R & D. Support for prototype production has been much rarer, although it was integral the NRDC's involvement in the computers industry in to the 1950s. The Corporation also supported a lone textile machinery prototype in the 1970s. Prototype support was also the intent of the formal Pre-Production Order Scheme instituted in the 1960s to stimulate machine tool innovations but also applied in two instances to loom development. During the following decade the Scheme fell into virtual disuse, but its provisions were later incorporated within the Product and Process Development Scheme.

Capital investment provision has been more common in the machine tool and textile machinery industries than in computers where only the NEB, late in the 1970s, provided such finance to Data Recording Instruments Ltd. and QI. With regard to machine tools the IRC made available funds for investment in production facilities to three makers of advanced machine tools, Herbert-Ingersoll, Kearney & Trecker and Marwin, and less directed finance to Plessey Numerical Controls. Later, KTM and Alfred Herbert and some smaller companies received further general assistance from the NEB and under the provisions of the Industrial Act, 1972. Although it cannot be determined how these monies were spent, it was noted earlier that in the case of Alfred Herbert that much went to pay off the company's accumulating overdrafts as well as its acquisition by the state. Other capital investment finance was provided under the Selective Investment Scheme and more particularly the Machine Tool Industry Scheme. The similar Textile Machinery Scheme was also a source of investment funds which had previously only been provided on a couple of isolated occasions by the NRDC.

Marketing assistance has also been rare. The work of the Textile Machinery SWP was noted in this regard, while some of the non-directed investments from the IRC and NEB in machine tools could have been used for this purpose. However, the most prominent state involvements in this particular activity concerned the NEB and NRDC which during the 1970s both set up organisations to arrange for the marketing of software developed under their aegis.

Apart from the emphasis upon R & D perhaps the main point that can be made from this short summary of the state's varied firm-located technology policy actions is the lack of coordination between them. It is not so much that less support has been provided for prototype production, manufacture or marketing than for R & D than it is has not, in general, made available packages of assistance tailored to the innovation needs of particular firms: here one phase of the process has been supported, there another. A few counterexamples stand out. It was noted above that the NRDC and NEB have both provided coordinated support for software development and marketing. In the 1950s the NRDC provided for the development and prototype production of certain computers as well as purchasing initial batch runs. With regard to textile machinery, it was argued in Chapter 6 that the timing of support from the NRDC and under the Pre-Production Order Scheme for two separate loom developments represented a rare example of collaboration between different sources of assistance.

This discussion of support for different activities involved in the innovation process leads on to the next topic which concerns the location of state-funded R & D, that is whether it is carried on within or outwith the firm, and mechanisms for the transfer of technology from public laboratories to the private sector. It was proposed in Chapter 2 that company-based R & D was necessary both for the generation and assimilation of requisite information and that a close coupling between organisations was the best means of transferring research results. This is not an argument in favour of locating all state-financed R & D within firms. R & D is a catchall term to cover research and development of different types and with different aims. In the majority of R & D performing firms such activities are predominantly directed toward the proprietary development of products and processes. They are likely to evince much less interest in fundamental or generic research - the elucidation of scientific laws, determination of properties, etc. - the results of which are regarded as a public rather than a private good. Moreover, the nature of R & D performed varies between industries and technological discplines. As described in Chapter 2 in areas such as computing with a quickly progressing scientific base and rapid rates of technical innovation it may well benefit companies to engage in research as well as development in order to keep abreast of technological advances.

In the three case studies different patterns of R & D funding were observed. Intra-firm research was an important aspect of the computer study. Before the creation of ICL the NRDC provided major support to its prior constituents, arguably during the 1950s to foster and maintain R & D resources in the industry. Other funding was available under the Advanced Computer Technology Project and from the Ministry of Technology as extra-mural contracts, the latter also supporting R & D carried out in public laboratories. With its formation, ICL became naturally enough the focus of direct government R & D support to the industry. Lesser amounts of funding continued to be on offer from the other sources noted until they were rationalised under the Computers, Electronics and Systems Requirements Board. Outside that dual framework, other R & D assistance particularly for software and peripherals development was available from the NRDC and as part of the NEB's more general investments.

In contrast to the computers study there was little intra-firm R & D support to the machine tool industry prior to 1964. Although the DSIR was apparently keen to award development contracts to machine tool firms after its own and the Mitchell Reports recommended such action, it had little success. The NRDC too did not enter into a venture with a machine tool firm until 1965. During the remainder of the 1960s direct Government contracts were the main channel for such support until they were subsumed under the Mechanical Engineering and Machine Tools Requirements Board umbrella in 1972. Outside the Board's influence development funding continued to be available from the NRDC, which became more interested in the industry in the 1970s, under the Industry Scheme, and later under PPDS. IRC, NEB and DTI/DoI investments in Alfred Herbert and KTM, in particular, may also have been used for R & D purposes.

Again in contrast, textile machinery firms attacted far less intra-firm R & D support than did their counterparts in the other two industries. It began in 1968 with the NRDC's assistance for Stone-Platt's break-spinning project. Before the TMIS was set in train in 1976, the NRDC remained the only source of such support apart perhaps from some unspecified contracts placed by the two Requirements Boards involved. A feature of this case study was the small number of companies that received R & D or indeed support of any kind before TMIS.

The institutional context of extra-firm R & D too forms a major difference between policy toward the three industries. With the important exception of NPL during the 1950s almost all computer research conducted outside firms has been centred at universities, which have contributed substantially to computer design in the UK. Nonetheless, specific funding of computer research by the DSIR did not begin until the 1960s. Such was the laxity of the Department in this field that it was the NRDC which took the lead and provided for the first post-graduate computer science studentships in the country. Funding increased under the SRC in the second half of the 1960s but, perhaps surprisingly, tailed off in the next decade. Computer design was also an aspect of NPL's work from the end of the War until about 1960, during which time the Pilot ACE and ACE were constructed. After ACE, NPL's computer energies were turned toward component and applications development and technical supervision of ACTP.

Institutional machine tool research on the other hand has in the main been split between universities and colleges, the Machine Tool Industry Research Association, and NEL, while PERA and the short-lived Institute of

Advanced Machine Tool and Control Technology have also been centres. Specific funding for academic research again began with the NRDC in the absence of any DSIR activity. Although the DSIR took subsequent responsibility for the NRDC project and the establishment of other centres of academic research at the end of the 1950s, attention to academic NC research appeared to wane thereafter until resurrected by the SRC during the second half of the 1970s. Throughout the whole period NEL has been an important location of state-performed R & D, absorbing the IAMTCT after it had been in existence for a mere two years.

Once again the textile machinery case study exhibits important differences to the other two, in that the research associations have been the major location of institutionally performed R & D. When both DSIR and NRDC made their first investments in textile machinery R & D they were sited at the Shirley Institute rather than with a firm. There is little evidence of much textile machinery related research in higher education or government laboratories, although the NRDC funded a couple of projects involving university research in the 1970s.

Mechanisms to smooth the transfer of research results from the state to the private sector have largely been arranged on an ad hoc basis. An exception was the NRDC's Patent Pool based on its extensive patent holdings. A lesson perhaps can be drawn from NPL's different experiences with its Pilot ACE and ACE. The former, developed in conjunction with English Electric, became the basis of the company's DEUCE range, relatively successful for its time. In this case intimate involvement meant that publicly funded development was quickly assimilated by a private firm. ACE itself, however, built without any such involvement and without reference to technological changes in componentry had minimal commercial impact. If English Electric, for instance, had been involved in development the need to incorporate newer technolgies might have been pressed home more firmly. In the other industries there has been some collaboration between the textile research associations and industrial machinery workers, particularly Stone-Platt, while more recently the SRC actively encouraged the involvement of machine tool firms in joint research programmes.

Given these inter-industry differences in patterns of R & D funding, how can they be explained? Taking machine tools first, the poor response to civil R & D contracts from the DSIR and Mintech as against the relative popularity of the Pre Production Order Scheme, especially when not restricted to particularly innovative machines, can it is argued be accounted for partly in terms of existing levels and the kind of intra-firm R & D conducted. In-house R & D provides a platform from which a firm can take more on board. It has the experience of conducting the activity, some of the basic necessary resources, and is already exhibiting a pro-R & D attitude. Without such a base it is restricted in its ability to formulate, argue for and execute projects part-funded by other bodies. However, it is still in a position to desire and attract support for new products incorporating design or minor technical changes rather than greater technical advances stemming from formal R & D. The establishment of academic centres of machine tool reseach, MTIRA, and later the IAMTCT, and the expansion of NEL's activities in this area can thus be viewed as attempts to supplant rather than supplement industrial R & D, and ones which were not likely to be effective in promoting innovation without an adequate industrial R & D base. Some division of research responsibilities occurred with the proliferation of institutional locations' with MTIRA concentrating on general research topics such as safety and vibration, while the other laboratories were more involved with generic research concerning NC, spindle speeds, bearings and slides, etc. The late establishment of machine tool research as an adacemic discipline is indicative of the DSIR's general failure to support technological research in higher education. (Chapter 3.2) The initially good response to MTIS R & D provisions suggests, according to the view just put forward, that firms were then in a better position to accommodate R & D but the later shortfall in take-up indicates the fragility of attitudes to R & D in times of recession.

Some of the same arguments can be put forward to explain patterns of state-funded R & D in textile machinery, although its comparative lack of state attention also has important implications. As with machine tools, a low level of in-house R & D meant that few development contracts could be awarded and that state institutions became the focus of R & D spending. With no tradition of textile machinery research at NEL or within academia the textile research associations became, even if by default, the centre of a wider range of research activities than did MTIRA, taking on board, for instance, contracts from the NRDC and DSIR specifically aimed at producing innovations rather than knowledge of a general utility. Once again the encouraging response to, but poor final take-up of monies under TMIS, indicates a changing attitude to and capability for research but ones still dependent upon immediate trading conditions.

The computers case study, however, reveals a different picture. All the firms involved in mainframe manufacture, that is ICL and its antecedents, conducted relatively large volumes of in-house R & D. Because of the pace of technical change in the industry much had to be close to the technological frontier. Universities with their bias toward fundamental research have been an appropriate home for other state-funded research although, as with the other two industries, specific funding was initiated rather late in the day. University designs were taken up by computer manufacturers and close collaboration evolved particularly between ICL (and previously Ferranti and ICT) and the University of Manchester. Such collaboration itself is based on the ability of the firm to incorporate a quickly changing corpus of new knowledge successfully, and thus on the existence and extent of its own R & D activities. With few firms involved and because of the nature of R & D performed there has been no need for a research association, although different circumstances pertain in the computer services industry.

The different patterns of state R & D funding toward these three industries therefore appear related to the existing and evolving institutional and industrial structures. The kind and level of R & D perfomed at different types of location - firms, universities etc. - was mediated by these structures. Funding to institutions largely served to supplant industry-based R & D in the machine tool and textile machinery industries but complement it in the computer study. Best transfer of state conducted R & D manifestly occurred with regard to computers which affirms the argument that it is dependent upon adequate levels of in-house research to be effective.

The next set of questions concern what was termed in Chapter 2 the supplier-user nexus. Success at innovation is strongly determined by the innovator's ability to grasp user needs which, it was argued, was best achieved through close contact with potential users when the product is being developed. It was also argued that successful innovation was additionally dependent upon the supplier's ability to offer as complete an array as necessary of services to the user in order to lessen uncertainty during and after adoption. Public assistance for product related services, however, only appear in the computer case study and took two restricted forms, the underwriting of various learning companies and support for the in-house development of applications software particularly at ICT.

The promotion of user needs was more widely represented but it was by no means extensive and was an implicit rather than an explicit policy objective. The Pre-Production Order Scheme institutionalised a means whereby users were involved in one stage of the innovation process, but this was intended to provide a realistic setting for working trials rather than to allow for a full and early understanding of user needs. Nonetheless any such contact before product launch would be valuable. A forum through which user needs could be well articulated was in theory available through the textile research associations, but there is little evidence that any such formal considerations were involved. MEMTRB's support for the 600 Group's pilot FMS installation gave an opportunity for 'supplier-user' contact in its most intimate form as the Group was a potential FMS supplier.

Perhaps the area in which most useful contact could have ensured was in the Government's direct support for ICL both as a provider of R & D funds and as a guaranteed source of orders. The ICL merger agreement, allowing the Government a say in the framing of the company's R & D policy, thus included a clearly defined procedure by which user requirements could be brought to notice during the course of development. However, it was argued in Chapter 4 that in the absence of a central body to coordinate all computer activities within government the possibilities of the Government's role were likely to have been dissipated.

It is also worthwhile noting here the IRC's £10m. loan to BLMC in 1970 to fund its machine tool purchases. The intention behind the loan was that the car firm would inform the IRC as to its wants, and the Corporation would then pass this information on to selected machine tool manufacturers to allow them to develop new machines as necessary knowing that there would be a market awaiting them. Within the scheme there was implicit scope for more direct contact between BLMC and potential suppliers, but in the event the forward looking provisions of the loan appeared to have been lain aside at the company's insistance under a new Government antipathetic to the IRC.

Little encouragement therefore has been given by the state to either strand of the user-supplier nexus but the few instances detailed of user-supplier contacts offer some suggestions for how they might be assisted. There is a difference between the situations when the state is a potential customer and when it is not. When it is, as many commentators have noted, the state is in a position to use its purchasing power to ensure that its own needs at least are heeded and the services it thinks appropriate are provided. For several goods, however, the state is only one of many purchasers and if it was to push its own specific requirements forward it would have to consider carefully if and how they coincided with those of other customers. In either case, the state could more powerfully affect the course of innovation by providing other support tied to procurement contracts.

When the state is not itself a customer it could nonetheless, as the IRC/BLMC example indicates, direct its investments in private companies to foster collaboration between suppliers and users to aid innovation. Such investments would of course require that their recipients accept the onus placed upon them to help specify lines of development and the delays before final delivery. But the intervention would have a dual impact, providing structured assistance to two or more companies with possibly more than the usual benefits accruing from a state investment.

The last set of points arising from Chapter 2 concerns the adoption and diffusion of innovations, in particular the need for policy to treat diffusion as an integral part of the process of innovation, and recognise the burdens placed on the innovating firm during diffusion, the importance of certain markets, and the technical and managerial demands of adoption.

Concurrent policies for the supply and diffusion of both computers and NC machine tools were pursued by the 1964-70 Labour Government. In each case diffusion burgeoned but effects of policy cannot be clearly established. The Trial Period Scheme, administered by the NRDC, attracted little take-up, while the NC Advisory and Demonostration Services, the only scheme observed in the case studies that was specifically aimed at individual adoptions, was not believed to be very effective by the Way Committee.

With regard to computers, investment grants subsidising the cost of adoption were open to machines of any national origin and their influence upon the domestic industry was thus likely to have been diluted. When grants were withdrawn the rate of diffusion slowed dramatically but, as argued in Chapter 4, there were a number of other factors involved at the time which would have impeded computer sales.

While in these two industries policies for diffusion were for a time meshed with those for the stimulation of innovation, no such cohesion was revealed in the textile machinery case study. Indeed, the one concerted scheme for stimulating development (TMIS) was introduced after the DTI had funded a capital investment scheme for the wool textile industry. Whatever the problems of establishing the effects of policy, it seems quite reasonable that the full innovation potential of TMIS was thus lessened by having missed this earlier wave of machinery investment.

A feature of the NRDC's early activities in the computer industry was its underwriting of first production batches thereby guaranteeing an initial if small market at a time before diffusion was truly underway. However, the most obvious example appearing in the case studies of a guaranteed market was the Government's computer procurement policy centred on ICL and its forerunners. One problem that has faced the computer industry in particular has been the advantages gained by American manufacturers by virtue of the greater and earlier development of their domestic market. They have consequently enjoyed economies of scale not open to the indigenous manufacturers of other countries and have been able to enter developing markets with ready proven products. With these advantages giving rise to fierce American competition and evidence that IBM attempted to dislodge existing ICL customers by offering special price discounts, without a secure central government market for its large machines it is difficult to believe that ICL would have survived through the

1970s. Conversely, with no similar privilege UK minicomputer makers were unable to compete once American firms arrived in the British market. Even if the British machines were initially not as good as their American rivials - and this is by no means certain - a secure market base would have at least provided some time to allow for the development of better successors. But in the event the British market was soon swamped and the independent UK minicomputer industry was lost.

It was suggested in Chapter 2 that particular user industries exerted an important but changing influence on the patterns of diffusion of some innovations. This influence results from characteristics specific to the technology and customers concerned. The computers and machine tool industries have heterogeneous market bases, but textile machinery has only a single though differentiated customer industry, textiles. Although UK textile machinery manufacturers have routinely exported a large proportion of their output, the role of the domestic market in sustaining orders and calling forth innovation should not be underestimated. But in spite of various schemes to promote investment, low levels have generally prevailed and with conservative tastes the possibilities of the textile industry's role have not been explored.

To some extent similar arguments can be applied to the more varied machine tool market. Domestic demand for machine tools dropped by a third between the 1950s and 1970s, while the especially important motor vehicle industry was particularly depressed from the middle sixties onwards. Without longer term continuing programmes of investment the incentive to innovate is likely to be reduced.

This short concluding review suggests that there was plenty of room for improvement in the innovation promoting content of policy pursued toward the three industries studies. However, the similarities and differences between the case studies together with the account of technology policy development in Chapter 3 can be used to highlight some more general characteristics of policy.

The case studies are arranged according to three time periods, pre-1964, 1964-1970,and 1970-1971, each coinciding with a particular phase in the development of policy. Prior to 1964 policy amounted to the separate activities of the DSIR and NRDC. Little direct Government control was exercised and each agency was allowed to determine its own policies very much as it wished. As a result, there was little coordination between them and in both the computer and machine tool case studies examples were recorded where the more interventionist NRDC supported university research or studentships, the proper responsibility of the DSIR.

The establishment of the Ministry of Technology in 1964 brought some measure of centralised control over policy as well as a greater emphasis upon technology per se. Plans were laid for both the computer and machine tool industries and more wide ranging and interventionist systems of support for both were introduced. New agencies and schemes proliferated but, often without a clear guiding rationale or purpose, their areas of responsibility frequently continued to overlap. Some like the NC Trial Period Scheme and IAMTCT were short lived. Even under Mintech's wing the NRDC and IRC essentially formulated their own policies, although both at times showed signs of coordinating their activities with those originating elsewhere. In one example, British Northrop Ltd. received related support from the NRDC and under the Pre-Production Order Scheme for two different projects.

A feature of policy from this period which continued through the next decade was the way in which short-term (not short-lived) measures began to be mingled with those with longer term objectives. Possibly, one-off schemes like the various machine tool stockbuilding exercises and the ad hoc rescues of firms like Alfred Herbert can be regarded as inevitable consequences of a stronger interventionist ethos. But it can also be argued that while quick action may be forced by a crisis, inability to foresee it and attempt to deal with it beforehand indicates a lack of good information and a well articulated plan for how policy should deal with such matters.

After policy was reversed in the first couple of years in the 1970s, during which time some of the apparatus built up over the previous few years was dismantled, it soon returned to the earlier interventionist approach of the 1964-1970 period. Although the Requirements Boards represented an attempt to rationalise industrial R & D support from central government, the formulation and conduct of technology policy remained spread across a number of schemes and agencies. However, in the absence of stated policy objectives, policy for instance toward the mahcine tool and computer industries hardly developed. Machine tool policy was dominated by rescues, in particular that of Alfred Herbert Ltd. Policy toward computers too ossified around one company, although assistance to ICL cannot be compared with that for Alfred Herbert. By its concentration upon ICL and the identification of Government policy with ICL's commercial policy, opportunities to help the emergent minicomputer and peripherals fields were ignored. However, the advantages of a pluralistic policy apparatus were displayed by the activities of the NRDC and especially NEB to strengthen the computer services industry. Policy toward the textile machinery industry, however, did progress in the sense that only from the late 1960s did it become subject to state attention in its own right.

Changes in Government usually presaged some reorganisation but overall the technology policy framework has developed by addition and abolition, principlally addition, rather than by any fundamental restructuring. Without clear objectives, new responsibilities have been vested in new schemes and new agencies rather than given to existing bodies. Taking machine tools as an example, by the late 1970s assistance for intra-firm R & D in one form or another was available from MEMTRB, NRDC, NEB, SRC, and under MTIS and PPDS. The outcome was thus an increasingly complex structure without a clear definition of roles and purposes, a complaint made by the Trend Committee fifteen years earlier when the whole structure was much simpler.

The effectiveness of policy too was likely to have been adversely affected by the conflicting responsibilities of central Government departments. In the case of computers, for instance, disputes over preference for ICL occurred between the company's sponsoring department and purchasing departments. Moreover, the split of the UK computer market into civil and military applications, with ICL restricted to the former, led to essentially two parallel industries, with probably some unhelpful duplication of effort and state support.

Reference to the Trend Report leads to a related point concerning the acceptance or otherwise by Governments of advice from its own or other officially commissioned reports. On the basis of those referred to in Chapter 3-6 it could be posited that Governments do not often act on such advice. The recommendations of the Trend Report and the Ministry of Technology's Green Paper on the reorganisation of publicly funded R & D were not taken up but those of the Rothschild Report were. With regard to machine tools, the DSIR acted on its own report but little attempt was made to redress the major deficiencies outlined in the contemporaneous Mitchell Report, which rejected the conclusions of the Melman Report, or act on the proposals of the Way Committee a decade later. In between, the recommendations of Mintech's Working Party on the industry's cyclical problems with respect to stockpiling schemes went unheeded by that and the later Labour Government. The Select Committee on Science and Technology's Report on the UK computer industry, too met a similar fate. On the other hand, the Evershed Committee's Report on the textile machinery industry required no consequent state action unless plans for greater investment in the cotton industry had made it necessary.

To a certain extent, the reception given these Reports can be explained in terms of the political attitudes of the Government of the day. Those Reports commissioned by a previous Government have been ignored (the Way Report), or rejected in favour of policy proposals either constructed in opposition (the Trend Report) or put forward in another Report ordered by the new administration (the Mintech Green Paper) and the Rothschild Report). Reports too have had to reflect the views of the Government on industrial assistance to be acceptable. Thus the Way and Select Committee Reports were not acted upon by the Conservative Government because they advocated increased state support. Conversely, the recommendations not to institute stockpiling schemes was not complied with because the whole ethos of Mintech was based on action rather than inaction. The foregoing points help to underline the potential nature and context of technology policy. However, the politics involved extend beyond the Party political arena to the battles for influence between various sectional interest groups in the formulation of policy. The most obvious examples come from the computer case study to which the following paragraphs refer.

ICT's appointment of a Government Relations Officer in 1964, together with the wide distribution of a document in which the company presented its own version of how UK computer policy ought to be composed, marked the company's recognition of the influence it could exert upon a Government willing to intervene in industry but without ready formulated plans. Mintech's subsequent procurement policy operated secretly because of the Ministry's need to balance its sponsorship of the indigenous industry with the desire to encourage American firms to invest in the development areas. Once the limits of the policy became public the US companies fought to stop its extension either to a wider range of computing equipment or to a larger customer base. Honeywell's threats to decamp to France and its court action against the Anglian Water Authority showed its unwillingness to accept greate public preferene for UK-owned firms.

In a sense, Honeywell's threats demonstrate some of reasons why successive British Governments have succoured a British-owned industry and prevented its control passing to foreign owned multinationals able to relocate their operations subject to decisions made without reference to the needs of the British economy or strategic interests. The US Government's long standing influence over computer equipment exports to the Iron Curtain countries and its blockage of a sale of two large computers to France, though later rescinded, further exposed the dangers of technological dependence. But although successive Governments have shown a certain suspicion, therefore, of American computer firms, they have displayed some willingness to promote a pan-European computer industry involving ICL which would have furthered UK ambitions in the Economic Community.

Whilst there is, as remarked, plenty of scope to increase the innovation capability of policy measures, their effectiveness is also constrained by various other factors. This thesis has shown that policy is spread across a number of agencies and schemes with overlapping responsibilities : a more rational structure with a clear definition of roles and objectives and ensuring better coordination would not go amiss. But policy is not only a matter of content and organisation it is also a matter of political attitudes and imperatives : they too need to be considered and addressed in the formulation and execution of policy.

Much of this concluding discussion has dwelt on the innovation content of policy and thus its ability to positively affect technical change. The expanding literature of innovation is likely to provide further insights into how policy influences the behaviour of individual firms. More empirical studies at the company or project level, exploring the ramifications of policy and its precise effects upon how firms operate, would enrich the literature considerably. In particular, a firm's long term experience of an reactions to policy would be especially illuminating. But, as argued in the Introduction, specific examinations of single projects or policy measures need to be complemented by wider studies whose purpose is to detail the development and general characteristics of policy.

Parallel case studies of technology policy in other countries, particularly focussing on industries where performance has diverged from the UK experience, would introduce a new element into the debates about institutional structures and the funding and volume of support. However, UK technology policy toward many important industries has yet to be detailed. How far the case studies presented in this thesis are representative remains open to question, but the differences they display suggests that within the broad confines of technology policy there may be considerble variations also in the experiences of other industries.

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15. DSIR. Annual report, 1947/48. London, HMSO, 1949. p. 16.

16. DSIR. Annual report, 1948/49. London, HMSO, 1950. p. 12. It was also stated that fundamental research had been neglected during the War and needed a reasonable amount of effort devoted to it.

17. ACSP. Annual report, 1947/48. ... op. cit., p. 9.

18. Committee on Industrial Productivity. First report. London, HMSO, 1949. p. 16. See also the Committee's Second report. London, HMSO, 1950.

19. DSIR Annual report, 1947/48...op. cit. p. 3.

20. DSIR. Annual report, 1954/55. London, HMSO, 1955. p. 13.

21. Moseley, R. Science, government and industrial research ... op. cit., p. 292.

22. Manchester Joint Research Council. Industry and science. Manchester University Press, 1954.

23. DSIR. Report of a Committee of Enquiry (Cmnd. 9734). London, HMSO, 1956. p. 1.

24. Department of Scientific and Industrial Research Act, 1956. Para. 1.

25. The first of these was open at the Royal College for Science and Technology, Glasgow in 1958.

26. ACSP. Annual report 1959/60. London, HMSO, 1960. p. 12.

27. King, A. Science and management. The Manager, 23, 507-511, 1955. A similar view was also expressed by other DSIR staff, see, Thorogood, A. L. Technical knowledge - key to

production. Liverpool Trade Review, 57, 69-71, 1952, and, Urquart, D. J. New ideas and the small firm. Aslib Proceedings, 7, 15-22, 1955.

26. DSIR. Estimates of resources devoted to scientific and engineering research and development in British manufacturing industry, 1955. London HMSO, 1958; DSIR. Industrial research and development expenditure, 1958. London. HMSO, 1960.

27. DSIR. Research and development requirements of the shipbuilding and marine engineering industries. London, HMSO, 1960.

30. DSIR. Engineering design. London, HMSO, 1963.

31. ACSP. Annual report, 1952/53. London, HMSO, 1953. p. 7.

32. DSIR. Annual report, 1952/53. London, HMSO, 1953. p. 25.

33. ACSP. Annual report, 1959/60 ... op. cit., p. 11

34. DSIR. Annual report, 1963. London, HMSO, 1964. p. 11.

35. Keith, S. T. Inventions, patents, and commerical development from Government financed research in Great Britain : the origins of the National Research Development Corporation. Minerva, 19, 92-122, 1981.

36. Keith, S. T. The National Research Development Corporation, 1949-1964. (Unpublished M.Sc. Thesis, University of Aston, 1978). p. 32.

37. ibid.

38. It is also in some contradiction to Keith's point, ref. 37.

39. NRDC. Annual report, 1971/72. London, 1972. p. 8.

40. Ministry of Defence. Defence : outline of future policy (Cmnd. 124). London, HMSO, 1957.

41. Carter, C. & Williams, B. Science in industry : policy for progress. London, Oxford Univeristy Press, 1959. p. 103.

42. Shanks, M. The stagnant society. Harmondsworth, Penguin, 1961. p. 198.

43. Vig, N. Science and technology in British politics. London, Pergomon, 1968. p. 68

44. Office of the Minister for Science. The management and control of research and development. London, HMSO, 1961.

45. Report of the Committee of Enquiry into the Organisation of Civil Science. (Cmnd. 2171) London, HMSO, 1963. p. 22.

46. ibid., p. 25.

47. Vig, N., op. cit., p. 51 ; see also Rose, H. & Rose, S., op. cit., pp. 88-91.

48. Conservative Political Centre. Science in industry : the influence of government policy. London, 1962.

49. Conservative Party. Prosperity with a purpose. London, 1964.

50. Vig, N., op. cit., p. 80.

51. Labour Party. Let's go with Labour for the New Britain. London, 1964.

52. For an account of the DEA see Roll, E. The machinery for economic planning : 1. The Department of Economic Affairs. Public Administration, 44, 1-11, 1966.

53. Department of Economic Affairs. The National Plan. (Cmnd. 2764). London, HMSO, 1965. For accounts of the fate of the Plan, see Opie, R. Economic planning and growth, pp. 157-177, in Beckerman, W. (ed.) The Labour Government economic record, 1964-1970. London, Duckworth, 1972, and Budd, A., op. cit.

54. See Gummett, P. J. & Williams, R. Assessing the Council for Scientific Policy. Nature, 240, 329-332, 1972, and Gummett, P. J. Aspects of recent British Science policy, with particular reference to the Council for Scientific Policy. (Unpublished M.Sc. Thesis, University of Manchester, 1971).

55. A large amount of evidence on this point was collected, for instance Neild, R. R. Replacment policy. National Institute Economic Review, 27, 30-43, 1964; Treasury. Report of the Committee on Taxation Turnover. (Cmnd. 2300). London, HMSO, 1964; National Economic Development Council. Investment in machine tools. London, HMSO, 1965. For a short discussion of the political arguments of the changeover see Beckerman, W. op. cit., pp. 35-36.

56. Department of Economic Affairs. Public purchasing and industrial efficiency. (Cmnd. 3291) London, HMSO, 1967.

57. The Board was established under the Shipbuilding Industry Act, 1967, the result of the Board of Trade. Report of the Shipbuilding Inquiry Committee, 1965-66. (Cmnd. 2937). London, HMSO, 1966. (The Geddes Report).

58. See Ministry of Aviation. Report of the Committee of Inquiry into the Aircraft Industry. (Cmnd. 2853). London HMSO, 1966.

59. Maddock, I. Stimulating technological innovation in industry : the role of the Ministry of Technology. Proceedings of the Institute of Mechanical Engineers, 182, 685-701, 1968. p. 687.

60. Ministry of Technology. Industrial expansion. (Cmnd. 3509). London, HMSO, 1968. p. 3.

61. Industrial Expansion Act, 1968, para 2.

62. Ministry of Technology. *Industrial expansion...op. cit.*, p. 2.

63. See Ministry of Technology. *The Aluminium Industry (Invergordon Project) Scheme 1968, and the Aluminium Industry (Anglesey Project) Scheme 1968.* (Cmnd. 3819). London, HMSO. 1969.

64. Labour Party. *Lets go with Labour... op. cit.*

65. Ministry of Technology. *The Ministry of Technology.* London, HMSO, 1967. p.1.

66. Rose, H. & Rose, S., *op. cit.* 119.

67. Ministry of Technology, *The Ministry of Technology, op. cit.*, p. 2.

68. This has been remarked upon by the Roses, *op. cit.*, p. 124. Science and technology attracted twelve mentions in the Labour Party's 1964 General Election manifesto, including three on the first page, but only three in the 1966 Election manifesto, all relegated to its small print.

69. Williams, B. R. Research and economic growth - what should we expect. *Minerva, 3,* 57-71, 1964. During this period Williams had a close relationship with the Labour Party (Vig, N. *op.cit.*, p. 92) and it is reported that at the first meeting of the ACT that Benn attended as Minister (Beesley, M. & Mencher, A. G. Managing intervention : an interpretation of the Mintech experience. *London Business School Journal, 2* (1), 5-12, 24, 1976) this paper was presented with great effect. Due recognition of William's work appeared in Wedgwood Benn, A. *The Government's policy for technology.* (A special lecture given at Imperial College of Science and Technology, 17 October 1967). London, Ministry of Technology 1967.

70. Dell, E. Political responsibility and industry. London, George Allen & Unwin, 1973. pp. 35-36. Dell was Parliamentary Secretary at Mintech at this time.

71. Wedgwood Benn, A. Yesterday's men at Mintech. New Statesman, 80, 76-77, 24 July 197

72. Mencher, A. G. Lessons for American policy making from the British Labor Government's 1964-1970 experience in applying technology to economic objectives. (Sic). London, Graduate School of Business Studies, 1975. p. 69.

73. ibid, p. 73.

74. Wedgwood Benn, A. The Government's policy for technology, op. cit., p. 9.

75. Wilson, H. Labour's plan for science. London, Labour Party, 1963. A reprint of Wilson's speech to the Party's Annual Conference, Scarborough, 1 October 1963.

76. Wedgwood Benn, A. Mintech at the beginning of 1967. New Technology, 1 1-2, Jan 1967. p. 1.

77. Blackett, P.M.S. Memorandum to the Select Committee on Science and Technology. Nature, 219, 1107-1110, 1968. Blackett was Deputy-Chairman of the ACT.

78. Blackett, P.M.S. Blackett on British technology. Nature, 213, 755, 1967.

79. Ministry of Technology. The Ministry of Technology, op. cit., p.2.

80. Clarke, R. Mintech in retrospect. Omega, 1, 25-38, 137-163, 1973. Sir Richard was Permanent Secretary at Mintech from 1966-1970.

81. ibid.

82. Wilson, H. The Labour Government, 1964-1970 : a personal record. London, Weidenfeld & Michael Joseph, 1971. pp. 708-710.

83. Civil Supply Estimates, appropriate years.

84. Central Statistical Office. Research and development expenditure. (Official Studies in Statistics, 21). London, HMSO, 1973: Bowles, J. R. Research and development : expenditure and employment in the seventies. Economic Trends, 334, 94-111, August 1981.

85. Industrial Reorganisation Corporation Act, 1966.

86. Young, S. & Lowe, A. ., op. cit., p. 51.

87. IRC. Report, 1969. London 1969. p. 8..

88. These are listed in Young, S. & Lowe, A.V. op. cit., p. 231-236. In addition the IRC conducted various enquiries for Government agencies.

89. ibid., pp. 60-65 for a discussion of these critria.

90. Hills, J. The Industrial Reorganisation Corporation : the case of the AEI/GEC and English Electric/GEC mergers. Public Administration, 59, 63-84, 1981.

91. Using deflators taken from Bowles, J. R., op. cit., p. 108, the SRC's expenditures in 1965/66, 1972/73, and 1978/79 at 1975 prices were £72.5m., £109m., and £105.8m. respectively.

92. SRC. Report, 1966/67. London, 1967. p.5.

93. SRC. Report, 1968/69. London, 1969. p. 1.

94. SRC. Report, 1973/74. London, 1974. p. 27.

95. For a critical discussion of these policies; see Farina, C. & Gibbons, M. A quantitative analysis of the Science Research Council's policy of 'selectivity and concentration'. Research Policy, 8, 306-338, 1979.

96. For a complete list, see SRC. Report, 1978/79. London, 1979. p.30.

97. SRC. Reports, appropriate years. These figures, because of the introduction of a new classificatory scheme, are not comparable to earlier DSIR ones.

98. SRC. Reports, appropriate years. Again these figures are not strictly comparable to earlier DSIR ones for the reasons given above.

99. Blackett, P.M.S. Blackett on British technology, op. cit.

100. Wedgwood Benn, A. The Government's policy for technology, op. cit.

101. Central Advisory Committee for Science and Technology. Technological innovation in Britain. London, HMSO, 1968. p.16.

102. Ministry of Technology. Industrial research and development in Government laboratories : a new organisation for the seventies. London, HMSO, 1970. p. 11.

103. ibid.

104. Conservative Party. A better tomorrow. London, 1970.

105. ibid.

106. Keith Joseph in a speech 24 January 1970, quoted in Young, S. & Lowe, A. V., op. cit., p. 122.

107. Grant, W. The political economy of industrial policy. London, Butterworth, 1982. p. 50.

108. DTI. Industrial and regional development. (Cmnd. 4942). London, HMSO, 1972. p.1.

109. For a discussion of the NEDC's new role, see Leruez, J. Macroeconomic planning in mixed economies : the French and British experience, pp. 26-52, in, Hayward, J. & Narkiewicz, O. A. (eds.) Planning in Europe. London, Croom Helm, 1978.

110. Treasury/DoI. An approach to industrial strategy. (Cmnd. 6315). London, HMSO, 1975.

111. For an account of state intervention in North Sea oil exploitation, see Jenkin, M. British industry and the North Sea. London, Macmillan, 1981.

112. In 1976 two committees were established to review this role of financial institutions, a joint NEDO-Bank of England Committee on Finance for Investment, and the Wilson Committee, Report of the Committee to Review the Functioning of the Financial Institutions. (Cmnd. 7937) London, HMSO, 1980. For an account of their role, see Zysman, J. Governments, markets and growth. Oxford, Robertson, 1983.

113. Civil Service Deparment. Reorganisation of central government. (Cmnd. 4506) London, HMSO, 1970. p.8.

114. ibid.

115. John Davies, Secretary of State for Trade and Industry, quoted in Young, S. & Lowe, A. V., op. cit., p. 147.

116. Civil Service Department, op. cit., pp. 8-9.

117. Young, S. & Lowe, A.V., op. cit., p. 137.

118. For instance, assistance to ICL, Chapter 4.5.

119. Young, S. Industrial policy in Britain, 1972-77, pp. 77-99, in, Hayward, J. & Narkiewicz, O. (eds), op. cit.

120. Sectoral schemes were initiated for the clothing, ferrous and non-ferrous foundry, paper and board, poultry and meat processing, footwear, drop forging, red meat slaughtering, instrumentation and electronic component industries, as well as those already mentioned. See Fleming, M.C. Industrial policy, pp. 141-168, in, Maunder P. (ed.) The British economy in the 1970s. London, Heinemann, 1980.

121. For instance, Central Advisory Committee for Science and Technology, op. cit.

122. See Fleming, M. C., op. cit.

123. Calculated from Bowles, J. R., op. cit.

124. Hill, J. Information technology and industrial policy. London, Croom Helm, 1984. pp. 203-222.

125. ibid., p. 219. After MAP had been launched, ACARD. The application of semiconductor technology. London, HMSO, 1978 largely concurred with the Project aims.

126. For descriptions of MAP, see Northcott, J. et. al. Microprocessors in manufactured products. (PSI, 590). London, Policy Studies Institute, 1980; Northcott, J. Policies for micro electronic applications in industry, pp. 213-224, in, Carter, C. (ed.) Industrial policy and innovation. London, Heinemann, 1981.

127. A framework for Government research and development. (Cmnd. 4814). London, HMSO, 1972. p. 3.

128. Framework for Government research and development. (Cmnd. 5046). London, HMSO, 1972; Williams, R. Independence and accountability after Rothschild. R & D Management, 2 131-135, 1972. For a discussion of consequent changes in other government departments see Gibbons, M & Gummett, P. Recent changes in the administration of Government research and development in Britain. Public Administration, 54, 247-266, 1976; and of its political repercussions Williams, R. Some political aspects of the Rothschild affair. Science Studies, 3, 31-46, 1973.

129. DTI. The non-reactor research and development activities of the Atomic Energy Authority and the industrial research establishments of the Department of Trade and Industry. (Cmnd. 5176). London, HMSO, 1972. p. 10.

130 Jeuan Maddock in evidence to House of Commons Select Committe on science and Technology. Research and development : minutes of evidence and apprendices. (Session 1971/72, HC 375). London, HMSO, 1972. p. 465.

131. DTI. The non-reactor..., op. cit., p. 11.

132. Oakley, B. The customer-contractor principle : first four years. Physics in Technology, 8, 179-183, 1977.

133. DoI. The regeneration of British industry. (Cmnd. 5710). London, HMSO, 1974.

134. Ganz, G. Government and industry : the provision of financial assistance to industry and its control. Abingdon, Professional Books, 1977. p. 51.

135. DoI. The National Enterprise Board : guidelines. London, 1977. Also published in NEB. Annual report, 1976. London, 1977. Appendix B.

136. Parr, M. The National Enterprise Board. National Westminister Bank Quarterly Review, 57-62, February 1979.

137. Fleming, M. C., op. cit., p. 149.

138. Hills, J. Information technology... op. cit., pp. 206-217.

139. OECD. Trends in industrial R & D, 1967-1975. Paris, 1979.

140. Maddock, I. Science, technology and society. Proceedings of the Royal Society, 345, 295-326, 1975.

141. Hills, J. Information technology...op. cit., p. 65.

142. See for instance Dickson, K. The influence of Ministry of Defence funding on semiconductor research and development in the United Kingdom. Research Policy, 12, 113-120, 1983.

CHAPTER FOUR

Note. Between 1969 and 1974 the House of Commons Select Committee on Science and Technology took evidence and reported on the UK computer industry. In order of publication its reports are:

<u>UK computer industry. 2 vols.</u> (Session 1969/70, HC 137, 272). London, HMSO, 1970.

<u>The prospects for the UK computer industry in the 1970s. 2 vols.</u> (Session 1970/71, HC 621 - I, II, III). London, HMSO, 1971.

<u>The prospects for the UK computer industry in the 1970s: reply by the Department of Trade and Industry.</u> (Session 1971/72, HC 473). London, HMSO, 1972.

<u>Minutes of evidence.</u> (Session 1972/73, HC 97 - I). London, HMSO, 1973.

<u>Second report on the UK computer industry.</u> (Session 1972/73, HC 309). London, HMSO, 1974.

<u>Minutes of evidence, 24 June 1974.</u> (Session 1974, HC 199 - I). London, HMSO, 1974.

For the sake of brevity they are referred to in this chapter's references in the form SCST ... (Session X, HCY), <u>op.cit.</u>

1. For useful histories of computer technology see: Metropolis, N. et al. A History of computing in the twentieth century: a collection of essays. London, Academic Press, 1960. Atherton, W. From compass to computer. San Francisco Press, 1984. pp. 269-309.

2. SCST ... (Session 1969/70, HC 137), op.cit., pp. 10-11. On the basis of a crude analysis of trade and production data for 1978, cpus and complete computer systems accounted for 32% of all UK deliveries by value, suggesting that the relative cost of cpus to total hardware is falling.

3. Stoneman, P. Technological diffusion and the computer revolution: the UK experience. Cambridge U.P., 1976. p.17.

4. Imitating IBM. Economist, 264, 64-65, 13 Aug 1977.

5. Hoffmann, W.D. Market structure and the strategies of R & D behaviour in the data processing market. Research Policy, 5, 334-353, 1976.

6. Brock, G.W. The US computer industry: a study of market power. Cambridge, Ballinger, 1975.

7. OECD. Electronic computers. Paris, 1969. pp.66-67.

8. Stoneman, P. Computers, pp.154-178, in, Johnson, P.S. (ed) The structure of British industry. London, Granada, 1980.

9. Katz, B.G. & Phillips, A. The computer industry, pp. 162-232, in, Nelson, R.R. (ed.) Government and technical progress. New York, Pergamon Press, 1982; Lavington, S.H. Early British computers. Manchester U.P., 1980; Rosen, S. Electronic computers: a historical survey. Computing Surveys, 1, 7-36, 1969.

10. Wilkes, M.V. Early computer developments at Cambridge: the EDSAC. _Radio and Electronic Engineer_, _45_, 332-335, 1975.

11. Booth, A.D. Computers in the University of London, 1945-1962. _ibid_, 341-345.

12. Williams, F.C. Early computers at Manchester University. _ibid_, 327-331.

13. Wilkinson, J.H. The pilot ACE at the National Physical Laboratory. _Ibid_, 336-340.

14. Clarke, S.L.H. The Elliott 400 series and before. _Ibid_, 415-421.

15. The hardware construction of the pilot ACE was subcontracted to the GPO for about a year; NPL. _Report, 1946_. London, HMSO, 1947, p.33; Wilkinson, J.H., _op.cit._

16. The Royal Society gave£35,000 in 1946. Lovell, S.J.B. Patrick Maynard Stuart Blackett. _Biographical Memoirs of Fellows of the Royal Society_, _21_, 1-115, 1975. p.48.

17. Williams, F.C., _op.cit._

18. Wilkes, M.V., _op.cit._

19. Wilkinson, J.H., _op.cit._

20. Lavington, S.H., _op.cit._, p.25.

21. Public Records Office DSIR 10, 317. H-SCM Paper 1.

22. _Ibid._, Paper 4.

23. Lord Halsbury, Managing Director, NRDC, in evidence to House of Commons Committee of Public Accounts. _Special Report and First, Second and Third Reports_. (Session 1957/58, HC 67-I, HC 106-I, HC 213-I, HC 256-I). London, HMSO, 1958. Q.4886. The Manchester patents concerned the invention of a cathode ray tube storage device.

24. Invitations were issued to British Tabulating Machinery, British Thomson-Houston, EMI, Elliott Bros., English Electric, Ferranti, GEC, Metropolitan Vickers, Plessey, Powers-Samas, Radio Communications and Electronic Engineering Association, and STC. The first and only meeting of the Panel was held on 14 December 1949. Public Records Office, op.cit, H-S CM Paper 12.

25. First and only meeting, 24 January 1950. Ibid, H-S CM Paper 14.

26. Public Records Office, op.cit, H-S CM Paper 15.

27. Lord Halsbury. Ten years of computer development. Computer Journal, 1, 153-159, 1959.

28. Public Records Office, op.cit, H-S CM Paper 18.

29. Drath, P. et al. The super-computer project: a case study of the interaction of science, government and industry in the UK. Research Policy, 6, 2-34, 1977; Scholes, J.F.M. A review of computer projects with industry, 1950-1975. (ECR 288). London, NRDC, 1975.

30. Public Records Office, op.cit., H-S CM Paper 31.

31. Drath, P. et al, op.cit; Schoels, J.F.M., op.cit.

32. Drath, P. The relationship between science and technology: university research and the computer industry, 1945-1962. (Unpublished Ph.D. Thesis, Victoria University of Manchester, 1973). pp. 3-21, 21.

33. Scholes, J.F.M., op.cit.

34. NRDC. Report 1955/56. London, HMSO, 1956. p.2.

35. Drath, P., op.cit.

36. NRDC. Report, 1956/57. London, HMSO, 1957. p.3.

37. Drath, P. *et al*, *op.cit.*

38. Scholes, J.F.M., *op.cit.*

39. NRDC. *Report 1953/54.* London, HMSO, 1953. p.6.

40. NRDC. *Report, 1966/67.* London, HMSO, 1967. p.53; Scholes, J.F.M. *op.cit.*

41. See *Inventions for Industry: Bulletin of the NRDC*, no.29, pp.19-20, Dec. 1966.

42. NRDC. *Report, 1955/56*, *op.cit*, p.2.

43. NRDC. *Report, 1959/60.* London, HMSO, 1960. p.14; - *Report, 1960/61.* London, HMSO, 1961. pp.15-16.

44. NRDC. *Report, 1954/55.* London, HMSO, 1955. pp.1-2.

45. NRDC. *Report, 1956/57*, *op.cit.*, p.4; - *Report, 1957/58.* London, HMSO, 1958. pp.2-3.

46. NRDC. *Report, 1956/57*, *op.cit.*, p.4.

47. 59 from universities, 30 from government, and 10 from industry. NRDC. *Report, 1951/52.* London, HMSO, 1952. p.8.

48. Lavington, S.H., *op.cit*, p.104.

49. House of Commons Committee of Public Accounts, *op.cit*, Q.4852-3.

50. NRDC. *Report, 1956/57*, *op.cit*, p.3; but see House of Commons Committee of Public Accounts, *op.cit.*, Q 4885 for further details.

51. Freeman, C. Research and development in electronic capital goods. *National Institute Economic Review*, *34*, 40-91, Nov. 1965. p.58.

52. NRDC. *Report, 1953/54.* London, HMSO, 1954.

53. House of Commons Committee of Public Accounts, *op.cit*, Q 4852-3.

54. Scholes, J.F.M., *op.cit.*

55. Note by H.J. Crawley, appended as a foreward to Scholes, J.F.M., *op.cit.* Crawley was at one time the NRDC's representative on the Brunt Committee.

56. NPL. *Report, 1948.* London, HMSO, 1949. p.2.

57. Haley, A.C.D. The inconspicuous computer. *Radio and Electronic Engineer,* *45,* 409-410, 1975. states that almost 50 were sold, Lavington, *op.cit,* 31, while Freeman, C., *op.cit.* finds that 32 were still installed in Britain in 1965.

58. NPL. *Report, 1958.* London, HMSO, 1959. p.3.

59. NPL. *Report, 1959.* London, HMSO, 1960. p.5.

60. NPL. *Report, 1960.* London, HMSO, 1961. p.60.

61. *Times,* p.6., 18 Nov. 1958.

62. *D.W. Davies: interview carried out by C. Evans.* (Pioneers in computing, 1). London, Science Museum, 1975. (Tape cassette).

63. NPL. *Report, 1957.* London, HMSO, 1958. p.2.

64. A separate Electronics Section was established at NPL in 1948 and charged with the application of control techniques in industry and the development of ACE. In 1954 this section became the CME Division.

65. Later document retrieval was added as a further section.

66. Previously the CME Division was the smallest at NPL. In 1955, for instance, it had just 10 senior scientific staff.

67. DSIR. *Report, 1961.* London, HMSO, 1962. p.11.

68. SCST... (Session 1970/17, HC 621-II), *op.cit.*, p.327.

69.

Firm	Topic	Total Amount*	Dates
Elliott Bros	Optoelectronics	£8,000	6.7.64-25.8.65
"	Tunnel diodes	£75,000	30.4.64-30.9.66
Ferranti	Integrated circuits	£24,000	"
ICT	Design of an experimental computer	£63,000	1.11.64-30.9.66
Mullard	Cryotron stores	£100,000	1.5.63-30.11.65
Plessey	Integrated circuits	£100,000	"
STC	Spark machining of masks	£30,000	1.1.64-31.12.65
"	Automatic maintenance (i)	£9,000	1.1.64-31.12.64
"	Automatic maintenance (ii)	£52,000	1.1.65-30.4.67

SCST ... (Session 1970/71, HC 621-II), op.cit, pp.332-4; HoCPD, 707, 264-6w, 3 March 1965.

* DSIR contribution is half of this amount.

70. DSIR. Report, 1964. London, HMSO, 1965. pp.14-15.

71. BTM first undertook the manufacture of computers to a design developed at Birkbeck College, London. A prototype, the HEC 1, was exhibited in 1953, and marketed as the BTM 1200 in 1954. The first commercial data processing version, the BTM

1201, was launched in 1956, with eventual sales of 70. (Booth, A.D., op.cit.,; Lavington, S.H., op.cit. p.64.) LEO Computers was formed in 1954 as a subsidiary of J. Lyons & Co. Ltd. the catering firm. Lyons had previously helped to fund the Cambridge University Computer Group, where EDSAC was re-engineered to become the LEO 1, which was installed at Lyons by the end of 1953 carrying out a full data processing service. However, a LEO computer was not delivered to another company until 1957. (Pinkerton, J.M.M. Performance problems with LEO 1. Radio and Electronic Engineer, 45, 411-414, 1975.

72. Goldsmith, J.A. The state of the art - (a) Commercial computers in Britain, June 1959. Computer Journal, 2, 97-99, 1960. Goldsmith estimates that 2 computers were installed for commercial purposes by June 1956 and 7 by a year later. Drath, P. op.cit, p.3-21, estimates that 6 dp computers were installed by end of 1966.

73. DSIR. Wage accounting by electronic computer. London, HMSO, 1956. p.1.

74. Ibid., p.51.

75. Concern in British computer industry. Times, p.17, 11 March 1959.

76. Economist, 196, 308, 16 July 1960.

77. Concern in British computer industry, op.cit.

78. OECD. op.cit., p.131.

79. HoCPD, 693, 205w, 23 April 1964.

80. Organisation for European Economic Cooperation. Integrated data processing and computers. (EPA Project 6/02B). 2nd ed. Paris, 1961.

81. Computers in management control: Continent outpacing Britain. Times, p.23, 21 Sept 1960.

82. British backwardness in computer industry. Times, p.19, 29 Nov 1960.

83. Times, p.15, 10 July 1962; see also Economist, 204, 178-9, 14 July 1962.

84. Economist, 208, 532-3, 10 Aug 1963. The takeover "strikes most people as a welcome further rationalisation of the still irrational computer industry."

85. Ferranti, B.Z. de & Swann, B.B. The history of Ferranti computers. Radio and Electronic Engineer, 45, 422-426, 1975.

86. Economist, 206, 630, 16 Feb 1963.

87. Wilson, H. The Labour Government, 1964-1970: a personal record. London, Weidenfeld and Nicolson & Joseph, 1971. p.9.

88. Ibid.

89. See Hills, J. Information technology and industrial policy. London, Croom Helm, 1984. pp. 153-154. More generally, Hills provides an excellent account of government policy toward computers, microelectronics, and microelectronics, 1964-1982, from a political science point of view.

90. Wilson, H., op.cit., p.90.

91. Murphy, B.M. The development of the British, French and German native computer industries, 1960-1978, pp. 873-878, in, Lavington, S.H. (ed.) Information processing 80. Amsterdam, North-Holland, 1980.

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93. Computer eats computer. *Economist*, *212*, 1251-3, 26 Sept 1964.

94. *HoCPD*, *707*, 924-928, 1 March 1965.

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101. *Ibid*.

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110. Campbell, D. Resisting IBM: the politics of the great computer war. New Statesman, 95, 628-630, 12 May 1978; Data Systems, pp.18, 67, Oct. 1968; Data Systems, pp.14, 35, Nov 1968.

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114. Ibid., 710, 22w, 14 April 1965.

115. Ibid., 722, 226, 7 Dec. 1965.

116. Ibid., 722, 406-7w, 21 Dec. 1965.

117. Ibid., 723, 185w, 1 Feb. 1966.

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119. Dr. J. Bray, interview, op.cit.

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121. Hills, J. Information technology ... op.cit, p.160.

122. HoCPD, 721, 53w, 23 Nov. 1965.

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124. Ibid., pp.106-112.

125. Ibid., p.335; New Technology, no.13, 4, Jan 1968.

126. SCST ... (Session 1970/71, HC 621-II), op.cit., p.335; Ministry of Technology. Ministry of Technology. London, HMSO, 1967, p.4.

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128. Report of the Comptroller and Auditor General, pp.66-70, in, NRDC. Report, 1966/67. London, HMSO, 1967.

129. NRDC. Evidence offered to the Committee to Review the Functioning of Financial Institutions (The Wilson Committee). London, 1978. p.28. A total of £ 6,736,074 was repaid representing a gross profit of more than£2.7m.

130. Scholes, J.F.M., op.cit.

131. Ibid. Total investment in ICT's development programme amounted to just under£4m.

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133. Dr. J. Bray, interview, op.cit.

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136. Sir Robert Cockburn, in evidence to, SCST ... (Session 1970/71, HC 621-II), op.cit. Q91. Sir Robert was then Chairman of the NCC.

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139. HoCPD, 806, 19, 9 Nov 1970.

140. Ibid., 804, 513, 18 Jan 1971.

141. Ibid., 817, 361w, 20 May 1971. Payment continued to be made for computing equipment bought before 27 Oct 1970.

142. SCST ... (Session 1970/71, HC 621-II), op.cit. p.90.

143. Mintech '70: new leader? new policy? Data Systems, 20-25, Jan 1970. Interview with David Price, M.P., Conservative spokesman on technology.

144. SCST ... (Session 1970/71, HC 621-II), op.cit, p.90.

145. HoCPD, 812, 419-20w, 2 March 1971.

146. SCST ... (Session 1970/71, HC 621-I, II, III). op.cit.

147. SCST ... (Session 1970/71 HC 621-I), op.cit., p.lx.

148. Ibid., p.lix.

149. Ibid., p.lxi.

150. Ibid., p.lv.

151. £50 milion for ICL. Economist, 241, 78, 81, 20 Nov 1971.

152. Is ICL in trouble? Ibid., 238, 56-57, 27 Feb 1971.

153. HoCPD, 822, 196-7w, 30 July 1971.

154. Ibid., 840, 34, 3 July 1972.

155. Ibid., 842, 145-7w, 2 Aug 1972.

156. SCST ... (Session 1971/72, HC 473), op.cit., Q12.

157. SCST ... (Session 1972/73, HC 309), op.cit., p.x.

158. Ibid., p.xv.

159. Ibid., p.xii.

160. <u>Ibid.</u>, p.xvi.

161. <u>HoCPD</u>, <u>859</u>, 529-30, 4 July 1973.

162. For full details see House of Commons Committee of Public Accounts. <u>Procurement of government computers</u>. (Session 1979/80, HC 463). London, HMSO, 1980. pp.xii-xiii. ICL's profits however failed to reach 7½% of turnover in any of the years 1977/78 - 1983/84, and although the Committee urged the Department of Industry and Treasury to ask the company for an <u>ex gratia</u> payment in recognition of their support, which they did, no monies were repaid to the Government.

163. See Buckle, J.K., <u>op.cit</u>.

164. Rodgers, P. ICL ready to go it alone. <u>Sunday Times</u>, 8 Aug 1976.

165. Williamson, M. Computers: the choice for the British Government. <u>Financial Times</u>, 1 June 1977.

166. ICL made this point, SCST ... (Session 1970/71, HC 621-II), <u>op.cit</u>, pp.158-9, and so did Burroughs, <u>ibid.</u>, p.388.

167. Burroughs reports that the level of leasing in the UK had increased from 50% to about 70%, 1969-1971, <u>ibid.</u>, p.390.

168. The US recession led to General Electric and then RCA to withdraw from computer manufacture. Their operations were taken over by Honeywell and Univac respectively.

169. ICL. <u>Annual report, 1972</u>. London, 1972.

170. Is ICL going places? <u>Economist</u>, <u>253</u>, 82, 26 Oct 1974.

171. ICL. <u>Annual report, 1977</u>. London, 1977.

172. ICL may buy overseas minicomputer company. <u>Times</u>, p.18, 3 May 1977.

173. Owen, K. Fresh concepts of design could put ICL ahead of American rivals. Times, p.23, 24 Oct 1974.

174. Dr. C. Wilson, quoted in, Owen, K. ICL: Coping with the problems of growth. ibid., p.23, 13 October 1978.

175. Campbell, D., op.cit.

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178. Computers: the right way out. Ibid., 237, 74, 14 Nov 1970.

179. Computer shambles. ibid., 244, 100, 1 July 1972.

180. Shotgun marriage. Ibid., 246, 92, 94, 17 Feb 1973.

181. Europe's oyster. Ibid., 93-4, 17 March 1973.

182. Sell ICL? Ibid., 245, 89, 18 Nov 1972.

183. ICL's suitor. Ibid., 261, 128, 20 Nov 1976.

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185. Tysoe, J. & Hickey, P. ICL and the computer industry. London, Laurie, Milbank & Co., 1979, p.7.

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187. ICL has a friend in Benn. Economist, 254, 78-9, 11 Jan 1975: Buy British? ibid., 71-2, 1 Feb 1975.

188. Buy British? ibid., 255, 66, 31 May 1975.

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190. Times, p.17, 15 May 1976. See also reports on this case study the rest of the month.

191. Ibid., p.20, 25 May 1976.

192. Owen, K. Computer industry seeks a long term strategy. Ibid., p.21, 11 May 1976.

193. HoCPD, 916, 2w, 26 July 1976.

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195. Ibid., p.20, 31 May 1977.

196. HoCPD, 936, 227-8w, 27 July 1977.

197. Hills, J. Information technology ... op.cit, p.167.

198. Ibid., p.163.

199. Malik, R. In, out of the cold. Data Systems, 34-5, July 1969.

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201. Hills, J. Information technology ... op.cit., p.166.

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203. Ibid., 913, 269-70w, 17 June 1976; NEB. Annual report, 1978. London, 1978.

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205. HoCPD, 939, 861-2w, 24 Nov 1977.

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209. NEB. Annual report, 1978, op.cit.

210. NEB. Annual report, 1979. London, 1979; Moralee, D. European peripherals centred in Britain. Electronics and Power, 25, 321-2, May 1979.

211. Hills, J. Information technology ... op.cit. p.168.

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215. Ibid.

216. Small computers - the coming revolution. Bulletin of the NRDC, 36, 22-3, Oct 1970.

217. NRDC. Annual report, 1980-81. London, 1981.

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CHAPTER FIVE

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18. *Machinery*, *77*, 98, 1950.

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22. *Ibid.*, *80*, 468, 1952.

23. DSIR. *Report of the Mechanical Engineering Research Board, 1947-50*. Edinburgh, HMSO, 1951. p.27.

24. Ibid.

25. NPL. *Report, 1953.* London, HMSO, 1954. p.20.

26. Langrish, J. *et al*. *Wealth from knowledge.* London, Macmillan, 1972. p.263.

27. Ibid., pp.180-181; Bishop, G. Sitting by NEL. New Technology, 7, 4-5, July 1967.

28. NRDC. Annual report, 1957-58. London, HMSO, 1958. p.4.

29. Ibid.

30. Machinery, 86, 1175-76, 1955.

31. Ibid., 97, 1203-4, 1960.

32. Board of Trade. The machine tool industry. (The Mitchell Report). London, HMSO, 1960. Appendix B.

33. Besides the grant already noted, the DSIR made three separate grants totalling £ 39,000 to the University of Birmingham, and single grants of £ 13,185 to the Royal Aeroautics, Cranfield. In addition a further grant of £18,000 was made to Imperial College of Science and Technology, University of London. DSIR. DSIR, universities and colleges, 1956-1960. London, HMSO, 1962. pp.191-228.

34. The first meeting of this conference was held at the University of Birmingham in 1960. Thereafter it was held alternately in Manchester and Birmingham. Its proceedings are published in the International Journal for Machine Tool Design and Research.

35. Public Records Office. DSIR 16/197. Approaches from the Institution of Production Engineers and the MTTA between 1938 and 1944 to the DSIR for funding for a research association, sited either at the IPE itself or Loughborough Technical College, were turned down because the Department thought both sites for various reasons inappropriate.

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39. Observer, pp.3-4, 2 Feb 1960.

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41. Metalworking Production, 103, 2068-69, 1959.

42. Ibid.

43. Board of Trade, op.cit., p.5.

44. Ibid., p.33.

45. Ibid., p.27.

46. Ibid., p.29.

47. See for instance D.A. Oliver, Director of Research, BSA Group Research Centre, quoted in, Metalworking Production, 104, 95, 23 Nov 1960. Research expenditure reached £3.5m. in 1964 (Table 5.7) but after increasing through the early 1960s, see Ref. 52.

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49. Metalworking Production, 104, 11-14, 16 Nov 1960.

50. Ibid.

51. Ibid. 12-13, 23 Nov 1960.

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University of Reading, 1971). p.134.

For instance, Herbert opened a new research department (Metalworking Production 105, 11, 21 June 1961) as did Wickman Ltd. (ibid., 106, 77, 6 June 1962).

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54. DSIR. Annual Report, 1963. London, HMSO, 1964.

55. DSIR. Annual Report, 1964. London, HMSO, 1965. p.29.

56. Ibid., p.28.

57. Metalworking Production, 106, 17, 14 Feb 1962.

58. Ibid., 108. 19, 4 March 1964.

59. Ibid., 16, 18 Nov 1964.

60. Quoted in, DSIR. Engineering design. London, HMSO, 1963. p.11.

61. Metalworking Production, 106, 15, 14 Feb 1962.

62. Ibid.

63. Labour Party. Forward with Labour. London, 1955.

64. Wilson, H. A four year plan for Britain. New Statesman, 61, 462-8, 24 March 1961, p.464.

65. MTTA. The British machine tool industry: a background and policy document. London, 1963. p.7.

66. Metalworking Production, 109, 13, 15, 10 Feb 1965.

67. HoCPD, 704, 1029, 22 Dec 1964; ibid, 707, 197-8w, 2 March 1965; ibid, 711, 194, 27 April 1965; ibid, 713, 183w, June 1965; Later Cousins was to say that public ownership in the industry had not been ruled out (ibid, 714, 35, 14 June 1965); and then the next day that there had never been and currently was no proposal for any form of nationalisation in the industry (ibid, 714, 232, 15 June 1965).

68. Recommendations published Machinery, 106, 1337-8, 1965.

69. Quoted in, Time for a shake-up? Spotlight on machine tools. Times Review of Industry and Technology, 3, 37-48, March 1965.

70. HoCPD, 714, 31-34, 14 June 1965.

71. £162,000 to Birmingham University for a study of high-energy rate forming; £ 30,000 to the Drop Forging Research Association for the applied process development of HERF; £7,000 to Vickers Ltd. for a design study for high pressure hydrostatic extrusion equipment; £300,000 to UKAEA and Fielding & Platt Ltd. for the development of hydrostatic extrusion and the supply of a 1600 ton hydrostatic extrustion machines; £82,000 to Ferranti Ltd. for the development of a national 2½ axis NC computer programme; and a £ 5,000 to Societe Genevoise for a design study for a large coordinate measuring machine. HoCPD, 727, 100w, 3 May 1966; Metalworking Production, 110, 15, 4 May 1966.

72. Metalworking Production, 109, 17, 28 July 1965.

73. House of Commons Industry and Trade Committee, Machine Tools and robotics. (Session 1982/83, HoC 346, 227-i-v). London, HMSO, 1983. p.136.

74. Metalworking Production, 110, 15, 6 April 1966.

75. HoCPD, 727, 378, 25 April 1966; Metalworking Production, 110, 15-16, 4 May 1966.

76. NRDC. Annual report, 1966/67. London, HMSO, 1967. pp.7-8.

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78. Ibid.

79. Quoted in Metalworking Production, 109, 17, 3 March 1965.

80. Ibid, 110, 17, 17 Aug 1966.

81. Ibid., 114, 13, 12 Aug 1970.

82. Irvine, A., *op.cit.*

83. *PERA Bulletin, 21* (3), 1968; *Metalworking Production*, *112*, 16, 14 Feb 1968.

84. PERA. *Annual Report, 1970*. Melton Mowbray, 1971.

85. *PERA Bulletin*, *20*(2), 1967; *ibid., 21*(5), 1968.

86. *Metalworking Production*, *113*, 13, 12 Feb 1969.

87. *Ibid.*, 15, 14 May 1968.

88. *Ibid. 111*, 16, 16 Aug 1967.

89. The 15 are listed in House of Commons Industry and Trade Committee, *op.cit.*, p.143. It later variously announced that 6 (*Metalworking Production*, *111*, 17, 24 May 1967) and 13 suppliers (NRDC. *Report 1967/68*. London, HMSO 1968. p.51) took part in the scheme.

90. For instance, Charles Churchill Ltd. and Alfred Herbert Ltd. (*Metalworking Production*, *111*, 15, 26 July 1967), Kearney & Trecker Ltd. (*ibid.*, 16, 8 Nov 1967).

91. NRDC. *Report 1968/69.* London, HMSO, 1969. p.51; House of Commons Industry and Trade Committee, *op.cit.*, p.137.

92. *Civil Appropriation Accounts* for years 1967/68 - 1970/71.

93. *Economist*, *225*, 1169,1967.

94. Ministry of Technology. *Report of the Working Party on the problems arising from the cyclical pattern of machine tool orders.* London, HMSO, 1966.

95. *HoCPD, 756,* 235-6w, 14 Dec 1967.

96. *Ibid. 764*, 7, 1968; *Civil Appropriation Accounts*, appropriate years.

97. *HoCPD, 744*, 239w, 13 April 1967.

98. *Metalworking Production*, *113*, 15, 30 April 1969.

99. DTI, op.cit., p.68.

100. Speech of Dr. C. Timms of the Ministry of Technology, quoted in, Metalworking Production, 112, 15, 16 Oct 1968.

101. Ibid., 113, 15, 9 July 1969.

102. IRC. Report, 1968/69. London, 1969. p.17.

103. Metalworking Production, 113, 15, 9 July 1969.

104. See ref 100.

105. House of Commons Expenditure Committee Public money in the private sector. (HC 347-ii) Session 1971-72, . London, HMSO, 1972. Q.1871, p.444.

106. IRC. Report, 1969/70. London, 1970. p.36.

107. Ibid., p.38.

108. IRC. Report, 1970/71. London, 1971, p.19.

109. Ibid., p.23.

110. IRC. Report 1969/70, op.cit., p.11.

111. Interview with Anthony Wedgwood Benn, Metalworking Production, 114, 14-15, 22 July 1970.

112. Ibid., 11, 15 July 1970.

113. DTI. op.cit., p.2.

114. Ibid., p.ii.

115. Ibid.

116. Ibid., p.44.

117. Ibid., p.82.

118. HoCPD, 812, 461w, 3 March 1971.

119. Ibid., 810, 241w, 1 Feb 1971.

120. By March 1973 no new orders had been placed for over a year, and just one application was under discussion. (HoCPD, 853, 19-20, 19 March 1973). Total expenditure on the scheme amounted to £0.8m

in 1970/71, nil in 1971/72, while a profit of £0.5m. was earned in 1972/73.

121. Expenditure of £7,789,000 on civil R & D contract in 1969/70 fell to £759,000 in 1971/72. HoCPD, 848, 17-18w, 11 Dec 1972.

122. Nicholas Ridley, junior Minister at the DTI; HoCPD, 827, 7w, 29 Nov 1971.

123. HoCPD, 836, 877-8, 8 May 1972.

124. Ibid., 840, 235w, 10 July 1972.

125. Ibid., 849, 1-3, 22 Jan 1973.

126. Ibid., 836, 877-8, 8 May 1972.

127. Ibid., 847, 284w, 4 Dec 1972.

128. Industry Act, 1972: annual report for the year ended 31 March 1973. London, HMSO, 1973. p.10.

129. Times, p.19, 6 June 1974.

130. House of Commons Public Accounts Committee. Sixth report, 1975/76. London, HMSO, 1976. p.xii.

131. HoCPD, 875, 291w, 21 June 1974.

132. Ibid,. 898, 297-8w, 24 Oct 1974.

133. Ibid., 901, 309-10w, 27 Nov 1975.

134. Industry Act 1972; annual report for the year ended 31 March 1977 London, HMSO, 1978. p.14.

135. Sir Peter Carey, Permanent Secretary (DoI) in evidence, House of Commons Public Accounts Committee, op.cit., p.303.

136. £950,000: HoCPD, 913, 627-8w, 24 June 1976.

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138. HoCPD, 842, 399-400w, 8 Aug 1972.

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140. House of Commons Public Accounts Committee, op.cit, pp.301-320.

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146. Ibid., 895, 155-6w, 9 July 1975.

147. Ibid., 901, 122-3w, 25 Nov 1975.

148. Ibid.

149. Ibid., 901, 1633, 2 Dec 1975; ibid., 909, 7w, 15w, 5 April 1976.

150. House of Commons Trade and Industry Committee, op.cit, p.138.

151. NEB. Annual Report, 1977. London, 1977.

152. NEB. Annual Report, 1978. London, 1978.

153. Economist, 268, 71, 5 Aug 1978.

154. House of Commons Trade and Industry Committee, op.cit., p.138.

155. Economist, 268, op.cit.

156. House of Commons Trade and Industry Committee, op.cit, p.138.

157. Bob Cryer, Under Secretary of State Department of Industry, HoCPD, 955, 685-6, 1 Aug 1978.

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1968. Taking this to be constant, 1965-1973, total NEL machine tool research expenditure in that period would be £5.2m.

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CHAPTER SIX

1. For fuller accounts of textile manufacture see the entry *in* *Encyclopedia Britannica*, Vol. 18, 15th ed. Chicago, Benton, 1974, pp 170-189, and in particular Collier, A.M. *A handbook of textiles*. Oxford, Pergamon, 1970. A good historical account appears *in* Williams, I. *A history of technology*, Vol. VII(1) Oxford, Clarendon Press, 1978.

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24. In a typical American mill machinery was worked 139 hours per week compared with 48 hours in the UK.

25. Hugh Dalton, President of the Board of Trade, HoCPD, 410, 2249-50, 15 May 1945.

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29. ibid, p. 17.

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31. The Minister paid tribute to TMM "for the spirit in which they have responded to the suggestions made by the Committee during the course of their enquiry". HoCPD, 438, 20w, 1 Dec. 1947.

33. Stafford Cripps, HoCPD, 415, 189, 29 Oct. 1945.

34. Herbert Morrison, Lord President of the Council, ibid, 447, 1340, 19 Feb 1948.

35. Cripps, ibid, 438, 29-30, June 1947, "the output of textile machinery will continue to be divided between home and export markets with full regard for the importance of home requirements": Belcher, President of the Board of Trade, ibid, 445, 1184-5, 11 Dec 1947; "we cannot ignore the fact that textile machinery has always been an important export from this country and, in the face of the present difficulties, we cannot afford to ignore the long-term position of this export trade in regard to textile machinery."

36. See Miles, C., op cit, for a full description of this Act.

37. Harold Wilson, President of the Board of Trade, HoCPD, 448, 1576, 12 March 1948. BNL were the major UK suppliers of automatic looms.

38. See for instance, Textile Institute and Industry, 6, 85, 1968 for a short account of the Laboratory's work on air-bearings.

39. See DSIR, Annual Reports, appropriate years.

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41 See Catling, H. & Rothwell, R. Automation in textile machinery. Research Policy, 6, 164-176, 1977, for a description and analysis of this project.

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50. HoCPD, 567, 238w, 17 Dec 1958; also raised during the debate on the cotton Industry, ibid., 590, 878-1012, 30 June 1958, especially c 975.

51. Output per head employed in spinning, 1950-1957, rose by 3% in the UK, 56% in Germany and 59% in France while the equivalent figures in weaving were 4%, 30% and 66%. Spindles in the UK were in use on average for 2,124 hours per year, compared with 6,117 hours in USA, 4,000 hours in West Germany, and 3,707 hours in France.

52. See Miles, C. op cit, for a full description and analysis of the effects of this Act.

53. HoCPD, 606, 472, 4 June 1959.

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55. HoCPD, 613, 577-8, 12 Nov 1959.

56. This report was never published and the author has never come across any references to the completed report. Enquiries of the Shirley Institute, HATRA, WIRA, SERC, DTI and Sir Charles Carter, then Chairman of the DSIR's Economics Committee which was in charge of these reports, have all failed to reveal its existence.

57. These grants were £ 1325 over 1 year from 1.10.1959 to Professor J.J. Vincent, 'Weft trajectories in free pick weft insertion', £ 5000 over 2 years from 1.9.1960 to Prof. R.H. Peters, 'Non-woven fabrics'; £2400 over 2 years from 1.1.1961 to Mr. H.A. Turner 'Fundamental processes in textile printing. DSIR. DSIR, universities and colleges, 1956-1960. London, HMSO, 1962.

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Electronic Computers SWP

Machine Tools EDC

Textile Machinery SWP

National Engineering Laboratory

National Enterprise Board

National Physical Laboratory

National Research Development Corporation

Production Engineering Research Association

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