RESEARCH AND DEVELOPMENT

IN THE

IRISH ELECTRONICS INDUSTRY

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DEDICATION

TO PATRICIA, WHOSE HELP AND SUPPORT MADE THIS WORK POSSIBLE AND WORTHWHILE

DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of MBA is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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ABSTRACT

RESEARCH AND DEVELOPMENT IN THE IRISH ELECTRONICS INDUSTRY

JOE MADDEN

The electronics industry is a rapidly changing technology driven industry. Intensive research and development activity in electronics has been partly responsible for the emergence of Japan as an economic superpower and the rapid development of the Korean economy.

Following the publication of the Telesis Review of Industrial Policy in 1982, the Irish Government undertook a gradually more interventionist policy towards the indigenous electronics industry. In the ten years since Telesis there has been significant growth in business expenditure on R & D in electronics but this growth has come exclusively from multinational companies.

Indigenous expenditure on R & D has remained static but has become concentrated in specific sectors. These sectors are industrial control, security systems and electronics for the building industry where economies of scale are not important and in the power supply sectors where economies of scale are not possible.

Factors critical to effective research and development in the Irish electronic industry have been identified as:

(1) The availability of skilled people
(2) Knowledge of the market
(3) Interaction with customers

A university ethos supportive of industrial development and R & D intensive multinational companies have been found to contribute to the development of R & D intensive indigenous companies.

Gorvernment intervention has lacked focus and has not been effective in improving the competitiveness of the industry.

A model of a national system of innovation, based on that proposed by Mjoset, has been developed. The policy changes required to make such a model work have been identified as focused state support for specific industries, focused state support for the development of related technologies, inclusion of the banking system into the system of innovation and the encouragement through the use of R & D grants user producer co-operation in the development of new producer cooperation in the development of new products.

It is proposed that such a national system of innovation could be used to create a self sustaining virtuous circle of economic development in electronics.

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1 INTRODUCTION AND BACKGROUND

1.1 Introduction

The electronics industry has been central to economic development in the advanced world over the past 40 years.

It has been a technology driven industry with developments like TV receivers, transistors, integrated circuits, microwave ovens, computers and 'walkmans' meeting latent rather than expressed needs in the market.

Electronics has also been central to the success of the outward looking industrial policy adopted by the Irish Government in the 1960s with the establishment of major multinational companies like Digital and General Electric in the early 1970s up to the recent establishment by Intel of its "586" microprocessor manufacturing facility in Ireland.

The Telesis Report published in 1982, questioned the technology level of the electronics industry in Ireland criticising the low level of R & D in the MNC's based here. It also questioned the over dependence on Foreign companies to drive economic development in Ireland.

In Ireland the electronics industry still appears to be dependent on MNC's set up principally as manufacturing operations for products conceived and designed in other countries. The role of MNC's in any country's system of innovation in electronics must therefore be considered. Their role can only be a secondary one with the product development capability of indigenous electronic industry being of primary importance.

This thesis will review the evolution of R & D in electronics in Ireland since the time of the Telesis study.

For the purpose of comparison and for identification of suitable models, it will begin by examining the relationship between innovation and economic growth and the impact of R & D policies in electronics in Japan, United Kingdom Korea and the European Community. The macro-economic performance of the Irish electronics industry will be reviewed using Census of Industrial Production figures and the Porter Diamond Model of national competitive advantage. The Porter model will be examined with particular reference to the role of R & D in creating national competitive advantage.

The generally poor performance of Irish industry including the electronics sector will be viewed in the context of "National systems of innovation and virtuous and vicious circles". This will set the background for a detailed study of Irish electronics companies undertaking R & D and of the institutions supporting them.

The performance of indigenous and multinational companies will be compared. The effect of government policy will be investigated. The IDA data on R & D grants will be used to examine the R & D performance at a microeconomics level. This will be supplemented by data from a survey of a sample of Irish companies who have received grants.

The review will provide an overview of the R & D performance of the Irish electronics industry and an indication of what is necessary and possible to do to provide a national system of innovation in electronics.

1.1.1 Objectives

The objectives of the thesis are:

(1) To review the R & D performance of the Irish electronics industry

(2) To review the contribution of Government policy and state institutions to the development of R & D in the electronics industry

(3) To review the experiences of selected countries in developing a national system of innovation in electronics

(4) To develop, based on these reviews, a national system of R & D and innovation for the electronics industry in Ireland

1.2 The Development of Electronics

The 1870s saw a transition from the first to the second industrialisation phase of the industrial revolution with a shift in focus from steel coal and textiles in the UK to electricity and chemicals in Germany and the US. (Hughes. 1983)

Pioneers in the electrical industry were inventors/entrepreneurs and included Edison, Westinghouse and Sprague, in the US whose names live on as part of the major electrical/electronics companies they founded. Halske and Siemens, the German pioneers founded AEG and Siemens, the two leading German electronics companies of today.

During the 19th century, the electrical industry relied on pneumatic controls to control electrical output and large electrical equipment and machinery while smaller scale and domestic equipment was controlled by on-off manual switches.

The invention of the "electron tube" by De Forrest in 1906 represents the beginning of the electronics industry. This was a device that looked like a light bulb with five instead of two connection points. One of the problems with early light bulbs was that after a short period of operation the glass blackened.

De Forrest, proposed that the blackness was caused by "electrons" coming off the filament and to prove it he inserted extra terminals through which the release of electrons could be controlled.

By applying one signal the flow of electrons could be stopped altogether and by applying the opposite the flow could be maximised - he therefore made the first electronic switch.

Initially however, the signal was continuously variable (analogue) rather than on/off (digital) and used to control the volume on radios, the speed of motors or the brightness in lights. The first computer developed in Berkeley in 1945 used 18,000 of these electron tubes or valves.

In 1948, the first transistor was developed by Schottky in Bell Laboratories in the US. This reduced the size of the "electronic control" device from that of a light bulb to that of a pea.

The invention was first commercialised by Sony with the development of the transistor radio (Morita. 1988).

In 1959, the first integrated circuit was developed as part of a US Defence research contract (Friedrick & Schoff. 1982). This allowed 4 switches to be placed in a single piece of silicon or chip.

Since then progress has been incremental but dramatic.

The latest device announced by Samsung, the 64Mbit DRAM, allows 64 million switches to be placed on the same centimeter scale chip. (International Business. 1993. P. 30).

This rapid development in the "core" technology of electronics, - the electronic switch - has resulted in:

(1) corresponding development in many of the related disciplines such as software in order to take advantage of the developments in the hardware.

(2) The extension of electronics to many areas that were previously non-electronic - including telecommunications systems, process control equipment, instruments (e g weighing scales) and children's toys.

A study of UK industry (Northcoff and Rogers. 1984), showed that for companies employing more than 1,000 people 35% of them employed micro electronics in their products and 96% employed microelectronics in their processes. The use of electronics in all sectors across both process and product increased between 1981 and 1983 from 30% to 47%.

In 1991, the world electrical/electronic market had reached about 1,400 billion ECU (Commission of the European Community, 1991). Through information technology it has impacted every industry. It is recognised as the key technology in terms of national competitiveness (Mjoset. 1992) and the electronics/information technology is now seen as the "second industrial revolution" (Howell et al. 1988)

There has been a strong correlation between national economic development and participation in the electronic revolution. A significant part of US Growth in the 1960s and 70's was due to the clear lead it had established in electronic technology. Electronics has also been a key element in the emergence of Japan as a world economic power and in the rapid development of the Korean economy.

In Europe, value added in the German electronics industry in 1991 at 30 billion ECU, was over twice that of France and almost three times that of the UK (Commission of the European Community, 1991) again reflecting the relative strengths of the three economies.

1.3 Technological Unemployment

One of the fears of this new technology particularly among trade unions is that it leads to job losses. This fear is understandable when one considers the significant volume of anecdotal and empirical evidence which supports it.

This fear is also justified by the Classical Aggregate Demand and Supply model of economic behaviour (Lovell. 1975. P. 318). The aggregate model which represents a refinement of the 1S-LM Model can be used to model the impact on the economy (details included in Appendix A) of a technological change which increases aggregate output without requiring additional labour or capital. According to this model the net effect of technological change is increased output, lower prices with reduced employment.

In Europe, between 1982 and 1991 electronic production output increased from 79 billion ECUs to 174 billion ECUs while employment increased from 1.4 million to 1.5 million. (Commission of the European Community. 1991)

1.4 Solow's Study on the Contribution of Technology to US growth

The Aggregate Model of Demand and Supply of the impact of technology was countered somewhat by an empirical study carried out by Professor Robert Solow, who studied the contribution to US growth between 1909 and 1949 made by capital accumulation and improvements in the techniques of production (Solow. 1957). Solow saw the increase in output as being a result of the impact of the increased labour, the increase in accumulated capital plus the contribution of technological advance.

The increase in output was 216%. The increase in labour was 54% and the increase in accumulated capital was 102%. When these numbers were plugged into a model he had developed, it showed that technological change accounted for 146% of the 216% increase in output over the period.

Further studies of Solow's work suggest that while the technological contribution to economic growth is important, his results probably place an upper bound on the magnitude of this contribution. (Lovell. 1975. P.305)

1.5 Marx and Schumpeter

The theoretical basis for the role of technology and innovation in economic development was established by Karl Marx and J A Schumpeter (an explanation of the relevant Marxist terms is provided in Appendix D). Marx was in the classical tradition of economists. Marx shared an interest in the division of labour with Adam Smith. In his analysis of the "Nature and Causes of the Wealth of Nations", Smith argued that changes in productive technique are built around the division of labour both in production and in Society as a whole. His definition of the division of labour was so broad that it also included technical progress.

Marx had the benefit of the industrial revolution experiences to draw on in the development of his economic theories relating to technology.

He understood the process of technological change and his model of it can be as equally applied to the electronic revolution underway today as it was to the industrial revolution of his time.

According to the Marxist model technological advances resulted in extended reproduction which led to surplus profits.

These surplus profits were invested in further mechanisation. Because of the technology diffusion the rate of profit would fall and each enterprise returned to a system of simple reproduction.

Marx saw the accumulation and competition process as leading to continuous crises in the capitalist system.

J A Schumpeter who began writing in the 1920s presented a similar analysis of technical innovation to that of Marx. He developed the concept of circular flow. Circular flow exists when the costs of running an operation equal the income derived from it and the net profit equals zero. In this state the operation makes continuous adaptations to small external changes.

Marx saw innovation as part of the process of capitalist disintegration while Schumpeter saw it as the driving force of economic development. It introduced dis-equilibrium into the circular flow which then became unstable until a new neighbourhood of equilibrium was found. He saw this innovation as having a band-wagon effect with its diffusion throughout the economic system. Dis-equilibrium disturbance results in business cycles with a period of economic growth immediately after the introduction of the innovation and during the period of technical diffusion but with a period of recession as the new equilibrium state becomes stable The similarity between the concepts of Schumpeter and Marx is significant. Circular flow in its stable state is equivalent to simple reproduction, where Schumpeter treats income to the owners as part of the costs. The concept of business cycles was not specifically mentioned by Marx but the "phenomena stood clearly before his eyes" (Hagedoorn, 1989). Schumpeter distinguishes between economic growth which he sees as part of the stable circular flow and economic development which he sees as a result of innovation. He defines innovation very broadly as:

(1) the introduction of a new good - that is one with which consumers are not yet familiar - or a new quality of goods.

(2) the introduction of a new method of production that is not yet tested by experience in the branch of manufacture concerned, and can also exist in a new way of handling commodity commercially.

(3) the opening of a new market, ie a market into which a branch of manufacture of the country in question is not previously entered whether or not this market has existed before.

(4) the conquest of a new source of supply of raw materials or for half manufactured goods, again irrespective of whether this source already exists or whether it has first to be created.

(5) the carrying out of the new organisation of any industry such as the creation of a monopoly position or the breaking up of a monopoly position (Hagedoorn. 1989).

Innovation has generated a number of business cycles in the electronics industry,such as the replacement of valves by transistors, the displacement of radios by TV's, and the more recent rise in the use of personal computers coupled with the decline in use of main frame computers.

1.6 Sources of Innovation

Because of its political ethos, Marx's economic theory has tended not to be critically evaluated. Neo-Markist literature has tended to explain and defend "Das Kapital". Marx himself had a complete understanding of technological development and its implications for industry, while Neo-Markists have tended to focus on the more abstract and ethereal issues. Few have made an attempt to go beyond or even expand the field of research laid out by Marx himself (Hagadoorn. 1989. P. 62)). Schumpeter on the other hand being in main stream economics has been more analysed and reassessed. Kamien and Schwartz have summarised a set of Schumpeter aspired hypotheses on market structure and innovation as follows:

(1) Innovation is greater in monopolistic industries than in competitive ones because:
   - (a) a firm with monopoly power can prevent imitation and thereby can capture more profit from innovation
   - (b) a firm with monopoly profits is better able to finance research and development

(2) large firms are more innovative than small firms because:
   - (a) a large firm can finance a larger research and development staff
   - (b) a large diversified firm is better able to exploit unforeseen innovations
   - (c) indivisibility in cost reducing innovations makes them more profitable for large firms

(3) innovation is spurred by technical opportunity

(4) innovation is spurred by market opportunity (demand pull).

(Kamien and Schwartz. 1982. P. 47).

This view that large firms are the source of major innovation is further developed by Galbraith, who mentions six consequences of modern technology for companies.

(1) longer time span from beginning to end of innovation
(2) large capital investment required
(3) large division of tasks and means of production
(4) more specialised manpower
(5) more organisational efforts and
(6) more planning.

(Galbraith. 1985. P. 12-16).

However, the opposite position was taken by Blair, who developed his theory on the "creative backwardness of bigness". This 'backwardness' he ascribed to:

(1) the desire to protect the investment in older technology
(2) indifference to technological advance
(3) underestimation of demand for products
(4) neglect of the inventor
(5) misdirection of research and
(6) incompatibility between organisation and creativity.

(Blair. 1972. P. 228-257).

There is no clear conclusion in the literature on this argument. There are some industries such as aerospace, motor vehicles and pharmaceuticals where the industry structure makes it very difficult for small firms to make any contribution to innovation. Other attempts have been made to develop a theory in which the different roles of small and large companies are explained. According to Sher (1980) small and medium sized firms play a role in the early stages of innovation but larger firms are required to take over the innovative process when significant investments are required and bring the innovation to commercial success. Dosi, sees small firms predominating primarily in new fields of technology where there is a high rate of birth and mortality of new companies. Of particular relevance to the Irish electronics industry is a study by (Rothwell and Zegveld. 1982. P. 45 - 54), who saw the disadvantages for small company innovation as :

(1) their lack of qualified R & D personnel

(2) shortcomings in external communications and in particular a lack of information on technology and markets

(3) lack of management skills

(4) constraints of financial resources

(5) problems related to economies of scale

(6) inability to take advantage of government measures

(7) problems related to growth of the firm

The summary of the functional sources of innovation is provided in table 1.1.

Table 1.1 Sources of Innovation.

Innovation Type	Innovation Developed by User	Manufacturer	Supplier	Other	NA[a] (n)	Total (n)
Scientific Instruments*	77	23	0	0	17	111
Semiconductor and printed circuit board process*	67	21	0	12	6	49
Pultrusion process	90	10	0	0	0	10
Tractor shovel-related	6	94	0	0	0	16
Engineering plastics	10	90	0	0	0	5
Plastics additives	8	92	0	0	4	16
Industrial gas - using	42	17	33	8	0	12
Thermoplastics - using	43	14	36	7	0	14
Wire termination equipment	11	33	56	0	2	20

*Electronic Industry Related

a: The source of innovation was not identified

(Source Von Hippel. 1988)

Here the innovator is defined as the individual or firm that first develops innovation to a useful state as proven by documented useful output. Von Hippel (1988) found that the innovator is the person or firm to whom the economic rent from innovation mostly accrues. He found that in the electronics industry this was predominantly the user rather than the manufacturer.

1.7 Conclusion

The development of electronics has been very fast and at a national level its economic impact does not appear to conform with the Aggergate Demand and Supply Model of economic behavior, but the industry is subject to Schumpeterian innovation driven business cycles.

In the electronics industry the major source of innovation is the user.

The companies in the Irish electronics industry are small and therefore have to deal with a number of disadvantages related to small company innovation.

2 The Irish Electronics Industry

2 THE IRISH ELECTRONICS INDUSTRY

2.1 National Policy and Innovation

Product innovation in electronics is seen as crucial to economic development in all the industrialised and newly industrialised countries. It is also recognised in these countries that there is a formal role for Government in the support of this innovation process.

A study by Mansfield (1980), showed that the social rate of return on innovation was 56% while the private rate of return on the investment in innovation was only 25%. This data justifies investment by states in the innovation process and support by the state of private investment in innovation.

The optimum form of this support is not universally agreed. In their book, "Nurturing Advanced Technology Enterprises", Allen and Levine (1986. P.15) review the three traditional economic development approaches -

(a) regulatory

(b) fiscal/tax and

(c) expenditure

They conclude, based on a review of the literature including Campbell 1958, Spegelmann 1964, Vaughan 1980, Bridges 1965 and Fischel 1975, that tax deductions don't help and that expenditures on fiscal/tax incentives known previously as 'smoke stack' chasing and more recently as 'chip chasing' have had only limited impact on business developments and have had little or no impact on the long term behaviour of firms. Mulkey and Dilliman in their work "Location and the Effects of State and Local Development Subsidies" have found that "most subsidies to large firms are probably wasted". (Mulkey and Dillman. 1976. P. 71-80). They conclude that expenditure policies such as the creation of business parks are equally ineffective.

A study of multinational companies in Scotland showed that direct grants had no impact on innovation or research and development budgets or the level of activity (Hung and Pizzi. 1985. P. 197-206).

Allen and Levine argue that the development of advanced technology companies and advanced technology entails integrated and private sector activities. Underlying these activities, there are three essential prerequisites.

These are - the availability of the required technical and professional labour, this includes the correct environment for these technical and professional workers with favourable cultural and recreational amenities, community amenities such as favourable climate, quality schools and a strong civic culture and a suitable tax environment. The second prerequisite is suitable post secondary educational institutions for the training and education of a professional and technical workforce. The third prerequisite is a technological development infrastructure incorporating technological support organisations that can meet a wide range of needs. Allen and Levine focused their study on the experience of the State of Pennsylvania.

These prerequisites are broadly similar to Porter's "advanced factors" (discussed later) but place a greater emphasis on a suitable environment for high skilled personnel.

They also take account of the personal tax environment which Porter tends to ignore but which was perceived as the major obstacle to industrial development in Ireland by the Industrial Review Group (Industrial Review Group. 1992).

Most developed countries provide significant state funding for applied research projects in electronics and related industries.

Some examples are:

Japan	Jupiter (advanced robots)	18 billion yen
Germany	Festigungstechnik CAD/CAM	D610 M
Italy	Robotics	Lira 95 billion
Finland	Tekes (mechatronic programme)	$7.5 M
Norway	National Action Programme for IT	NCR 1.7 billion
US	Strategic Computing Program (MIL)	$100 M pa
France	Integrated Circuits	FF 3 billion

(OECD. 1989)

These programmes all include significant industrial interaction. The optimum form this interaction should take for maximum economic development is dependent on other external factors. For example the military funding of research in the US has provided significant industrial spin-off while in the UK it hasn't. Up to 1989, Ireland had no such programmes. The experiences of three countries and the EC in operating such systems, two, Japan and Korea very successful and one, the UK not so successful, can provide some framework for the Irish electronics industry to assess how it should proceed.

2.2 Japan

The relationship between the Japanese government and the electronics industry is depicted schematically in Fig.2.1.

MITI is the Ministry for International Trade and Industry and is a government agency principally responsible for directing Japan's extraordinary post-war economic growth. MITI provides strategic guidance and financial assistance to the industry and jointly participates with Japanese companies in R & D for commercial applications in industry/government joint laboratories.

The Ministry of Education and Culture funds university research and supports several large national research facilities in electronics R & D.

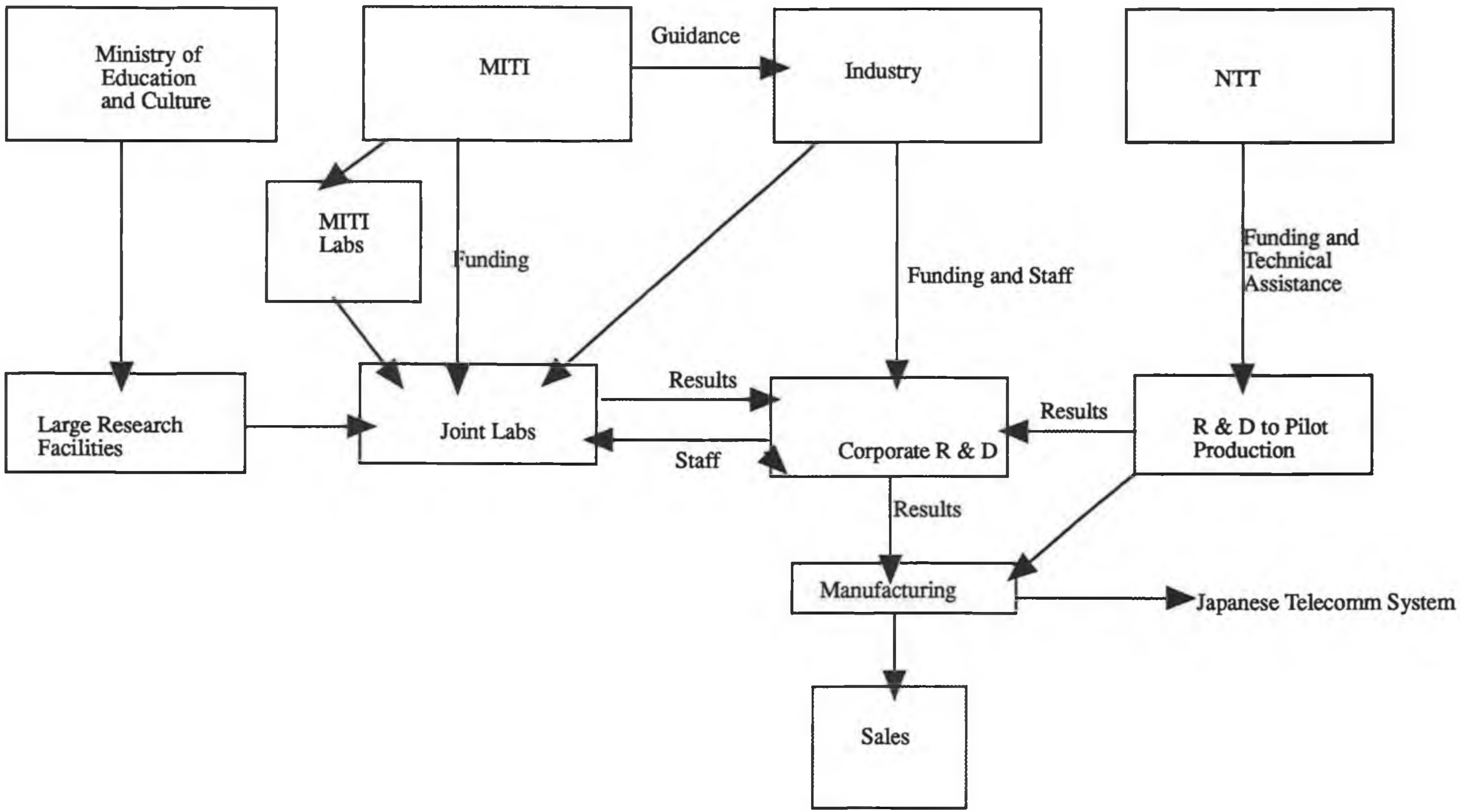


Fig 2.1 Japanese Nationese National System of Innovationin in Information Technology (Source :Howell et al, 1988 P45)

Nippon Telephone and Telegraph (NTT), is controlled by the Japanese Ministry of Post and Telecommunications (MPT). The MPT and MITI are both influential Ministries in Japan and they play a role in virtually every policy area affecting the information and electronics industry. They compete with one another to woo the industry through the provision of progressively greater promotional benefits (Johnson. 1986).

MITI have taken a very proactive role in the development of Japanese electronics industry. They have fostered a rapid development of indigenous computer and semiconductor industries through the provision of subsidies for Research and Development throughhome market protection and the development of an infrastructure that is suitable for international competition. It has sponsored a number of joint research and development projects. These projects are listed in Table 2.1. They are focused on specific technological areas each with a clear market objective. They are funded entirely by MITI who select the companies which participate on joint research programmes.

TABLE 2.1 MITI-Sponsored Joint Research and Development Projects in Micorelectronics

Project	MITI VLSI	Opto Electrtonics	Super Computer	New Function	SORTEC	Optoelectronic Devices	Fifth Generation Computer
Time Frame	1975-79	1979-86	1981-89	1981-90	1986-96	1986-96	1981-91
Technological Focus	VLSI Manufacturing	Optical Semi-conductors	High Speed Devices	VLSI Device & Process	Synchortron Lithography	Optical Semi-conductors	VLSI Logic
Govt. Funding* ($ Million)	112	80	135	140	62	42	NA
Participants	NEC Hitachi Fujitsu Toshiba Mitsubishi	NEC Hitachi Fujitsu Toshiba Mutsubishi Oki Sumitomo	NEC Hitachi Fujitsu Toshiba Mutsubishi Oki Sharp	NEC Hitachi Fujitsu Toshiba Mitsubishi Oki Sharp Sanyo Dumitomo Matsushita	NEC Hicachi Fujitsu Toshiba Mitsubishi Oki Sharp Sanyo Sumitomo Nippon Sh. Gls. Matsushita Nippon Kogaku	NEC Hitachi Fujitsu Toshiba Mitsubishi Oki Sharp Sanyo Sumitomo Nippon Sh. Glass Fujikura	NEC Hitachi Fujitsu Toshiba Mitsubishi Oki Sharp

*Yen dolllar conversion average for the period

MITI's promotional efforts have been augmented by special legislation authorising the provision of subsidies, tax benefits, low interest loans and exemptions from anti-monopoly laws for designated priority industries. MITI focuses on technological development while its bureaucratic rival MPT works directly with a family of telecommunications companies including NEC, Hitachi, Fujitsu and OKI. NTT which is controlled by MPT has developed semiconductor device technology which it has then transferred to these firms, supplying them with significant competitive advantage. NTT was privatised in 1985 and through the sale of shares in the company and the collection of dividends on the remaining shares, the Government has generated a significant off-budget fund which has been channelled back into Japan's high technology electronic industries via NTT. Between 1978 and 1986, MITI was spending sixty billion yen per annum on technology development and during this same period Japan's electronic producers moved into a position of world leadership in a number of new technologies (Howell et al. 1988).

Japan has a clearly identifiable national system of innovation in electronics focused on technology development in a competitive environment.

2.3 The United Kingdom

Over the same time period, the United Kingdom has developed and implemented a wide variety of industrial policies in support of innovation. The first post-war encouragement for invention was the setting up of the National Research Development Corporation in 1948. This organisation was intended to exploit inventions which had not been taken up by private enterprise that had arisen from Government or academic research work.

In the areas of electronics, the British Government has introduced a number of specific programmes. In 1975, the Machine Tool Industry Scheme (MTIS) was launched with the objective of encouraging the development of new products and processes for the machine tool industry. The machine tool industry had moved from a stage of being primarily a pneumatic control industry to becoming an electronic control industry and there was valid concern in the UK that the UK industry was not keeping up with US, Japanese and European manufacturers. The scheme involved the provision of loans and grants to machines tool manufacturers for the development of new machines. Financial assistance was always kept below 50% of the total costs. Despite this support in the area of technological development and other more general financial support, particularly to Herbert Machine Tools, the largest manufacturing company in the UK, the UK machine tool industry continued to decline.

In a survey carried out on the MTIS scheme by Ann Daly (Daly. 1981), she found that while the beneficiaries of the scheme commented favourably on it, this should not be taken as a judgement of its overall success. In more detailed interviews with respondents she found that insufficient capital was not an inhibiting factor to innovation except for the smallest firms. The MTIS assumed that this would have been the main inhibitor.

Another British initiative in the area of technology support to the electronics industry was the Microprocessor Application Project. The scheme had four parts:

(a) a programme of seminars and publicity to generate a greater awareness of opportunities and threats in the area of microelectronics

(b) a programme of crash courses to train more people in the necessary special skills

(c) a grant of £2000 towards the costs of a consultants feasibility study on new applications and

(d) a contribution of 25% of the development costs of viable new applications.

This scheme was chosen as the subject of study a by the Policy Studies Institute (PSI). Their report, *Microprocessors and Manufacture Products* was published in 1980. They found that the consultancy element was useful to companies but that the delay in vetting procedures by the programmes administration often resulted in product developments happening later than they would have if there had been no support. A 25% grant was paid on the principle of additionally, ie that without the grant, the scheme would not go ahead. This according to the report favoured companies who knew the ropes and maintained a 'martini man' to pull in any handouts that might be on offer and it penalised firms that were open in their dealings. The problem was that it is seldom clear-cut whether or not a project would go ahead without the grant and if the grant was only to support projects that wouldn't go ahead, it would provide disproportionate support towards less promising projects.

The first ambitious project undertaken in the UK in the area of electronics was the INMOS project. This was approved by the National Enterprise Board (NEB) in 1978. The project involved a £50 million investment of British Government funding at a start-up phase. When a Conservative Government took power in 1979, they carried out a general review of the NEB operation. They sought to replace the Government funding by private industry funding. However, none of the major British electronic companies had any interest in the project. The project went ahead with Government funding and a £25 million production plant was built in South Wales. The INMOS project was driven by Dick Petricz, the founder of Mostec and Ian Barron, the founder of Computer Technology, a leading UK microcomputer company. It represented a new approach in information processing using a device called a transputer as opposed to the by then standard microprocessor. The concept has been favourably reviewed both by industry and academia but up to the time of the sale of INMOS to SGS Thomson in 1990 the company had not made any profit.

Despite its reluctance to get involved in the INMOS Project, the UK government following the recommendations of the Alvey Committee (Alvey. 1982) initiated the Alvey Programme in 1983. This was a £376M programme with government funding of £211M.

The interim evaluation report while generally positive suggested that "more emphasis needs to be placed on the UK's problem in exploiting research". (Georghiou et al. 1987). The problem was that while a great deal of research results had been provided, there was very little industrial spin-off.

The Bide report (Bide. 1986) recommended greater emphasis on longer term research and the cessation of innovation grants to industry with the exception of small firms.

Porter commented that Britain (along with Germany) has now 'correctly' moved away from the idea of providing direct grants to industry for R & D on the basis that it induces inefficiency. (Porter. 1990. P 634).

2.4 Korea

South Korea emerged from the Korean war with its economy destroyed and with no capital available for the rebuilding of its infrastructure. (Porter 1990 P. 467).

During the 1960s it relied on US aid. During the 70s and 80s as Korea demonstrated its capability to sustain progress, foreign capital poured into the country. The Korean Government channelled this capital into areas which it had identified as sectors for which Korea could establish national competitive advantage. They also encouraged the establishment and the growth of "Chaebol" or large industrial conglomerates.

During the late 70s and early 80s, Korean companies had become world leaders in many consumer electronics sectors. With the advent of video recording they have established very strong positions both in the equipment and video tape markets and similarly in microwave appliances (Mazaginer and Patinlun. 1989)

In the microelectronics sector, Korea had been a final assembly location for many of the major US semiconductor manufacturers. In 1982, the Korean government announced a semiconductor industry promotion plan which featured a variety of measures designed to encourage the development of an indigenous manufacturing capability in semiconductors (Howell et al. 1988 page 148). This was followed a year later by major investments by three of Korea's largest Chaebol - Samsung, Gold Star and Hyundai. By 1985 Korea had established domestic wafer fabrication facilities mainly focused in the manufacture of D-RAM chips. At the same time the Japanese D-RAM industry was in the process of capturing the world semiconductor D-RAM market through very low pricing. During this period, all US companies pulled out of the market, while in Korea, the Korean government invested a further $346m in 1985, in addition to $2 billion by the Chaebol. Part of this development effort was the establishment of the Semiconductor Joint Research Centre in 1985. This was a research project involving 17 universities to conduct joint research in semiconductors with industrial partners and also to train semiconductor specialist manpower. (Howell et al. 1988).

Samsung Korea's largest electronics manufacturer, has now released the world's first 64M bit D RAM. This puts the same memory capacity in a single chip as was available on 4 hard disc drives in 1986/87 and surpasses the 1985 objective of developing 4M bit DRAM chips by the early 1990's.

Porter notes that two of the determinants of national competitive advantage in his diamond model are missing in Korea ie demand conditions and related and supporting industries. (Porter. 1990. P. 479).

Freeman points out (1988 P. 81) that the cost advantages available to enterprises in larger economies such as learning by interacting and the availability of infrastructures are lacking in most developing countries and that policies directed towards the creation of a national system of innovation form the essential foundation for a catching up strategy in development. Park (1987) and Mody (1987) have shown that such policies have been extremely important in Korea. (Howell et al. 1988)

2.5 EC

During the 1960s and 70s the electronics industry in EC countries was dominated by national champions such as Olivetti and SGS in Italy, Siemens in Germany, Bull in France and GEC Plessey in the UK. By the end of the 70s it became apparent that these companies were not able to withstand the threat from US and Japanese competition in the electronics instrument and component industries. These large national companies while perceived to have been necessary to achieve the relevant economies of scale and had become complacent in their protected position in home markets and had failed to keep up with the relevant technologies (Sharp 1991. P. 63). At this time, Viscount Davignon, the EC Commissioner for industry initiated the first European Research and Technology Programme in electronics.

It was modelled on the Japanese approach discussed earlier and the pilot phase was launched in 1983/84. The programme was launched formally in 1984 and became known as ESPRIT, with ESPRIT 1 scheduled to last from 1984 - 1988 and ESPRIT II from 1988 -1992.

Essential to the start-up of the ESPRIT programme was agreement from Europe's leading electronics and information technology companies. These were ICL, GEC and Plessey from the UK, AEG, Nixdorf and Siemens from Germany, Thompson, Bull and CGE from France, Olivetti and Stet from Italy and Philips from the Netherlands. These companies, known as the "Big 12" represented 70% of the European electronics industry. The ESPRIT process consisted initially of a call for proposals issued by the commission. The call specified the research areas to be studied and was issued to

National Agencies who then promoted the concept in their national territory. Each proposal was required to have cross national collaboration and participation by industry. Industrial costs were funded at a 50% level, while research institutes and universities had direct costs funded to 100%. After the closing date for submission of proposals, technical evaluation of the proposals took place. A small number of proposals that were highly assessed were guaranteed funding. Others were considered of sufficient technical merit to receive funding and the remainder were considered unsuitable for funding. Those in the middle category became the subject of political negotiation and selection depended more on political than technical considerations. In the pilot phase, 1983-1984, 80% of the funding went to proposals initiated within the big twelve and this pattern was maintained during the programme.

ESPRIT 1 ended in 1988 having spent 800m ECU.

Between 1987 and 1991, 5.6 billion ECU were earmarked for research and development by the EC. The largest share of this was earmarked for the information technology, ESPRIT programme - 37.5%. The next largest share was in energy, primarily nuclear energy which secured 25% of the total budget.

The ESPRIT programme has been subjected to reviews at the end of each phase. The independent review board in its evaluation of ESPRIT 2 noted that the programme had produced good technological results in numerous projects and many new standards from which exploitation activity can be based. However, it also noted that coupling between R & D and product development especially in large companies needed tightening and recommended that in future the programme concentrate around the more limited number of well focused technology areas. (European Commision. 1992)

Despite its shortcomings the programme has been responsible for putting European companies back in the forefront of information technology.

In 1991 SGS Thompson had a 29% share of the world risk processor market, the most advanced micro processing chip. This represents the largest market share of any company. Philips have established themselves as world leaders in multimedia technology using ESPRIT results and Siemens Nixdorf have established themselves as leaders in sub micron BICmos technology. (Commission of the European Community. 1992).

According to Porter, (1990. P. 637), the European consortia which in many cases involve only one dominant and often protected firm from each nation may play a role in catching up in areas of basic technology but have uncertain prospects in creating and successfully commercialising new technology. His main argument against it was, that, being a cooperative project it would dull the interfirm rivalry necessary for competitive advantage.

The results of the programmes suggest that it has created an Esprit de l'Europe in the European information technology industry and that the "Big 12" have significantly sharpened their international competitive edge. On the negative side however, it has also strengthened the European 'Rich man's club' and resulted in the limited technical resources of the smaller countries being focused on creating European competitive advantage rather than national competitive advantage (Braendgaard. 1988). This is discussed further in section 4.2

2.6 Conclusion

The experiences of Japan and Korea, illustrated the economic impact of a focused state policy on the promotion of R & D in the electronics industry.

The level of consultation with industry, in particular in Korea, appears to have been minimal and despite this it would appear that from an economic growth point of view the right decisions were made.

In both countries, the state or state institutions decided where national competitive advantage was to be created and created it by:

(1) providing very significant infrastructural R & D support in relevant industry sectors

(2) providing financial support to participating companies

The EC information technology (IT) programme ESPRIT has also been successful in improving the competitive position of European IT companies in some areas. It has provided "grants" to industry provided:

(1) They work in areas defined by the programme

(2) They have trans national cooperation

(3) They ensure third level institutions are included in the projects

It has been criticised for not being focused enough.

In the United Kingdom, there has been very little state direction of technology development and the policies that have been adopted have been adopted inconsistently.

Ireland has tended to follow the UK model of support for R & D. If a strong electronics industry is to be developed here, the lessons provided by Japan and Korea on State involvement in R & D in electronics need to be considered seriously and the practice, developed in ESPRIT of providing grants only to companies who work in specified areas and use prescribed structures could also be beneficial.

3 THE ELECTRONICS INDUSTRY IN IRELAND

3 THE ELECTRONICS INDUSTRY IN IRELAND

3.1 Industry Development 1979 - 1990

The Telesis Report (1982) had questioned the structure of the electronics industry in Ireland. There was no R & D or marketing in MNC's and the indigenous sector was very weak.

From 1984 the Census of Industrial production has provided data by ownership on industrial sectors. Table 3.1 compares 1984 data with 1990 data on the three sectors of the electronics industry.

Table 3.1 Irish Electronics Industrial Growth 1984-1990

		Data Processing		Electrical Eng		Instrument Eng	
		Irish	Foreign	Irish	Foreign	Irish	Foreign
No of firms	1984	16	34	112	100	22	39
	1990	25	31	163	128	34	47
Average No. per firm	1984	13	182	26	137	11	178
	1990	21	222	30	133	12	39
Net Output per person (£000)	1984	32	91	16	32	13.2	27
	1990	42	141	20	59	26	48

(Source: Census of Industrial Production, 1984, 1990)

The number of indigenous firms has increased in all sectors, and where the number of MNC's has grown the growth in numbers of indigenous companies has been greater.

The trend in size of firm (measured by number employed) has also been upwards, t but only marginally and there is still an order of magnitude difference between size of MNC's operating in Ireland and the size of indigenous companies.

The net output per company is a reasonable estimate of the value added per company although in the case of MNC's it may be distorted by transfer pricing to take advantage of Irish tax law.

Even taking this factor into account, there is still a very significant gap in the growth in value added per person in indigenous companies when compared with MNC's in both office and data processing and electrical engineering. However in instruments engineering the gap between MNC's and indigenous has narrowed.

The main thrust of Government policy (discussed below) was to increase the size and improve the economies of scale of the Irish electronics industry.

Telesis (1982) reported the average size of indigenous metal and engineering firms as 18; in 1984, the average size across the electronics/electrical sector was 21 and by 1990 this had reached 26.

3.2 The Telesis Report

The 1982 Telesis Report concluded that the Irish electronics industry was a low skill, low tech assembly operation. The report looked at different sectors of the electronics industry and compared their critical success factors with the functions which were based in Ireland. The report argued that the electronics industry consisted of a wide variety of business sectors with different competitive economics. It took a number of examples of business sectors and identified their key competitive factors. These sectors were printers, process control systems, customised and standardised integrated circuits and mainframe computer systems. The key competitive factors for each of these businesses is illustrated in Table 3.2.

TABLE 3.2 Key Competitive Factors for Sub-Sections of the Electronics Business

Sub Section	Key Competitive Factors	Role of Manufacturing
Printers	Product and Process Design	Minimal
Process Control Systems	Applications Engineering Product Research and Development Technical Service Sensor Design	Not a differentiating factor
Customised Integrated Circuits	Product Design Process Yield	Important if it can contribute to process yield
Mainframe Computers	System Design Configuration Marketing Warranty Service	Not crucial

The report noted that very few electronics companies in Ireland do significant marketing, research and development or integrated manufacturing in the country. It also noted that where R & D was being done, it was generally of a very minor nature and not contributing to the companies overall competitive advantage (Telesis. 1982. P.141)). The report stated that foreign companies were seeking sub-supply linkages in Ireland and were suffering serious cost penalties by importing components but that an indigenous sub-supplier system was not developing.

Out of 70 multinational companies in Ireland in 1980, the authors of the report could only find two - one in the instruments area and one in the integrated circuits business - described as self contained, containing marketing, R & D and integrated manufacturing.

The main thrust of the reports recommendation was to shift Government support from multinational companies to indigenous companies and from capital support to areas such as product and process technology, overseas marketing, skills development and applications engineering. The report included 13 recommendations but in presenting them, advised that the "philosophical approach, institutions and policies associated with our industrial development are fundamentally sound", (Telesis. 1982. P.35), and introduced its recommendations as a means to "improve an already excellent effort".

Between 1960 and 1980, Government policy had been a model of outward looking policies (O'Malley. 1989. P.72). The Telesis Report supported this policy and some of its recommendations reinforced it, such as, a sharp reduction of grants given to indigenous companies for non traded businesses and a substantial increase in funds devoted to the developments of indigenous export businesses. The report did not advocate Government protection of any industry, but it did argue in some of its recommendations for more specific Government intervention. Recommendation 4 advised the building of structurally strong Irish companies through direct intervention and support by semi-state organisations for companies they had identified as potential winners, while recommendation 5 suggested that the Government should encourage existing large indigenous companies to participate more in traded and skilled sub-supply businesses in Ireland. Recommendation 10 suggested that the Government should intervene directly with trade associations and encourage them to get involved in the areas of product and process design and various aspects of overseas advertising, marketing and distribution. The change of focus from support for foreign direct investment to support for indigenous companies also represented a change towards a more interventionist policy.

The changes recommended were relatively mild but the report did represent a serious questioning of Ireland's reliance on a non-interventionist outward looking policy in the promotion of industrial development.

The failure of this dependence was more thoroughly analysed by O'Malley (1989). He argues that outward looking policies would fail for latecomers because of the barriers to entry. These include economies of scale, product differentiation advantages, capital requirements of late entrants, proprietary technology, experience curves, access to distribution channels and customer switching costs. Foreign direct investment donesn't provide a complete solution because, according to O'Malley it happens on a relatively small scale and it has been concentrated in certain types of activity, usually technologically undemanding, very often relatively labour intensive and usually employing few highly skilled people.

In all sectors of the electronics industry product design is one of the key success factors. Good product design results from the successful implementation of new innovation. This innovation is usually the result of well managed and adequately funded research and development. The Telesis Report commented on the low level of research and development in the Irish electronics industry and recommended that Government policy and the IDA's implementation of this policy be modified so that R & D in both multinational and indigenous Irish companies was encouraged.

The Science Policy Research Centre at UCD carried out a study of the Irish electronics industry in 1981 (O'Brien. 1985). This report identified the lack of R & D being carried out in the industry as being the main obstacle to self sustained growth within the industry. It identified three separate approaches that might employed to achieve this.

The first, the attraction of multinational firms, it found (as did the Telesis Report) to be inadequate for building up the type of base required.

The second, the creation of a Silicon Valley type process it considered unlikely to succeed because of the low level of R & D being carried on and the lack of appropriate skills base.

The third option, which is recommended was the creation of large national champions with their required economies of scale and their protection as infant industries until they developed international competitiveness. However, this option was accepted as difficult to implement because of the openness of the Irish economy.

A report prepared by the NBST on the Microelectronics industry in Ireland (ICA Information. 1985) looked not just at the electronics industry itself but also at a potential applications of microelectronics in different sectors. The report produced sixteen recommendations, six of these were related to training in the areas of microelectronics, four related to increased support and promotion of R & D activity, two related to the development of the telecom system and one each to the creation of increased industry awareness of microelectronics, the development of indigenous industries, and the development of service industries in software.

The report consisting of 3 volumes represented a comprehensive guide to opportunities in microelectronics in Ireland.

3.3 Changes in Outward Looking Policies

3.3.1 Passive to Interventionist

During the 1960s and 70s, the Irish Government maintained almost classic outward looking policies in the promotion of Industry . New Grants, tax concessions and advisory services were introduced to promote exports and legislation was changed to encourage investment in export industries by foreign multinational firms. In the 1960's steps were taken to dismantle protection and return to free trade (O'Malley. 1987. P. 62)

Following the publication of the Telesis Report , Irish Government policy became slightly more interventionist. It took active steps to promote research and development in both multinational and Irish companies and to develop the technical and marketing capabilities of indigenous companies. Technology development was encouraged by the establishment of institutes such as the Microprocessor Applications Centre, The National Microelectronics Research Centre. Coras Trachtala actively participated in the promotion of specific Irish companies abroad.

A report published in 1985 by the Sectoral Development Committee (SDC) (Sectoral Development Committee. 1985), recommended that the State industrial promotion and advisory agencies should identify market opportunities within specific sub sectors and should actively support larger firms in exploiting these opportunities and should support new market opportunities and promising new technologies by focusing existing technological supports and resources on them. The report also recommended that the Confederation of Irish Industry (CII) should establish technology committees as part of their industry federations.

This report also looked specifically at the electronics industry. In its conclusions it noted that compared to the Irish level, R & D in electronics was high but low compared to international competition. It also noted that while the overall level of Government support for the industry R & D was 15% of total expenditure, the indigenous R & D performing companies received 26%. This preferential treatment of indigenous electronics R & D performing companies was maintained throughout the '80s. and represented a more interventionist approach on the part of the Government.

The Sectoral Development Committee Report also noted the need for firms to achieve sufficient size to support their R & D activities at an adequate level .

In his 1987 ESRI paper O'Malley (1987), focused on the need to develop companies with adequate size in order to compete internationally. In its policy recommendation this paper proposed that "the State could play a more active role in developing selected target industries in a number of different ways".

The report also identified a number of industries in which it thought Ireland could compete. The conclusions it reached on the type of industries to set up were basically what was left after it went through a series of exclusions. These exclusions were:

(1) very large scale activities
(2) capital intensive industries
(3) industries in which low wages provide a distinct competitive advantage.

It then suggested the industry should have strong growth potential and that a group of related industries rather than a single industry should be developed. For the electronics engineering industry it reccommended instrument engineering but this reccommendation was not shown to meet the growth and related industry criteria.

This report found that the number of small firms in the electronics and engineering industry had grown rapidly "indicating considerable entrepreneurial initiative and an ability to take increasing advantage of the more accessible opportunities". By international standards, it found "that there is a marked lack of technology intensive industries in indigenous engineering".

It was this type of analysis which laid the basis for the 'Strategy for Irish Owned Electronics Industry' (Department of Industry and Commerce.1989). This policy document outlined a much more interventionist approach from Government. The objectives of this strategy were:

(1) the creation of a number of companies with annual sales of £20m +

(2) the development of a large number of medium sized companies with annual sales of £5m and

(3) maintaining the existing level of small start-ups.

The priorities however, it stated, had to be those of 1 and 2.

The new strategy included exceptional support packages "including support for marketing initiatives in terms of new market support services and financial assistance for marketing drives, financial and other support for increasing management capabilities especially in the areas of international marketing and quality and infrastructural technical support by the establishment of centres of excellence concentrated on the identified needs of developing companies, significant levels of financial support for market orientated product development, financial and other support for technology transfer." (Dept. of Industry and Commerce. 1989)

To carry out these plans an interagency electronics team made up of IDA, CTT, Eolas and SFADCO was put in place with participation from the Department of Industry and Commerce.

In pursuit of this policy, a number of companies were targeted for special development and investment capital was made available from semi state organisations.

On a national level, the most spectacular development was that of Team Aer Lingus. In the electronics sector, Hormann Electronics in Cork received substantial investment from the ESB and Advanced Microelectronics in Sandyford were provided with substantial indirect support.

A joint venture between Aer Lingus and the ESB to develop and manufacture EMI shielded plastic was established as Top Tech.

A significant investment in technology development was proposed and carried out as part of the 1989 - 1993 Structural Programme for industrial development (Gorvernment of Ireland. 1990). This was part of the European Regional Development Fund expenditure.

Expenditure for the programme is classified into sub-programmes, e.g. Inward Investment, Marketing Development.

Each sub-programmesme is further broken down into 'measures'.

Under the Science and Technology sub programmes five measures were listed.

Measure 1	£54m Budget	Programmes in Advanced Technology
Measure 2	£20m Budget	Higher Education Industry links.
Measures 3 and 4	£20m. Budget	Improvement of Technological Services to Industry, (funding of technology audits, development of the National Electrical Test Centre(NETC) .
Measure 5	£47m. Budget	Development of Regional Technical support. (Based on a regional technical support centre in the South East Region, covering the 5 counties of Carlow, Kilkenny, Wexford, Waterford and Tipperary South)

A further measure, measure 6 was introduced in 1991. This represented a return to passive policies rather than the more interventionist ones of the previous 5 measures . It provided £13m per annum for R & D grants to industry for new projects.

3.3.2 Backing Winners

The Telesis Report had advocated the development of strong companies rather than the development of strong agencies. This was to be done through the identification and subsequent support of "winning companies". Who the identified winners were was not published and the basis on which they were selected was not always clear. The Department of Industry and Commerce's policy document (Department of Industry &

Commerce. 1989), identified a number of product technology sectors in which it felt considerable opportunities for development existed. These sectors covered a broad range of the electronics industry including Optoelectronics, Sensors, Electromagnetics, Automation and Measurement, Control and Telecommunications network interfacing products. Each of these categories has a large number of sub categories, yet some of the companies known to have been targeted did not come from these sectors.

IDA Executives implementing this policy are faced with a number of problems:

(1) winners must be chosen from the existing population of companies

(2) each IDA region must have its own quota of winners

(3) the choice must be based on measurable data rather than on for example an assessment of competence of the management.

In its 1992 Annual Report, the IDA (1992) still viewed its company development programme as a key factor in indigenous company development, "throughout the 1980s the programme expanded in scope to become the IDA's modus operandi in its work with Irish companies". The programme requires more intense involvement by the State agencies in the companies activity.

3.4 Analysis of the Irish Electronics Industry using the Porter's Diamond Model

3.4.1 The Porter Model

Michael Porter proposed that the competitive advantage of nations was determined by four factors (Porter. 1990) each of which formed a corner of a diamond (figure 3.1). He demonstrated the effectiveness of his model as an analytical tool in examining the

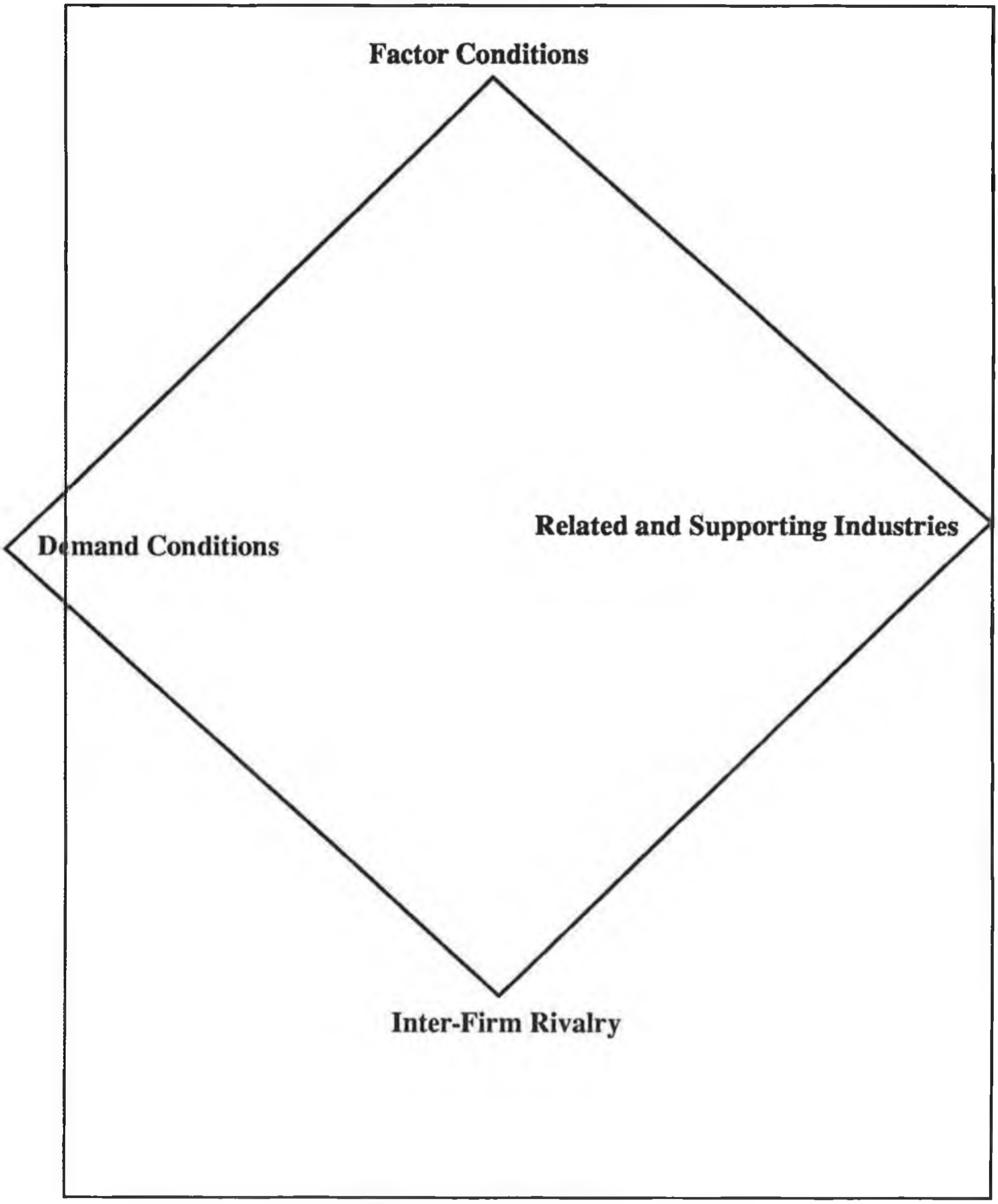


Fig 3.1 Porter's Diamond Model of National Competitive Advantage

competitive position of companies in ten advanced nations - Denmark, Germany, Italy, Japan, Korea, Singapore, Sweden, Switzerland, the United Kingdom and the United States. Porter's basic thesis is that the competitive advantage of companies is derived from their national roots and that these advantages are determined by the four factors.

Porter, acknowledges in his work that other factors can have an influence on his determining factors. Among these he includes chance and the role of Government. He analyses in detail the effect that Government policy can have on these determining factors. Porter also accepts social and political history and cultural norms can play a role in the competitive advantage of many industries. Mjoset (1992) argues that if determinants are determined by other more encompassing factors, the latter factors should figure as the starting point of the explanation.

One of the reasons Porter puts forward for not including the role of Government as a determinant is that it is not "useful". The major attraction of Porter's model, despite its limitations is the fact that it is very useful. The four factors which determine the competitive position of a nation in a particular industry are

(1) Factor conditions

(2) Related and supporting industries

(3) Demand conditions

(4) Firm strategy, structure and rivalry

The Diamond model implies there is no hierarchy among these determinants and they interact with one another in providing competitive advantage for a nation. It provides a framework for analysing the performance and potential of an industry sector.

3.4.2 Factor Conditions

Factor conditions would traditionally have been seen as the major source of competitive advantage for nations, eg coal in the UK, steel in Sweden, capital in the USA and low cost labour in Japan and the Far East. Porter classes these factors as basic factors and argues that they provide the basis of only a limited competitive advantage. More important are what he considers advanced factors. These would include - modern communications networks, high standards of education, availability of highly skilled people and research institutes.

It is only advanced factor conditions which are of relevance to the electronics industry. These are the availability of advanced telecommunications networks, the availability of appropriately skilled personnel and University and Research institutes working in related disciplines. Ireland's telecommunications system is one of the most advanced networks in Europe, (Industrial Policy Review Group. 1992. page 46). A digital switching network was introduced in 1980 and this system has been progressively upgraded since then through the use of optical fibre cable systems. This system can now provide video conference links and high speed computer links using broadband 140 megabits transmission systems (Dwyer, 1987). Despite its technical progress however, the Industrial Policy Review Group found that international charges were higher than competitive countries and that Telecom revenue in Ireland as a percentage of GDP was 2.7% compared with a maximum of 1.8% in other European community member states. (Industrial Review Group. 1992. p 46-47).

In promoting Ireland as a centre for mobile international investment, the IDA have emphasised its "the well educated workforce". They have produced a brochure showing ads in The Irish Times placed by Scottish based companies like Wang and Westinghouse entitled "The Best Hitech Personnel are Easy to Find, When You know Where to Look" (Donohue. 1985).

The key reason for Intel's eventual decision to locate in Ireland according to Kieran McGowan (McGowan. 1991), was the availability of educated skilled people. These skilled people however, were not working in Ireland. According to McGowan, the consultants interviewed 250 of them in Holland, Germany and the UK and 80% of those interviewed said they wanted to return to Ireland if they could find appropriate employment. According to the Industrial Policy Review Group "the perception of many managers that there is not a skilled shortage may itself be part of the skills problem facing Irish industry" (Industrial Policy Review Group. 1992). The group noted that 'in particular there was a serious deficiency of intermediate production skills and an absence of multiskilling both among technicians and crafts people and an absence of integrated financial and technical skills at management level'.

The first Irish electronics research institute was theMicroprocessor Applications Centre was set up in 1977. It was based in the University of Limerick campus and it had loose links with the University. The support that could be offered by the centre was limited. More recently however, the centre has demonstrated increased technical competence. (McGowan. 1992).

The National Microelectronics Research Centre was established in UCC in July 1983 to serve as a training centre in microelectronics for Irish industry and as University based research centre for industry/university research and development projects. The centre has worked closely with Analog Devices who have provided funding of £250,000 per annum (Hanna. 1983). As it developed the centre relied more and more on European Framework Programme Funding and by 1990 was involved with only three projects for Irish based companies (NMRC 1990). European Framework Programmes, in particular the ESPRIT programme has provided funding for the development of a number of research institutes in Ireland between 1984 and 1989. These include Thin Film Magnetics Facility in Limerick, Computer Integrated Manufacturing Centre in Galway, Computer Vision and Microelectronics Computer Programming Centres in Trinity College and a software development centre in DCU. From 1989 under the first Framework Programme funded from European Community Structural Funds, significantly increased funding was provided to the Higher Education Sector for the development of Programmes in Advanced Technology (PATs). Six of these Programmes have been set up - three of them Optronics, Telecommunications and Power Electronics are directly involved in the development of the electronics industry and two others - Advanced Manufacturing and Advanced Materials Development have the potential to make a significant contribution to the electronics industry. The effectiveness of these Programmes in institutions will be analysed later. However, they do provide Ireland with a source of highly trained graduates necessary to be competitive in the electronics industry.

3.4.3 Related and Supporting Industries

The national competitive advantage in one industry can be supported by related and supporting industries in that country when they are internationally competitive. Supporting industries can supply both components and capital goods. Related industries will use the same supplier base thereby contributing to its growth and competitiveness. The most important benefit that accrues to these clusters of industries is that they participate in the process of innovation and upgrading of one anothers products and components. When they are located in the home market, they are more visible and communication is easier between them.

The electronics industry in Ireland includes sections of the information technology industry, telecomms industry, industrial control, security and building related industries (see figure 3.2). These sections are inter related and in many cases mutually supporting as shown in the figure.

There has also developed in Ireland, a number of industries as suppliers to the electronics industry. These include a metal working industry, plastic extrusion, wire harnessing and printed circuit board manufacturing industries. These industries are predominantly indigenous.

In the electronics industry supply chain, indigenous companies are concentrated in the low tech component supply area while foreign multinational companies are dominant in the higher tech areas.

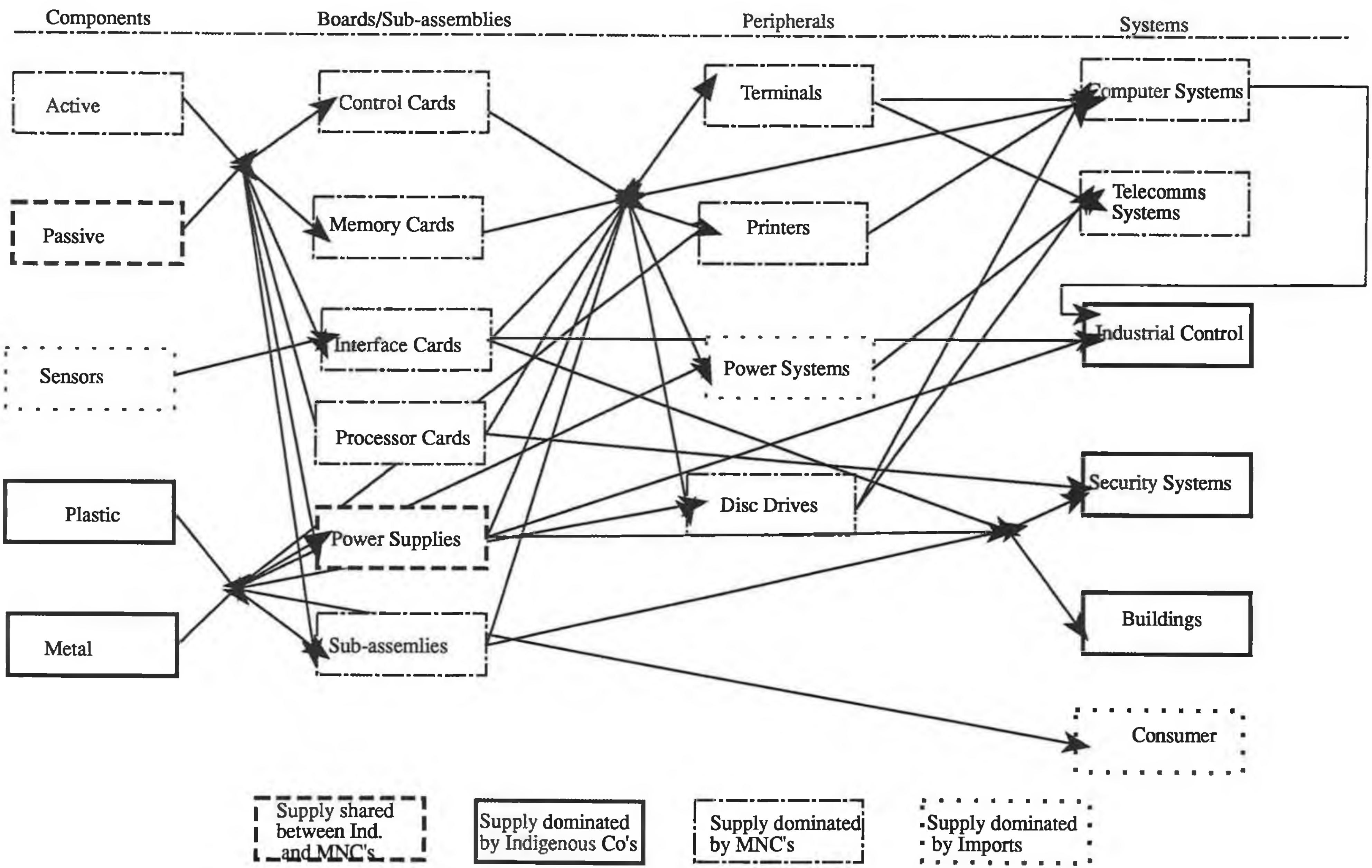


Fig. 3.2 Electronics Supply Chain Indicating Dominant Sources of Supply

The sub suppliers with Irish origins will generally not be operating at world class standards and would not be considered in Porter's terms internationally competitive, while in almost all cases the multinational sub suppliers would be. The few that are R & D intensive lack the economies of scale to be price competitive.

In the case of multinational sub suppliers to final equipment manufacturers, the supply relationship is usually one that has already been established in the US or Japanese market and has been transferred to Ireland to meet the requirements of world class manufacturing and overcome the disadvantage that a large distance from the equipment manufacturer would entail for the supplier. An example of this type of relationship is that which exists between Apple Computer in Cork and many of its sub suppliers. Sub suppliers that have relocated in Ireland include - Alps as manufacturers of keyboards, Logitech as manufacturers of mice and Quantum as manufacturer of disc drives. The first two companies have located close to Apple in Cork and the third is located in Dundalk. Located next to Quantum in Dundalk is their major component supplier, Matsuhitu of Japan. All of these companies are internationally competitive and have technology and marketing advantages which are in not linked in to the Irish economy. Apple has encouraged the establishment of local indigenous companies as suppliers in low technology areas such as printing and electronic assembly and as manufacturers of computer related add-ons.

There is very little multinational manufacturing presence in Ireland in capital equipment supply to the electronics industry. Most of this equipment, such as wave solder machines, automatic pick and place machines and surface mount equipment is imported. It is also in this area, particularly in specialised test equipment that a number of indigenous Irish companies have become internationally competitive. These companies operate in industries where the same economies of scale don't apply and have achieved their competitive position through their R & D activity.

In the security systems, buildings, process control and sensors sectors of the electronics industry, a cluster, linked primarily to indigenous companies exists.

Of the 96 companies listed by the Department of Industry & Commerce (Dept. of Industry & Commerce. 1989), 21 were involved in these sectors. These sectors are closely linked in terms of technology, markets and share similar economies of scale.

Thirteen of these companies are still trading and of these 11 received IDA R & D grants. Of the 8 who failed only one received an R & D grant and that was less than £5,000.

A further 2 companies (Microsol and Edpac), that were not listed have become internationally competitive since then, both of whom have received more than £50K IDA R & D grants.

A similar cluster is developing in the power supply/magnetic component sector (a subsection of the boards/sub assembly sector and passive components sectors).

6 of the 1989 Department of Industry & Commerce list were involved in this area, 2 in power supplies, 1 in power supply testing and 3 in transformers. All 3 power supply companies are still trading and have received IDA R & D grants, 2 of the transformer companies are still trading and since 1991 both have undertaken R & D projects.

The power supply industry is fragmented worldwide with no company holding more than 4% of the $1600 million European market. It has not been possible for economies of scale to be achieved in the manufacture of power supplies nor of transformers which represent their principal component cost.(Frost and Sullivan. 1991)

Some MNC's have been integrated with this cluster (Computer Products and Delaire) and one further internationally competitive indigenous company has been established since then.

3.4.4 Demand Conditions

Porter breaks demand conditions into three segments:

(1) Home demand composition

(2) Demand size and pattern of growth

(3) Internationalisation of domestic demands

For maximum impact on international competitiveness the composition of home demand should include segments which are bigger and more advanced than the corresponding segment on the world market.

Buyers should be demanding and sophisticated requiring product and service mix not yet available on the international market and home buyers should also be early adopters of new products and services which will eventually come to be demanded elsewhere.

For home demand size and patterns of growth to provide competitive advantage, the size of the home demand needs to be adequate to justify early investment decisions because home demand is more certain and easier to forecast than foreign demand. The absolute size of home demand is not that important provided economies of scale can be met by the international market.

The number of independent buyers should be high because the more buyers there are, the greater impact different users will have on product design and final configuration.

The rate of growth of home demand should be high. This will encourage firms to invest in new equipment and adopt the latest technology and invest in further innovation. If the home demand saturates early, it provides an impetus to the firm both to develop new products for the home market and to export. Early saturation also forces increased competition between competitors on the home market thereby further sharpening them for international competition.

The internationalisation of the domestic demand is presented by Porter as a particularly American phenomena whereby US buyers world-wide seek US hotels, rent a car and fast food companies. Equally, US companies locating plants abroad tend to seek their US sources of supply thereby encouraging them to internationalise.

There has been no evolutionary demand in Ireland for electronic products. During the period of protectionism, 1929-1951, industrial employment grew from 109,000 to 226,000 (O'Malley. 1989. page 59). This pattern of industrial growth according to O'Malley, was typical of what is commonly called the easy stage of import substitution. The greatest increase in relative size was in clothing and footwear with lesser increases in textiles, clay, glass and cement.

The emphasis in metals and engineering and other manufacturing was on the production and expansion of consumer goods and certain technically mature intermediate products (see table 3.3).

Table 3.3 Sectoral Composition and Exports of Manufacturing, 1951

	Employ ment ('000)	Employ ment (%)	Gross Output (£m.)	Gross Output (%)	Exports £m.)	Exports as % of Gross Output
Food	31.4	22.4	96.0	35.9	29.2	30.4
Drink and Tobacco	10.6	7.6	39.5	14.8	5.3	13.5
Textiles	14.9	10.6	22.9	8.6		
Clothing and Footwear	22.7	16.2	18.6	7.0		
Wood and Furniture	8.8	6.2	11.1	4.2		
Paper and Printing	12.3	8.8	14.7	5.5	8.2	6.2
Chemicals	4.4	3.1	10.8	4.1		
Clay, Glass & Cement	5.0	3.6	5.9	2.2		
Metals & Engineering	18.0	12.8	28.2	10.6		
Other	12.1	8.6	19.5	7.3		
TOTAL	140.3	100.0	267.3	100.0	42.7	16

Source O'Malley. 1989. P.62

Even with this growth, Ireland still had only 17.9% of the economically active population engaged in industry (O'Malley. 1989).

This industrial structure was unlikely to create the type of demand necessary to create or encourage the development of the electronics industry. With the adoption of outward looking policies, and the establishment of a large number of sophisticated multinational electronics companies in Ireland, between 1960 and 1990, the demand for an Irish based sub-supply industry has been created. The Telesis Report as already noted commented on the lack of an indigenous sub-supply industry which was causing many of the multinational companies to suffer serious cost penalties. (Telesis P. 140). Large electronics companies, such as Digital and Apple spend 90% of their production costs on materials. Meeting the required standards is generally far harder than most Irish component suppliers realise and where suppliers cannot be found, the Industrial Development Authority actively seeks to attract component suppliers from abroad. (McGowan. 1992). Indigenous companies have been successful in meeting sub-supply requirements in low tech areas such as printed circuit boards, cable harnesses, metal enclosures and plastic enclosures.

Products requiring research and development capability such as disc drives, printers, electronic component and monitors are supplied by Irish based multinational companies.

Multinational companies are sophisticated and demanding and will only source their components in Ireland if they can meet world class standards. The IDA are now focusing on Japan as a source of new green field investment in Ireland and already Irish companies are finding that Japanese standards for sub-suppliers are even higher than those for US companies.

One of the problems of depending on multinational buyers located in Ireland is that these buyers needs have already been met on the international market and Irish companies hoping to develop an international market will always be coming from behind.

The size of demand for electronics sub-supply in Ireland is significant. The IDA estimate that there is around one billion pounds worth of purchases made each year from non-Irish suppliers. Currently 10% of the materials requirements for large computers are sourced in Ireland and between 20% and 25% of those of PC manufacturers (McGowan. 1992).

Multinationals purchasing offices act independently and they represent a good cross section of electronics industry .

The demand conditions in the Irish electronics industry are conducive to the creation of competitive advantage but in general because of a lack of technical skills and product development from indigenous companies this demand in the hitech areas has been met by foreign companies locating in Ireland. Indigenous companies have been more successful in the development and supply of capital equipment to these companies and a small number of Irish companies are internationally competitive in the supply of test systems.

3.4.5 Firm Strategy Structure and Rivalry

National advantage occurs in a particular industry if there is a good match between the strategies and structures of firms within the industry and the other sources of competitive advantage for that particular industry. The structure of firms relates to how they are organised. The form of organisation can be determined by the national legal system and by inherited cultural norms. The firms strategy and goals will be to some extent determined by its structure, particularly its form of ownership. For example the strategy of German firms who are owned by institutions and Banks will usually undertake long term investment with corresponding long term payback. This strategy has worked in the chemicals industry in Germany. On the other hand Italian firms are usually privately owned and the shorter life cycles of the textile industry are more appropriate for their payback requirements.

The motivations of individuals who work in and manage firms can also impact their competitive advantage. This difference is very apparent between the UK or Ireland and Germany or Japan, where a national preference for liberal arts and administrative skills in the former can be contrasted with the preference for technical skills in the latter. This national preference in the former is is not conducive to the development of national competitive advantage in the electronics industry nor to the encouragement of electronic R & D activities in this industry.

Porter found in his work that the closest association existed between the persistence of competitive advantage in industry and vigorous domestic rivalry. Domestic rivalry creates pressures to innovate and upgrade. It supports the establishment of supporting and related industries. Domestic rivalry forces companies to employ national advantages with ever increasing efficiency. Without domestic rivalry competitive advantages tend to be relied on and employed with less efficiency.

The electronics industry serves in general a global market or at minimum a Western European market. Electronic distribution companies and manufacturers' sales organisations usually see the UK and Ireland as a single territory. The Irish market is therefore very small to allow for any significant degree of inter firm rivalry between electronic business operating out of Ireland. There has also been the belief in Irish industry that industrial enterprises were entitled to grants (Industrial Review Group 1992). The IDA in providing grants try to ensure that it wasn't contributing to over capacity in any industry. The result of this is that the first entrant into a particular product area tended to be left unchallenged by competing Irish enterprises and when competitiion does arise such as in the PCB industry, security equipment and sections of the metal work industry, each competitor has tended to carve out an area for himself where he remains unchallenged. The overall result is that even when the size of the country and the market for electronic equipment and components is taken into account inter firm rivalry in Ireland is very low.

3.4.6 Conclusions of Porter Analysis

Underlying the competitive advantages provided by Demand conditions, related and supporting industries and inter-firm rivalry is the industries' capacity to innovate and it is this capacity that is enhanced by advanced factor condition.

For companies in the electronics industry to be responsive to demand conditions, they must have the technical capability to meet this demand: to participate in the innovation process with supporting and related industries, they must be able to innovate. Competitive advantage in almost all markets in electronics is provided primarily through technology. The availability of advanced factors is both enhanced by and enhances the national R & D capability.

While Ireland may appear to score reasonably well in 3 of the 4 factors determining national competitive advantage in electronics, it needs a strong R & D capability to take advantage of this and it is through this R & D capability that it can create the fourth - strong firms with inter-firm rivalry.

It is in this context, where, having identified the problems one needs to look for a framework of solutions, that the analysis carried out by Mjoset (1992) is most useful. His criticism of Porter outlined above suggested that if the four determinants were determined by more encompassing factors, then it should be these factors which are sought.

3.5 National Systems of Innovation

A national system of innovation has been defined as "the institutions and economic structures which affect the rate and direction of innovative activities in the economy" (Edquis and Luundeval. 1992) The national system of innovation concept is a development of Schumpeter's economic analysis which sees Schumpeter's original heroic entrepreneur and his later large corporation being replaced by a number of institutional features both inside and outside the enterprises. Denmark's agro industrial complex is usually presented as the classical form of a national system of innovation that works effectively.

There is no prescribed national system of innovation. Its key feature is interactive learning whereby individuals and organisations increase their technical knowledge through interacting with one another rather than by independent research. This concept is similar to Porter's demand conditions but places the buyer supplier relationship on a more co-operative basis than Porter's model suggests. This type of relationship between buyer and supplier is now recommended practice in manufacturing operations (Schoenberger 1986).

National systems of innovation also recognise the importance of advanced factors and see a central role for Government in their creation. This analytic approach in line with Schumpeter sees innovation as the primary engine of economic growth. It recognises several key elements in this process. It recognises that their interdependence is related to the nations culture, habits and institutions. Essential to this approach is that these various elements combine to form a system. If these elements are inter-related in such a way as to enhance one another such as in the Danish Agro Industrial Complex, one has an effective national system of innovation.

In Scandinavia, these systems have contributed to economic and social development.. High levels of social justice and equality form virtuous circles where the various elements interact with economic factors and mutually support one another within those circles. The more elements that can be combined within a circle or interacting circles the greater the well-being of the community.

In his study of the Irish economy, Mjoset (1992) distinguishes between economic growth and socio economic development. The latter includes, in addition to simply the growth of output other conditions necessary for the fulfilment of human needs, such as the abolition of poverty and the provision of work for most of the labour force. He characterises the Western world in general with having socio economic development while the third world would be characterised by growth without development. He places Ireland between these two types.

In comparing Ireland with five contrasting countries, that is five European countries of similar size and population - Austria, Denmark, Finland, Sweden and Switzerland he identifies Ireland's fundamental problem as a weak national system of innovation. This weak national system of innovation is maintained by what he terms a vicious circle illustrated in figure 3.3.

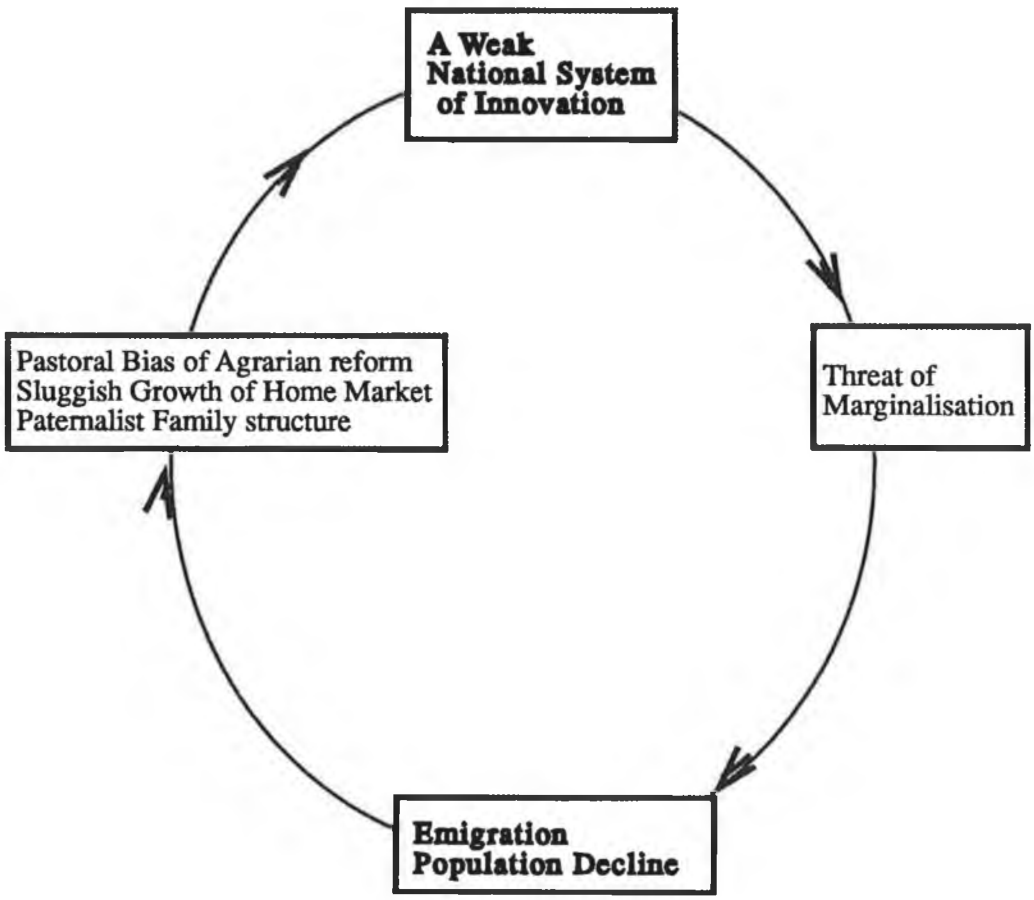


Fig. 3.3 Ireland's Basic Vicious Circle (Source Mjoset,1992 ,p.7)

The major reinforcing factor of this vicious circle is emigration, which has been a feature of Irish life since famine times. This fundamental circle is further reinforced by more specific circles which are linked to it. These are illustrated in figure 3.4 and 3.5.

Figure 3.5 illustrates the impact of the outward looking policies adopted in the late 1950s.

In this the basic vicious circle is reinforced by an industrialisation vicious circle.

The elements of the basic vicious circle remain - a weak system of innovation increases the risks of unemployment and poverty, encouraging people to emigrate. Emigration strengthens the pastoral agricultural bias, reduces the size of the home market and weakens the drive to innovate.

This weak innovation system allows for the diffusion of only the consumer and not the production elements of the "American way of Life" This weak indigenous industrial structure further strengthens the existing social structure and doesn't encourage the foreign owned companies to integrate into the economy or participate in joint innovation projects.

Non integrated foreign owned companies which create jobs and otherwise "mind their own business" encourages a non interventionist policy on the part of the state.

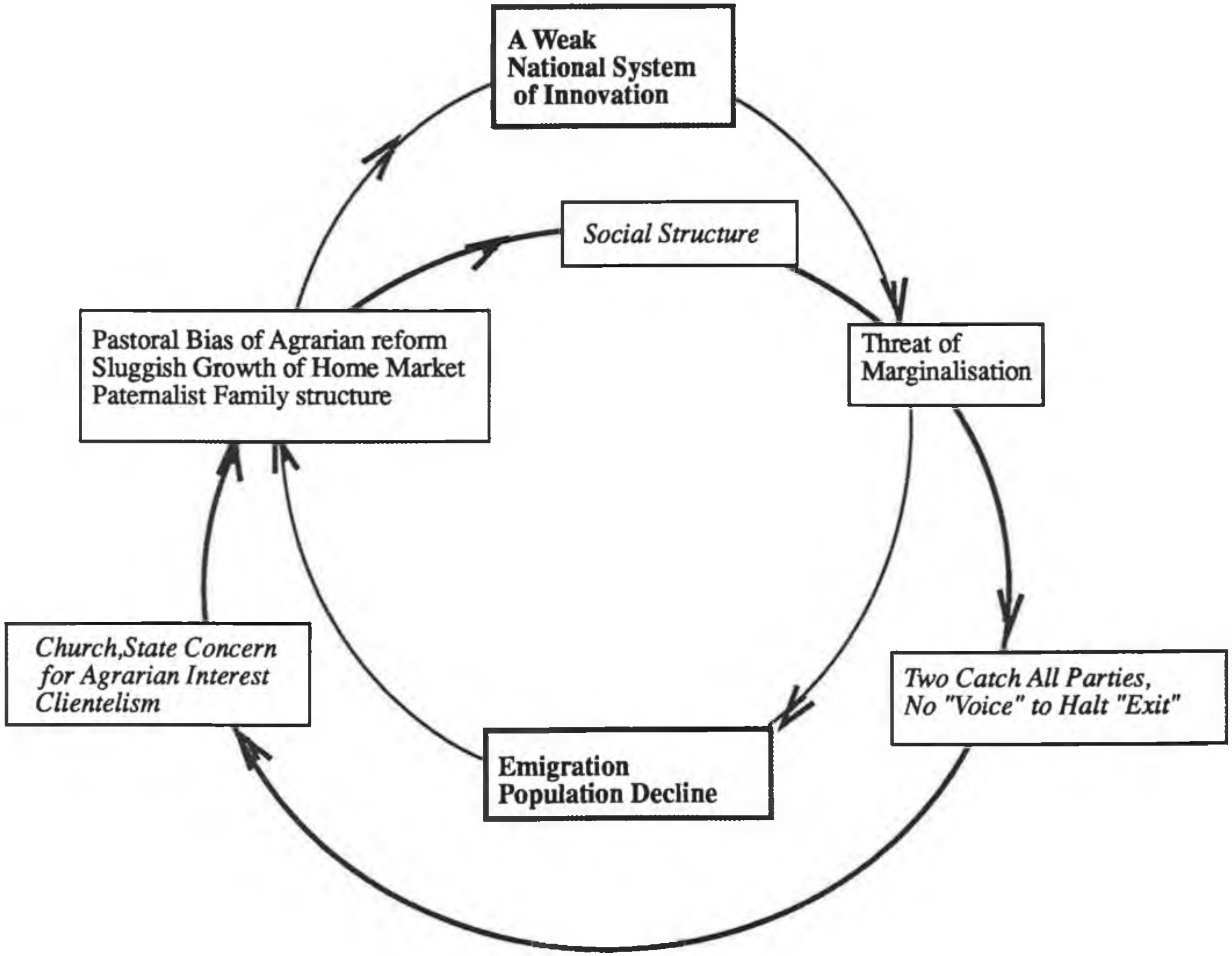


Fig. 3.4 Ireland's Socio-political Vicious Circle (Source Mjoset,1992 ,p.11)

Not intervening weakens the States capacity to do so, both of which contribute to a weak system of innovation.

The contrast countries, Mjoset argues adopted more interventionist policies and by refusing to depend on foreign owned companies strengthened their own national systems of innovation. The analysis carried out by Mjoset illustrates the dynamic influence of many of the factors identified by Porter. Mjoset argues that the extent to which these factors support national system of innovation is a key determinant of national competitive advantage. He also illustrates a potential national innovation system (figure 3.6). It suggests a much more pivotal role for Government in the creation of national competitive advantage than Porter concedes and places less emphasis on the importance of interfirm rivalry. (Mjoset. 1992 P.120).

This figures illustrates a generic social control system that could be used to create more innovative and effective enterprises.

It assumes the wage earners in the enterprise will be supportive of the enterprise in their interaction with society.

This interaction will therfore result in an educational system that will generate the right skills for the enterprise and a state policy that is itself supportive of the enterprise and will direct the banking system to be supportive also.

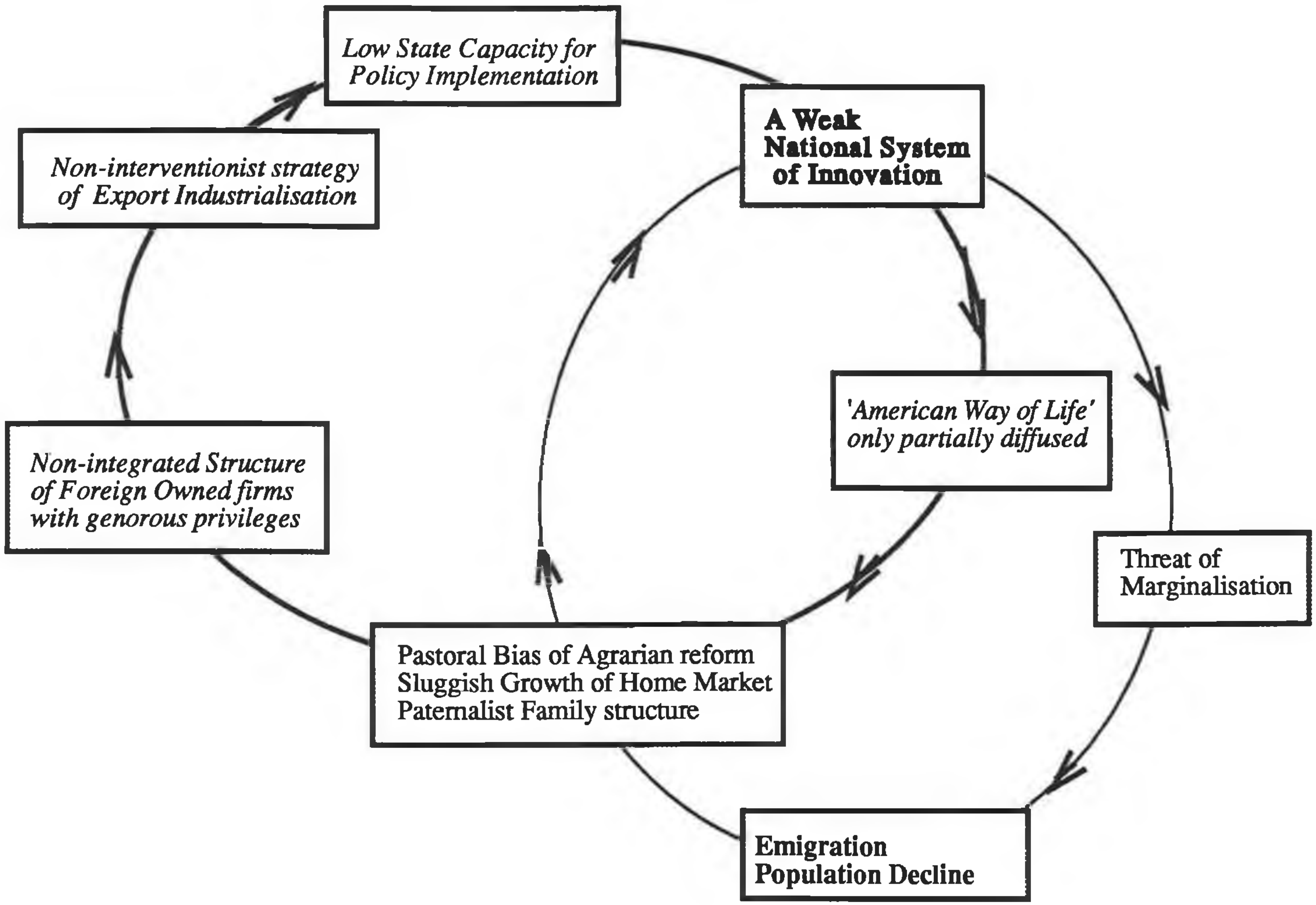


Fig. 3.5 Industrialisation Vicious Circle (Source Mjoset. 1992. P. 13)

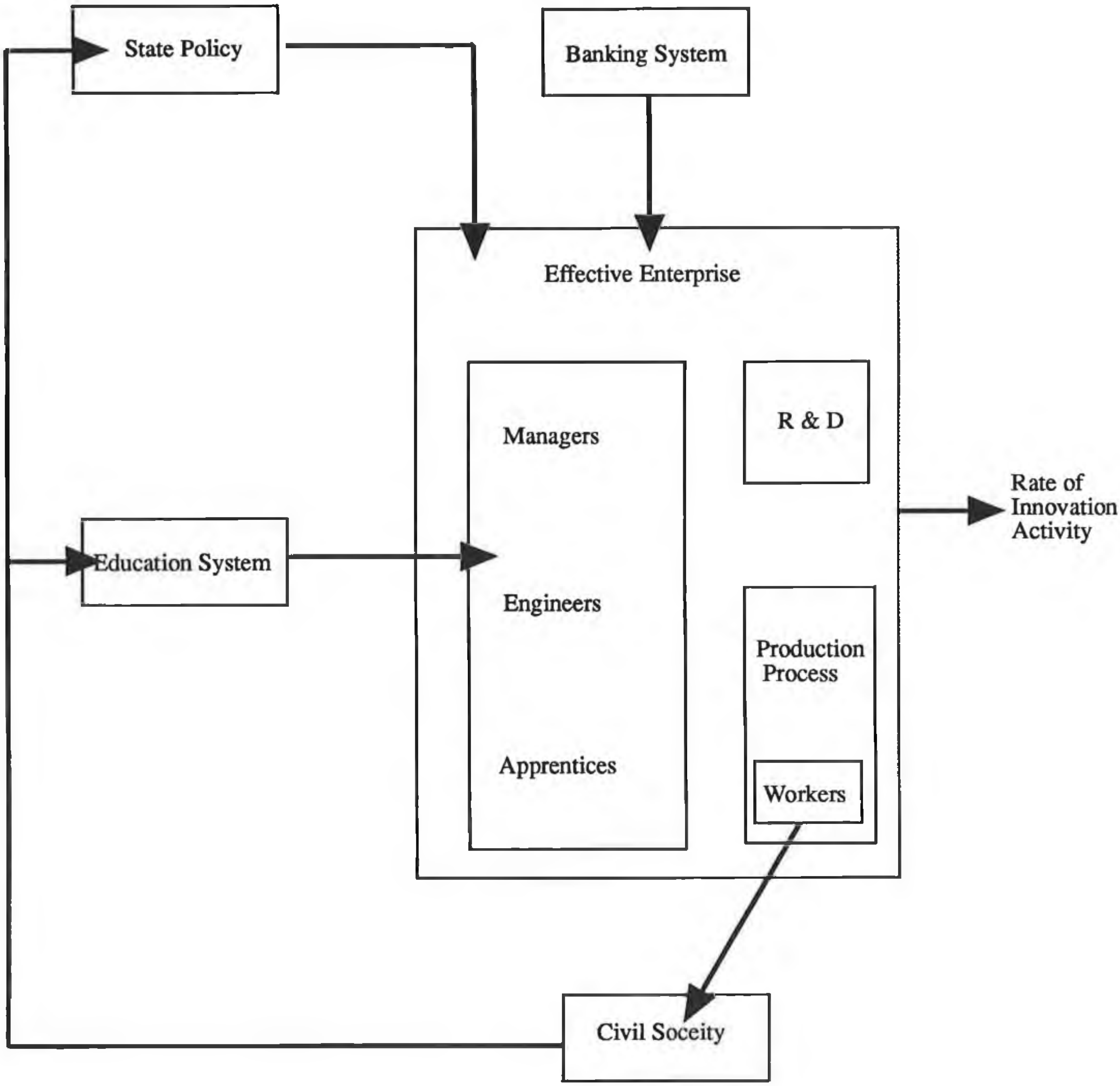


Fig. 3.6 Potential National System of Innovation (Source : Mjoset 1992 P. 120

The national system of innovation 'model' is a useful framework in looking at the impact of R & D in electronics in Ireland:

(1) It has a consistent economic foundation and is not based solely on empirical evidence and case studies.

(2) The empirical evidence which supports it is derived from small open economies.

(3) It recognises the dynamic effect of different factors and the importance in how they interact.

(4) It provides a framework in which a Porter analysis can be more usefully interpreted.

(5) It recognises the central role of innovation and R & D in economic development - ie it looks below the surface whereas a Porter analysis can be superficial.

Thus, an analysis of the national system of innovation in electronics requires an in-depth study of the innovation process in the Irish electronics industry.

3.6 Conclusion

Government policy towards the electronics industry has maintained an outward looking approach, encouraging exports and foreign investment in the industry.

Since the Telesis Report was published this policy has varied in its level and type by intervention.

In the early 1980s R & D was actively encouraged in the industry while since the mid eighties it has been less so.

Support for research institutes has also been variable. During the mid 1980s almost all electronic research activity was dependent on ESPRIT funding. Since 1989 significant funding has been made available for electronic research programmes in university research centres.

A Porter analysis of the industry suggests a relatively strong industry in terms of competitive advantage but one that lacks the innovative capability to capitalise on these competitive advantages. The analysis has identified a number of sectors in which the industry is strong and has highlighted the correlation between R & D activity and survival in these sectors

The national system of innovation concept is therefore developed as a more useful model in which to view the Irish electronics industry and the role R & D can play in its development.

4 Research and Development in the Irish Electronics Industry

4 RESEARCH AND DEVELOPMENT IN THE IRISH ELECTRONICS INDUSTRY

4.1 Methodology

In reviewing the performance of Irish electronics companies the following data sources are used:

(1) Eolas Science and Technology evaluation unit surveys of business expenditure on R & D, 1979-1991. The methodology of this survey and its limitations are discussed in Appendix C.

(2) The "Details of Capital Expenditure" sections of the IDA Annual reports published as Part 2 of the IDA Annual Report since 1982.
The details of expenditure on R & D in electronics by the IDA over the period 1979 to 1991 are included in Appendix E and the rationale for using R & D grants received as a proxy for R & D activity is discussed in Appendix F.

(3) The companies who had received more than £50,000 in grants over the 12 year period were compiled from Appendix E and these were used as population for a survey of R & D intensive companies. There are 86 companies on the list (Table 4.6) and of these 55 are still in existence.

(4) Kompass, Connect, ITPA and Maid databases were used to obtain further information on individual companies

(5) All of these companies were telephoned and asked if they would participate in a survey on R & D support factors and inhibiting factors and of the 55, 30 agreed to participate.

(6) The companies surveyed the questionnaire they were sent and details of the responses are included in Table 4.9. 20 responses were received in time to be included in the survey, two of these could provide no information because they were no longer doing R & D.

4.1.1 Business Expenditure on R & D (BERD) in the Electronics Sector

Statistics published on business expenditure in R & D published by EOLAS and the OECD are compiled using ISIC (international Standard of Industrial Calssification) codes (see Appendix C). R & D in electronics can fall under 1 of 3 sectors; each sector is made up of related ISIC codes.

Electrical machinery

Electronics

Instruments

The information on business expenditure in R & D (BERD) in the areas is presented in figures 4.1 to 4.5 and the detailed data supporting these figures is presented in appendix 4. All financial data in the figures are at constant 1982 prices.

4.1.2 Electronics Sector

The electronics sector includes ISIC codes 3832 (communications and office machinery) and 3825 (semiconductors and computers)

Figure 4.1 illustrates total business expenditure on R & D between 1979 and 1991 and the percentage of it made up by:

1 The Electronics sector

2 Governnment Grants

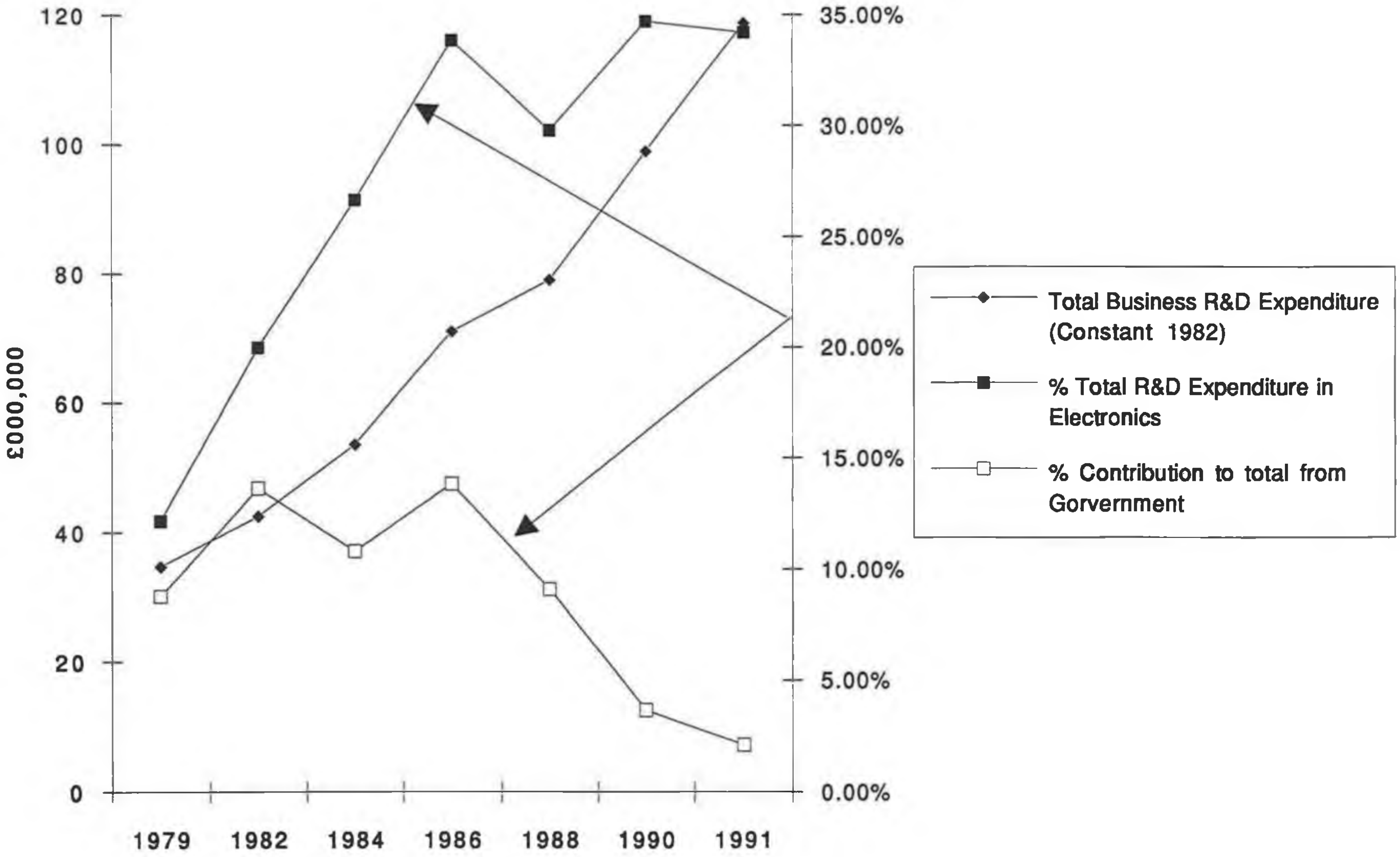


Fig 4.1 Total Business Expenditure on R and D 1979-1991

Expenditure on R & D has been growing at a steady rate of 9.6% per annum over the period in question.

Between 1979 and 1986 expenditure in the electronics sector grew from 12% of the total to 34% by 1986.

As can be seen from Figure 4.2 this growth was entirely due to the performance of the multinational sector.

This was the period which saw the introduction and phenomenal growth iof personal computers and the widespread industry acceptance of the microprocessor. A number of multinational companies set up or significantly expanded their R & D activity (Digital, Analog Devices and Inland Motors) while others ((Prime Computer, North Star, CPT) were set up incorporating an R & D function.

Since 1986 BERD in Electronics has grown at the same rate as the general level of BERD. This growth both in electronics and in general has been maintained despite the substantial decline from 15% to 1.5% in the States' contribution to the total.

Since 1979, expenditure by the indigenous sector in electronics R & D has remained fairly steady, at between two and three million pounds per annum at constant 1982 prices.

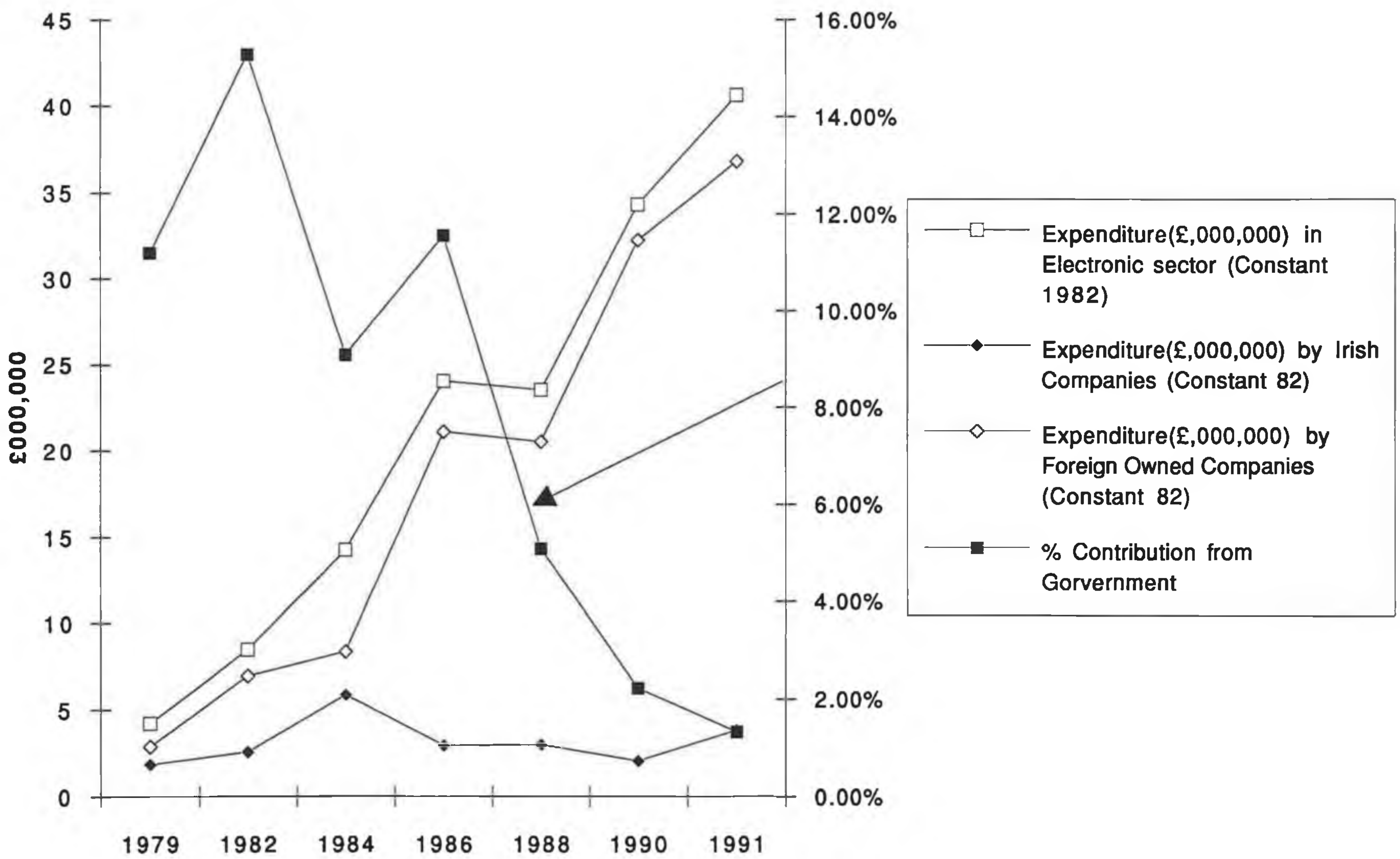


Fig 4.2 Business Expenditure on R and D in Electronics

Fig. 4.3 illustrates the number of companies engaged in R&D work in this sector.

Here there was a sharp increase in both the indigenous and multinational sectors between 1979 and 1984. Since then it has remained relatively stable with equal numbers of both indigenous and multinational firms carrying out R&D work.

4.1.3 Instrument Sector

Fig. 4.4 illustrates R & D activity in the instrumentation industry.

Here, the multinational sector again predominates with the Irish indigenous R & D effort relatively static since 1979. In this sector however, multinational spending on R & D seems closely related to the level of Government funding provided.

A decline in spending has only occurred in 1991. This decline, while it does appear to track Government funding with a two year log could equally be due to other once-off factors such as the reduction in the R & D activity undertaken by Technicon or Leeds and Northrop which occurred at this time.

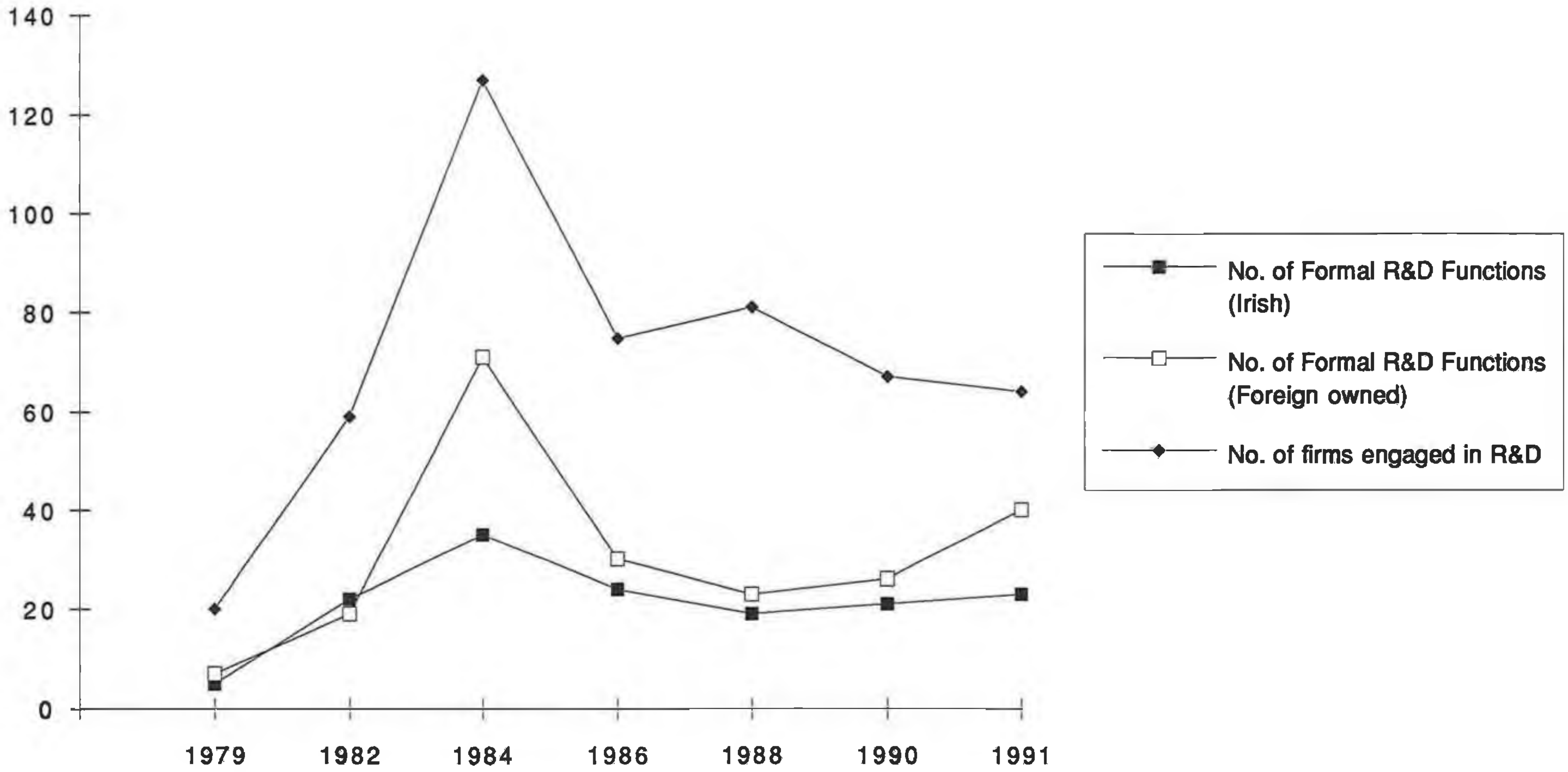


Fig. 4.3. Number of firms engaged in R and D.

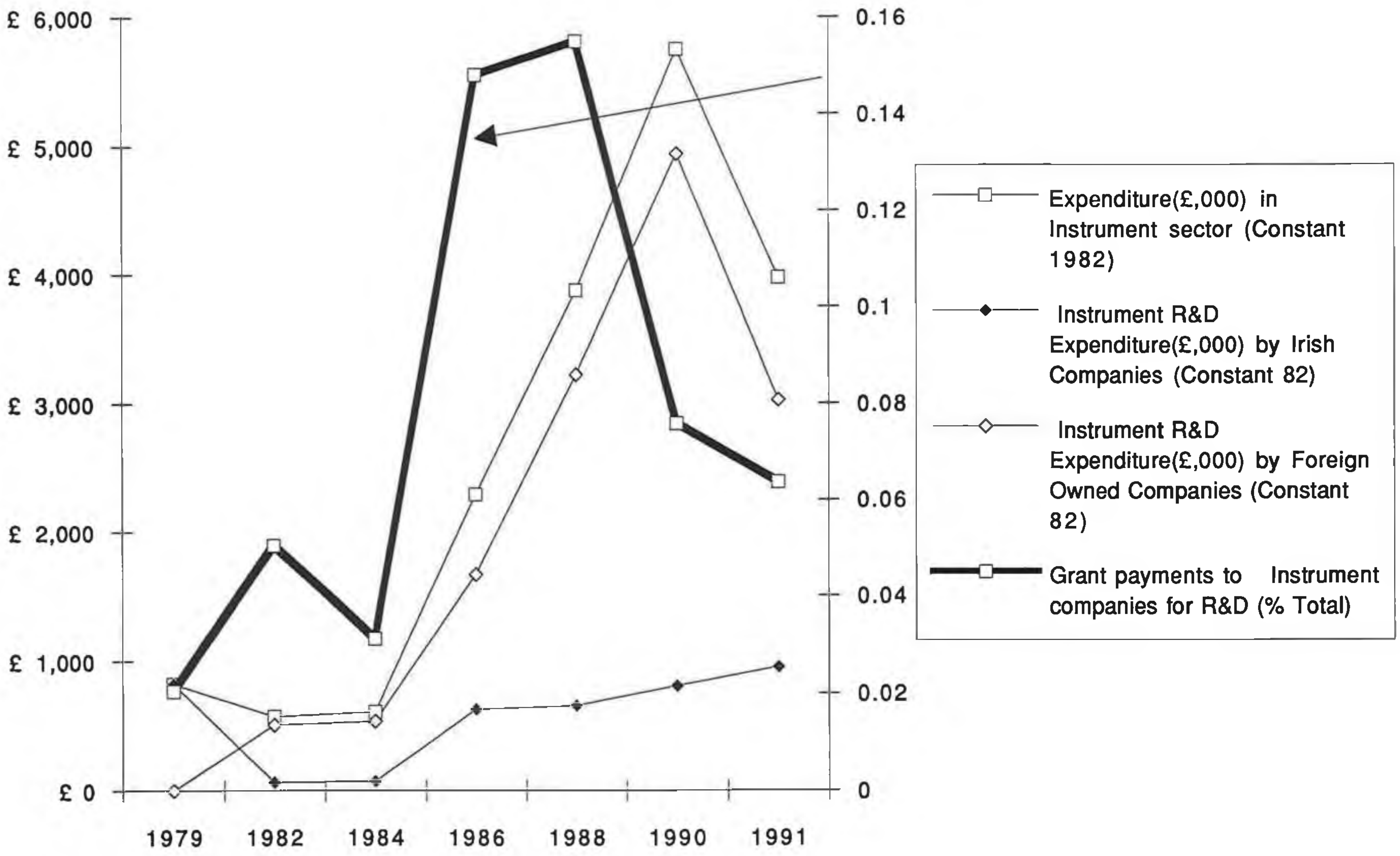


Fig 4.4 Business Expenditure on R and D in Instrumentation

4.1.4 Electrical Machinery Sector

The electrical machinery sector under ISIC 3831, includes the manufacture of electric motors, generators and transformers and the manufacture of switch gear, switchboard apparatus and electricity distribution equipment.

ISIC 3832 includes "manufacture of radio transformers". A company carrying out R & D activity can only be listed under one sector and the selection is made by the R & D evaluation unit in Eolas and not by the company.

The result is that:

(1) Much of the work in the development of motor control systems carried out in Ireland which is essentially R & D in electronics is classified under electrical machinery.

(2) Work in the modernisation of electrical distribution boards which again is electronic in nature is classified under electrical machinery

(3) Transformer design work where the transformer is part of an electronic design may be classified under electrical machinery

BERD in this area is illustrated in figure 4.5.
Indigenous companies involved in this sector are primarily involved in the transformer and electrical switch gear areas. Of 44 companies listed in Kompass as transformer manufacturers 42 are indigenous and 101 out of the 105 electrical switch gear listed are indigenous.

Transformer manufacturers are part of the power supply cluster of companies while manufacturers of electrical switch gear would be part of the industrial control cluster.

The growth in R & D by indigenous companies can be explained by the customised nature of these products. There is usually not a standard product available that will meet a particular customers' requirement and the manufacturer is obliged to have a design capability available to customise his products. The growing level of indigenous R & D in these areas reflects the growing strength of these industry clusters.

The design expertise required is usually not great and the materials used - copper and steel are costly to transport.

In switch gear and control panels there has also been a move towards more sophisticated sensing and display of electricity supply utilisation resulting in the use of more and more electronics. Some Irish companies have been focusing their design activity on the trend towards more sophisticated and display requirements on control panels and electrical switch gear.

The activity of multinational companies in this area has been erratic. Major design efforts by Inland Motors were significantly scaled down in the mid eighties while another by Hyster Automation ended with the closure of the company in 1987.

Telemecanique have carried out no R & D while Square D and ABB have started to undertake R & D on a small scale.

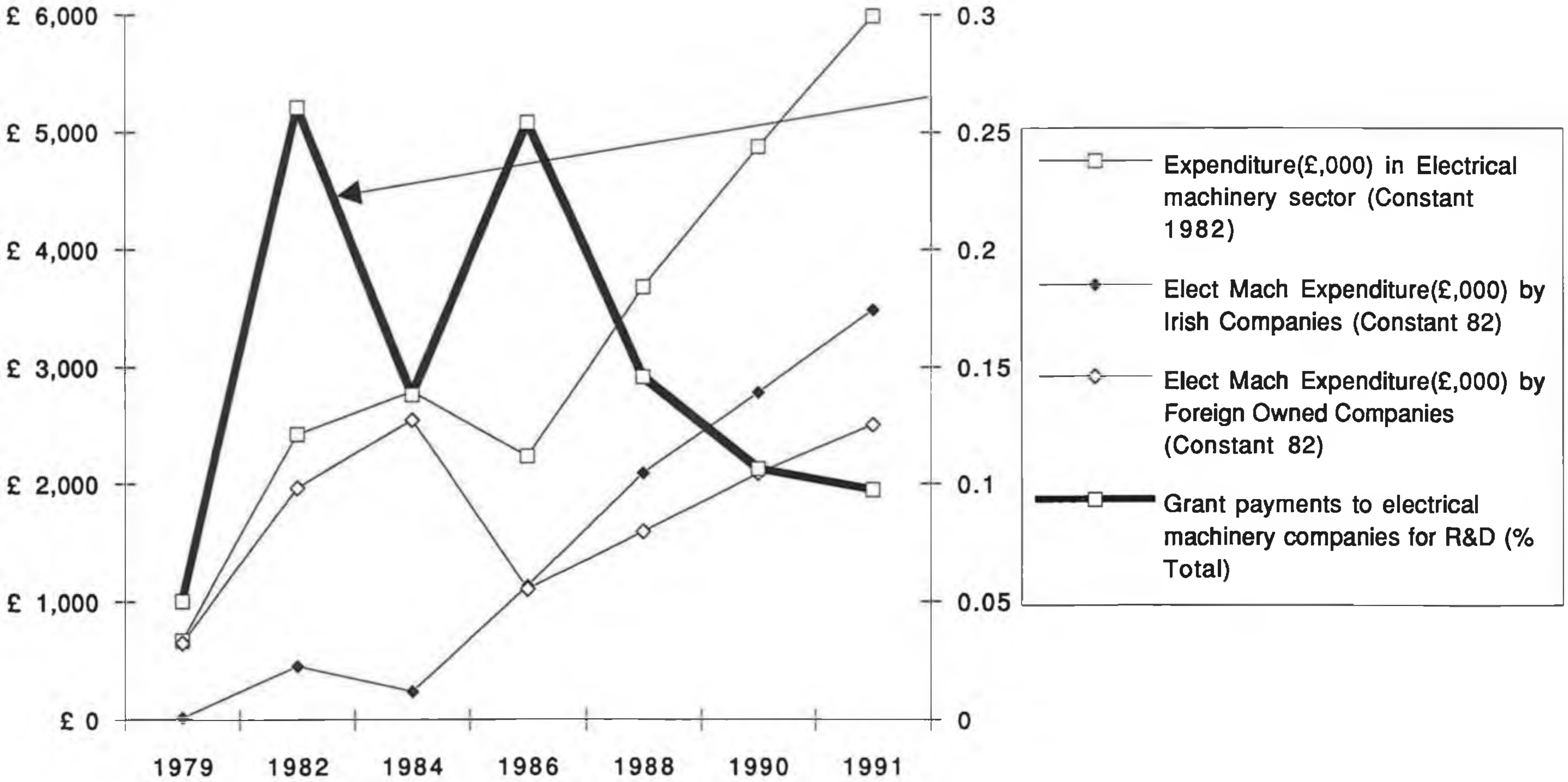


Fig 4.5 Business Expenditure on R and D in Electrical Machinery

4.1.5 Total BERD in Electronics

In figure 4.6 these 3 sub-categories added together provide a close approximation of the total BERD in electronics.

In this way they also provide a basis of comparison with figures provided in the census of industrial production. The three ISIC sectors added together are almost equivalent to the NACE codes 33, 34 and 37 while taken individually there is no equivalence.
The growth in net output, employment and R & D expenditure for indigenous and multinational firms is illustrated in table 4.1.

Table 4.1 Growth in Net output, Employment and Expenditure on R & D between 1984 and 1990 in Indigenous and Multinational Firms

Constant 1982 prices

	Net output (£M)		No's employed		R & D Expenditure(£)	
	Irish	MNC	Irish	MNC	Irish	MNC
1984	48.6	1071	3403	26401	6.2	11.5
1990	91.25	1628	5931	31476	5.7	41.4
Growth	+87%	+52%	+74%	+19%	-8%	+260%

(Source: Census of Industrial Production, 1984,1993; Eolas R&D statistics, 1984.1993.)

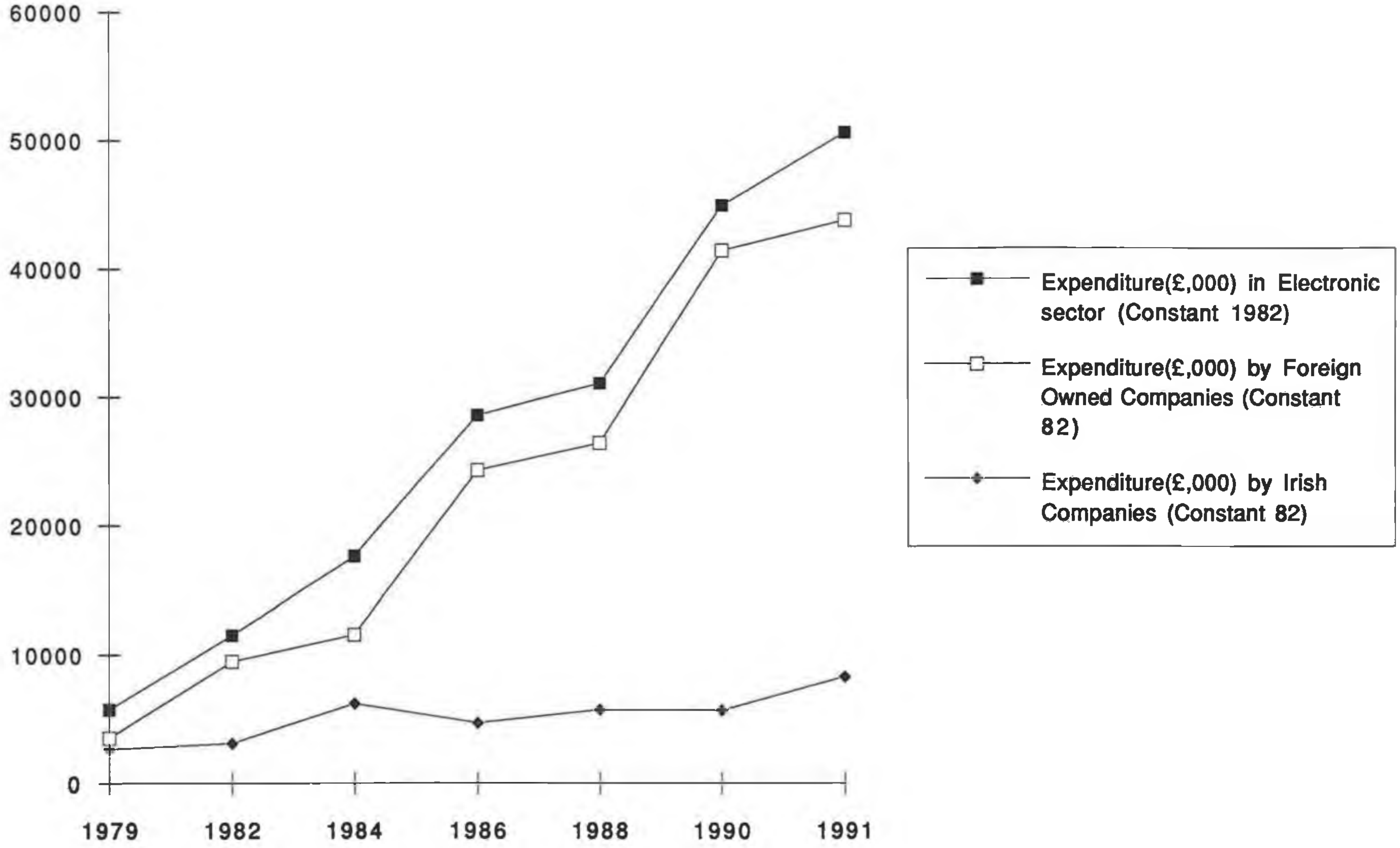


Fig 4.6 Total Business Expenditure on R and D in Electronic Sector

Net output and R & D expenditure are both at constant 1982 prices with the same annual deflators. The growth in R & D expenditure by MNC's is the most dramatic increase since, as shown in 4.3, the number of MNC's involved in R & D has remained fairly static. This represented a significant increase in expenditure by R & D performing companies.

The expenditure by indigenous companies has fallen over the six year period despite significant growth in output and employment levels. 1984 represented a peak in expenditure by indigenous companies on R & D (approx 6% of sales). This level of expenditure was unsustainable particularly when the low profitability of indigenous industry is considered, being only 2% of sales in 1985 (Kinsella. 1992). The 1990 level of expenditure by indigenous industry of 6.5% of net output or 3% of sales is more sustainable and this should rise in line with net output over the coming years.

The evidence then would suggest that :

1) the availability of significant grants for the setting up of R & D functions within multinational companies has had an impact on the decision of these companies to set up R & D centres.

2) the availability of grants has had no impact on the rate of expenditure on R & D of these MNC's.

(3) for indigenous companies, both the number of companies carrying out R & D and the amount of money they spend on it be related to the availability of grants.

They may have spent excessively on R & D when substantial grants were avialable in the early 1980's and may now be gearing their R & D expenditure to their business needs, irrespective of grant availability.

The structure and average output of indigenous companies not changed significantly over this period. There has not been the growth in £5M + and £20M + companies that government policies had targeted. In the office and data processing machinery sector (NACE Code 33) the average output per Irish firm was £12.7M compared to £65M for foreign owned firms while in electrical machinery it was £1.5M compared to £13M for foreign owned firms. However the growth in total output and in employment of indigenous companies has been higher that of MNC's.

4.2 International Comparisons

Table 4.1 illustrates Ireland's relative performance compared with twelve other OECD countries in terms of industry financed R & D as a percentage of GDP. The table illustrates that Ireland's performance has improved consistently since 1967 relative to all the other listed countries.

Table 4.2 Trends in Industry-financed R & D as a Percentage of GDP in 12 OECD countries, 1967-88

	1967	1975	1985	1988
United States	1.01	1.01	1.35	1.38
Japan	0.83	1.12	1.84	1.95
Belgium	0.59	0.75	1.06	1.13
Denmark	0.34	0.41	0.60	0.68
France	0.61	0.69	0.94	0.96
Federal Republic of Germany	0.94	1.12	1.58	1.78
Ireland	0.17	0.22	0.33	0.49
Italy	0.35	0.47	0.58	0.54
Netherlands	1.12	1.02	0.96	1.14
Spain	0.08	0.19	0.26	0.32
Sweden	0.72	0.96	1.71	1.74
Switzerland	1.78	1.67	1.59	2.20
United Kingdom	1.00	0.08	0.96	1.06
Western Europe	0.79	0.83	1.07	1.17

(Source : Patel & Pavitt. 1991 P.40)

A further indication of R & D performance is the share of US patents originating in Ireland. Again, table 4.2 indicates a continuous growth trend in Ireland's share of Western European patenting in the US.

Table 4.3 Percentage Shares of Western European Patenting in the United States, 1963-88

	1963-8	1969-73	1974-8	1979-83	1984-8
Fed. Republic of Germany	33.74	35.62	37.16	40.10	40.91
United Kingdom	24.80	21.56	18.16	15.91	14.67
France	13.42	13.99	14.45	14.29	14.60
Netherlands	4.67	4.36	4.32	4.49	4.62
Italy	4.27	4.77	4.72	5.37	5.83
Denmark	0.92	1.08	1.03	0.93	1.03
Belgium	1.63	1.88	1.84	1.64	1.55
Ireland	0.06	0.14	0.11	0.12	0.20
Spain	0.42	0.47	0.59	0.40	0.57
Greece	0.06	0.08	0.07	0.04	0.05
Portugal	0.03	0.03	0.03	0.02	0.02
Switzerland	8.66	8.41	8.81	8.33	7.31
Sweden	5.24	5.08	5.65	5.09	4.89
Austria	1.33	1.57	1.76	1.85	1.89
Norway	0.50	0.53	0.62	0.56	0.60
Finland	0.25	0.42	0.68	0.85	1.27
Total	100.00	100.00	100.00	100.00	100.00

(Source : Patel & Pavitt. 1991 P.41)

When broken down by sector, into sectoral patterns of relative technological advantage (Table 4.3), there is a shift from the motor vehicle and mechanical engineering areas towards the chemical/electronic areas. However, because the number of US patents originating in Ireland is relatively small, it would not be valid to draw any more detailed conclusions from these figures.

Table 4.4 Sectoral Patterns of Relative Technological Advantage (Sharp and Walker 1991. P. 42-43)

	Fine chem.	Indus chem.	Materials	Mech eng.	Motor vehic.	Elect. mach.	Electron cap.	Tele comm	Electron cons.	Raw mat. based	Defence
Ireland											
1963-68	0.00	0.39	0.00	1.28	2.99	0.00	0.00	0.65	0.00	0.55	0.00
1984-88	1.54	1.68	0.00	0.69	0.00	1.06	0.90	0.00	0.76	1.27	0.00

(Source : Patel & Pavitt. 1991 P.42-43)

In its review of Industrial Policy, the Cullilton Group drew attention to Ireland's apparently poor performance relative to "the smaller industrial nations in Europe when it comes to spending on R & D (even as a share as GDP)" (Industrial Policy Review Group. 1992. P.55). Although the group could be legitimately concerned at Ireland's performance (figure 4.7), it represents the best possible presentation of Ireland's performance in this areas and it ignores the fact that the great bulk of activity in Ireland's R & D effort is driven by innovation systems outside of the country (Foreign, MNC's and ESPRIT) and only very loosely coupled to the Irish economy.

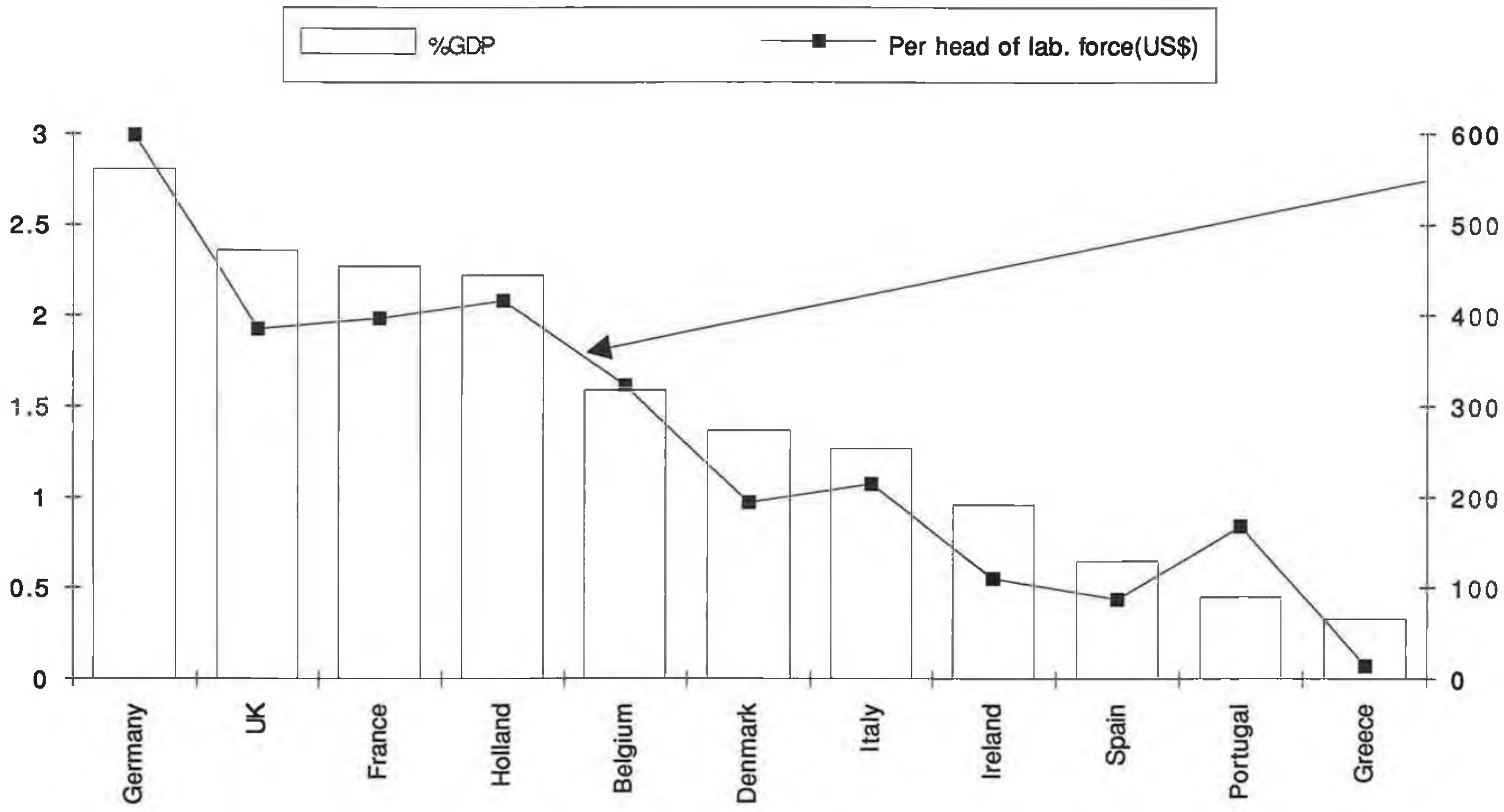


Fig 4.7 EC Spending on R & D

4.3 EC Framework Funding of Electronics R & D in Ireland

Funding for R & D in electronics in Ireland has come from the European Framework programmes, mainly through ESPRIT. ESPRIT is the information technology programmes (see section 2.5) and between 1984 and 1991, contracts worth £36m were secured by Irish interests. In 1984, 5.1million ECU went to Irish industry with 5.2 million ECU going to universities and institutes (Eolas).

Out of ten companies who received funds, four had some involvement in non software electronic projects. These were Farran Technology, Memory Computer Ltd, Digital Equipment Company and Mentec International Ltd. Of these only Farran Technology and Mentec International Ltd are still in existence. Of the software companies funded, one out of the six is still in existence.

In 1985, £3m was secured by eleven Irish companies. Four companies were not involved exclusively in software. Analog Devices BV, Farran, Mentec and Memory Computer.

In 1988, Farran Technologies was the only Irish company funded in the area of microelectronics and peripherals - the non software areas.

The RACE programme was set up in 1988, modelled on the ESPRIT project and managed in exactly the same way, with a total budget between '88 and '92 of 460 million ECUs of which 16 million went to Ireland. As with the ESPRIT programme, the funding was split between "industry and the university sector". Again, as with ESPRIT, the vast majority of the projects conducted in Ireland by industry have been software intensive and the commercial credentials of the industrial participants are even more questionable than in ESPRIT. Among them are Broadcom Eireann Research, Irish Medical Systems Ltd, Work Research Centre Ltd, Bray Information Technology and Letterkenny Information Technology Centre.

The framework programmes have been designed primarily to enhance European competitiveness with respect to the US and Japan. They have worked successfully with large European electronics and telecommunications companies. For Ireland they have meant that the scarce technical resources available in the colleges and third level institutions have been harnessed for the benefit of the large European companies. A study carried out in Denmark in 1987 (Braendgaard. 1988), found similar results in the Danish electronics industry including the establishment of a number of companies whose only function seemed to be to absorb a national allocation for industrial partners.

The study found that:

(1) the participating Danish companies were small by European standards and by Danish standards.

With the exception of the MNC's, Analog Devices and Digital, this is also true of all the participating Irish companies.

(2) The participating companies had as their main activity the delivery of "projects" for programmess such as ESA and ESPRIT.

The major Danish participant is described as follows: "It has great skills in landing international research contracts, first from the ESA and now mainly from the EEC. EUREKA is also emerging as a promising market for its products, which are 'projects'. Its orientation is almost entirely international, with few linkages to Danish firms. It employs about 200 people, mostly computer scientists and electronics engineers". (Braendgaard. 1988).

The same description could equally be applied to the NMRC Ireland's major participant. There has been no new product related spin off benefit to Irish industry from the advanced research activities being carried out in the Irish colleges under ESPRIT and RACE programmes, while the Irish "Industrial" partners are usually involved in "EC consultancy work" and not industrial electronic production. (Table 4.5).
Of the companies listed only 6 are involved in product manufacture and of these only two, Analog Devices and Mentec, employ more than 20 people. The others therefore are not capable or big enough to exploit the research results of the European programmes. They are involved as part of the ESPRIT industry that has grown up in the smaller European countries to soak up the national allocation of funds.

Table 4.5 Irish Industry Partners involved in ESPRIT and RACE Projects

Company	Size	Product	Market	European Programme
Analog Devices	750	Integrated Circuits	Worldwide	ESPRIT
Farran Technology	19	Integrated Circuits	EC	ESPRIT
AIC Ltd	Gone			ESPRIT
Work Research Centre Ltd	10	Consultancy	EC Ireland	ESPRIT
Baltimore Technologies Ltd	26	Consultancy	Ireland Europe	ESPRIT
Boole Ltd	18	Consultancy	Europe	ESPRIT
National Software Centre Ltd	Gone			ESPRIT
Cops Ltd	Gone			ESPRIT
Memory Computer Ltd	Gone			ESPRIT
ESB International	400	Consultancy	Worldwide	ESPRIT
MENTEC International	170	Computer System	Worldwide	ESPRIT
Nexus Europe Ltd	3	Electronic	Ireland	RACE
Norcontel Ltd	11	Consultancy	Worldwide	RACE
Bray Information Technology	<10	Consultancy	Ireland	RACE
Decision Support Systems Ltd	20	Consultancy		RACE
Hyperion	11	Data Collection Systems		RACE
Kentreel Ltd	19	Robots	World	RACE

(Sources: Eolas 1993, Kompass 1993)

4.4 Higher Education Sector

As outlined in section 3.4.2 the shortage of funds for R & D in the Higher Education Sector has forced this sector to look to Europe for funding for its research activities and with some exceptions this research activity has had very little to do with Irish industrial development. Where they have occurred these exceptions have taken two forms -

(1) Industry-University collaboration and

(2) The emergence of industrial enterprises out of the university environment

The university-industry collaboration can take three forms (Terkel 1991). These are research parks, cooperative research centres and industrial extension services.

Plassey Technological Park was the first research park established in Ireland. It was dominated by large multinational companies such as Wang and Verbatim with little interaction with the university, but it did contribute to a university culture and policy which supported industrial development. Neither of the other structures existed formally until the establishment of the Programmes in Advanced Technology in 1989.

Prior to this some colleges, in particular University College Cork, had implemented an ad hoc form of cooperative research centre. In an effort to make their research work more relevant to industry, they encouraged and received industrial support for a number of research projects.

A number of studies have illustrated the institutional inconsistencies between university and industrial needs in research. Azaroff (1982) identifies these inconsistencies or impediments as publications, patents, job performance and general attitudes.

In universities, promotion is determined by publications, while industry prefers not to publish. Universities will struggle to hold on to 'intellectual property', despite the fact that in their hands from the view point of industry it is usually worthless. Universities and industries have different perceptions as to what is important, in terms of job performance and in particular, scheduling. A study by Donald Fowler (Fowler. 1989) also highlighted the difference between the longer term view of the university research and the short term view of industry in terms of results.

Terkel in reviewing these studies concluded that the first and major consideration in determining the success of the university industry collaboration was the creation of a university culture which expresses a desire and commitment for cooperation with industry and the business community (Terkel 1991 p 536). This university culture is most evident in Ireland in the University of Limerick where in addition to a number of successful university industry collaborations, there has also been a number of successful university generated electronics enterprises.

These include Interpro test systems, the world leaders in automatic test systems for power supplies and Ashling Microsystems who have developed international competitiveness in small scale micro processor development systems.

4.5 Eolas

Eolas is the National Science & Technology Agency. It was formed in 1987 as a result of the merger of the Institute of Industrial Research and Standards (IIRS) and the National Board for Science & Technology (NBST). It provides technical and consultancy services in a number of areas none of which are related to electronics. Under its testing services in the National Electrical Test Centre, it has provided, a national electronic testing service for Irish companies. This was limited up to 1990 to product testing in accordance with the European low voltage directive. Since then it has been extended to include some telecommunications equipment testing, but to date it does not include testing for compliance with the European EMC directive.

Through its science and technology promotion section, Eolas acts as an agent for European Framework programmes discussed above and also disperses limited funding for third level research projects.

In an NBST industrial survey carried out in 1986, on semistate services provided to industry there was in general a high level of satisfaction (> 70%), with services provided by IDA, IIRS and CTT. The one exception was product development support from the IIRS. Of the seven companies who had used the service only one rated the service as satisfactory.

4.6 Technology Transfer

Technology transfer can take many forms. In its widest context, it is recommended by the OECD for late developing or Third world countries as a means of narrowing the technology gap between them and the advanced industrial nations. Initiatives undertaken in this context include the establishment of steel mills in Mexico and Brazil and installation of wafer fabrication facilities in Korea (OECD. 1992).

Included in this type of transfer is the process design, the product design, and the product design and process improvement capability.

When discussed in Ireland ,Technology transfer is normally used in its narrow context and means the transfer of a single product technology.

Technology transfer in this narrow context is sometimes seen by policy makers in Ireland as a shortcut to overcoming Ireland's technology gap. However, the ESRI Report (Conniffe & Kennedy, 1984. P. 102) points out that technology transfer is not a simple solution and quotes Stead (1976) who showed that over 90% of new product development costs would not be provided for in a technology transfer arrangement.

A study carried out in Hong Kong by Edward Chen (1983) identified the factors which influenced the technical progress of the receiving country as:

(1) the rate of technology diffusion

(2) the appropriate choice of technology and

(3) the appropriate transfer of technology

Chen was discussing primarily the impact of multinational companies on the host countries technical progress. His conclusions that for successful transfer the choice and the transfer must both be appropriate is valid for any technology transfer arrangements. The technology choice is appropriate if it supports the industrial development of the host country and there is the infrastructure within the country to use and assimilate the technology. The transfer is appropriate if it is a full and total transfer and includes:

(1) technical documents blueprints etc

(2) permission to use various knowledge, rights, assets and patents

(3) the use of capital, intermediate and/or final goods and

(4) a full transfer of learning know how etc. (Forsner & Ballance 1990).

Technology transfer between independent companies and individuals is supported at State level by an IDA grant scheme introduced in 1989 and by a technology brokerage service provided thorough Eolas. In 1990 seven companies availed of the technology acquisition grant from the IDA. (1990) The grant provides up to 50% of the direct cost of negotiating and acquiring the technology to licences, patents or know how agreements. Of the seven companies supported in 1990, one was from the electronics sector - Top Tech Ireland Ltd, a joint venture funded by Aer Lingus and the ESB who acquired a patented process of screening plastics to provide them with electromagnetic shielding properties. In 1991 a total of ten companies received technology acquisition grants, five of whom are in the electronics sector. (IDA. 1991)

Over the period 1989 to 1991, just £1m was spent on technology acquisition grants by the IDA. £560,000 went to the electronics industry, which represented just £100,000 per company. Of the six companies who have received technology transfers, the companies who have gained significantly from it have been Mentec and Top Tech. In both cases the technology was compatible with their existing processes and technological capability. Both companies had already a significant R & D capacity. In the case of a third company, the technology transfer, though in the same general area in which they already had demonstrated technological competence and carried out significant R & D was not easily assimilated and not compatible with their existing processes.

The Culliton Report included three specific recommendations in the area of science & technology. The first two related to the Programmes in Advanced technology (see paragraph 6.4) and the third was that greater emphasis should be placed on the acquisition of technology required to upgrade product quality and competitiveness in Irish industry. The basis of this recommendation was a report by the ESRI to the Industrial Policy Review Group (O'Malley et al. 1992). This Report argued that "the technology required for industry must be imported rather than generated domestically". The report naively suggested that "the key elements are: identification of suitable available technologies by international 'intelligence' gathering and the acquisition or transfer of such technologies". A brief review of the limited experience in Ireland of technology transfer would have highlighted the difficulties of this approach.

Technology transfer is an option which can be exercised to enhance existing R & D efforts. It is not an alternative to R & D and the experiences of Japan and Korea (or Mexico for contrast) show it is only effective when accompanied by intense R & D activity by the companies accepting the technology.

4.7 IDA R & D Grants Scheme

4.7.1 Development of the IDA Product and Process Development Grants Scheme

The IDA had an R & D grant scheme in operation from April 1970. (IDA 1972). Until 1980 the maximum funding available for a project was £50K (increased from £30K in 1978). Following the publication of the Telesis Report, the IDA placed new emphasis on the R & D grant scheme. A core unit within the IDA was given responsibility for the administration of the scheme and the new limit of £250K per project was established. Between 1980 and 83, this core unit promoted extensively both in multinational and indigenous companies the concept of doing research and development and provided generous funding to support it (see figures 4.1 to 4.3). In 1983, this core unit was disbanded and the R & D scheme was administered by the IDAs Account Executives.

Between 1983 and 1992, the IDAs grants committee made it progressively more difficult for companies to win approval for R & D grants. After 1988, the funding level was reduced from an expected 50% to 20% except for projects with exceptional risk. The IDA simultaneously began to link R & D grants to job creation and to make the grants repayable if job creation numbers were not achieved.

The overall result has been that there was a substantial increase in the number of international companies doing R & D in their Irish locations, since then this number has remained fairly static.

In the early 1980s, An Foras Teoranta, the State Rescue Operation was working with indigenous companies in financial difficullty. This body had a task of taking over companies that were in trouble, helping them to recover and preparing them for sale as a going concern. Lacking the management skills to identify the real problems facing a company, it often came to the premature conclusion that a company needed new or improved products. These companies would be recommended for and receive IDA grant assistance for product development.

In 1985, there were only five Irish indigenous electronic companies with more than three full time equivalent research workers (SDC. 1985 p 80). In 1989, out of a total of 97 indigenous firms in the electronics industry only five had more than three full time equivalent research workers. (Department of Industry and Commerce 1989, Eolas, 1990). For companies operating on such a small scale, the costs of applying for and managing an IDA grant often outweighed the benefits.

The IDA has provided on average a higher level of grant aid to indigenous companies. Despite this, both the number of R & D performing companies and their level of expenditure has remained static.

4.7.2 Analysis of the IDA R & D Grants Data

The IDA Annual Report each year includes a listing of all the companies who have received product and process development (R & D) grants and the amount that each company has received.

A rationale for using this data as a proxy for R & D activity is included in Appendix 4 and in the following analysis it will be used in this way. The full listing of all companies who have received IDA R & D Grants from 1979 to 1991 is included in Appendix 5.

4.7.2.1 Distribution

Figure 4.8 illustrates the distribution of grants by the total amount allocated to a company over the 12 year period.

Sixty two comapnies (26%) received less than £10,000.

The cost of application for administration of a grant would amount to at least £10K.

The companies falling into this category are:

(1) small Irish companies (Seagull Electronics)

(2) multinational companies who are augmenting their IDA main business grant by undertaking some nominal R & D (Assman Electronics)

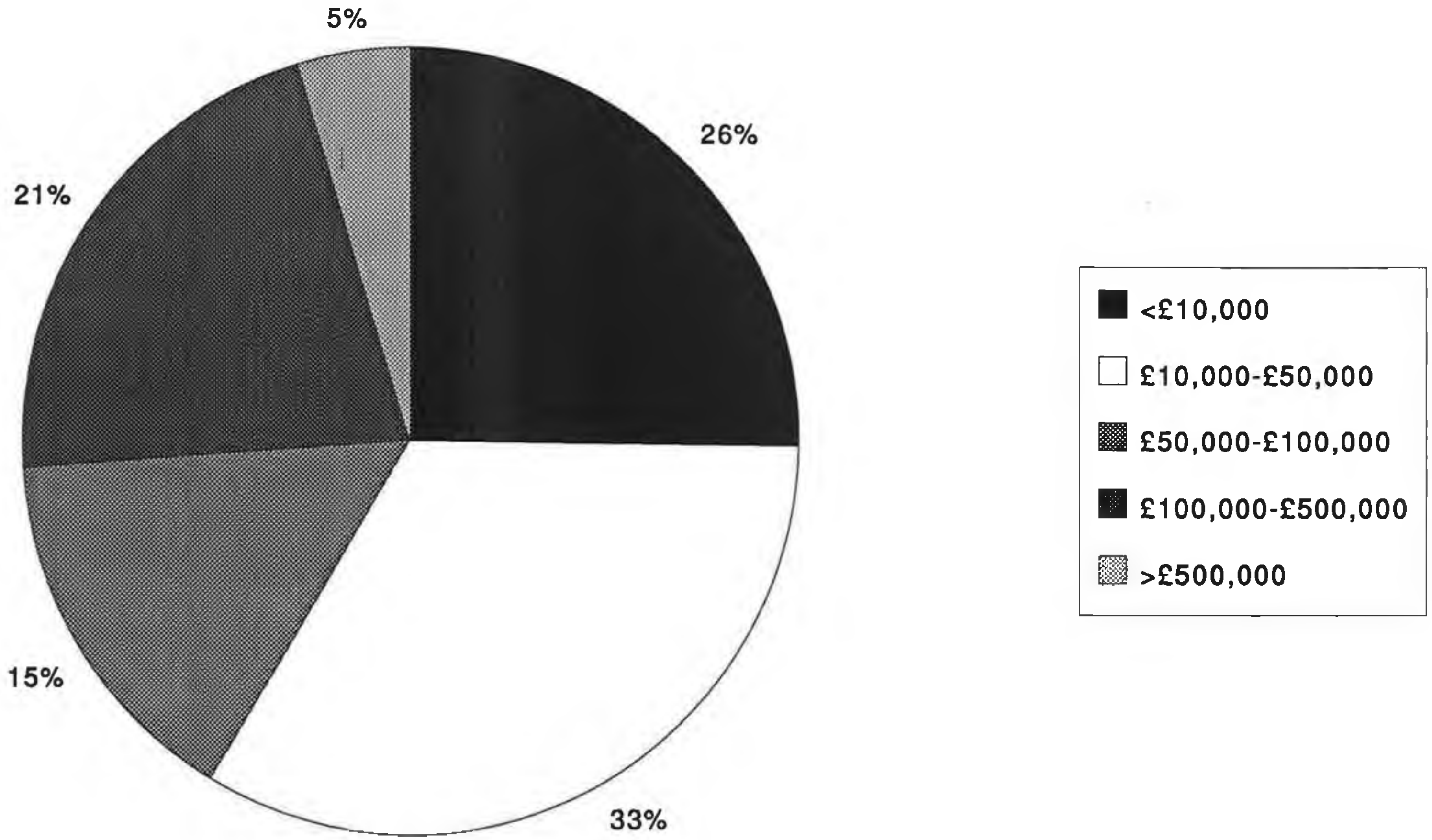
(3) companies who were starting projects in 1991

33% or 81 companies received between £10,000 and £50,000. This is the largest segment of companies on the distribution.

It includes multinational companies such as Apple Computer, Micromotor, EG & G, Hanimex, Square D and Siva Fuji and other multinational manufacturing companies located in Ireland undertaking small R & D projects.

Fig 4.8

Distribution of of Companies receiving IDA R&D Grants



It includes Irish companies set up to design and manufacture a single product such as Alternative Energy Company, Artic Environmental, Ship Co and Millimeter Wave Technology and Irish and MNC's with a low level of ongoing R & D such as PCAS, Gotech, SPS and EI. R & D grants greater than £50,000 indicate a serious level of R & D. The highest segment lies between £100,000 and £500,000. Since grant payments at this level would be very much linked to job creation the level of grant paid does not necessarily correlate with the amount of R & D undertaken. However the 11 companies who have received grants above £500,000 would certainly have the most R & D intensive operations in the country.

4.7.2.2 Location of R & D Activity

Table 4.5 illustrates the percentage of total grants paid by the IDA, to electronics companies for each county and also the total number of different electronics companies receiving IDA R & D grants in each county over the 12 year period.

The highest concentrations of R & D activity in electronics are in Limerick and Clare. This can be traced historically to :

(1) the existence of R & D intensive multinational companies in the area such and Analog Devices in Limerick, Inland Motors in Ennis and Verbatim in Limerick and

(2) the pro industry culture and electronic R & D activity in the University of Limerick.

Three other counties show above 50% concentration on electronics. These are Leitrim, Wicklow and Tipperary South. In Tipperary South, the high concentration is due to the existence of the Digital R & D facility in Clonmel which focused initially on power supply development and this led to the second company, Evans Development and Manufacturing Company, based in this area being established (also involved in the development of power converter technology). In Wicklow, the high concentration is due to the development work of AT & T in Bray who spend over £2m per annum on R & D and who have received £1.25M in grant assistance over the ten year period. Leitrim which has very little R & D activity, but includes some companies in the electronics sector.

Table 4.6 Location of Electronic R & D Activity

County	*Concentration of R&D in electronics*	*No. of R&D performing Companies*
Carlow	1%	1
Cavan	17%	2
Clare	75%	25
Cork	28%	35
Donegal	1%	4
Dublin	42%	97
Galway	36%	19
Kerry	17%	2
Kildare	17%	5
Kilkenny	0%	0
Laois	0%	0
Leitrim	57%	2
Limerick	76%	22
Longford	0%	0
Louth	38%	15
Mayo	0%	0
Meath	25%	4
Monaghan	0%	0
Offaly	7%	1
Roscommon	9%	2
Sligo	29%	3
Tipperary (South)	55%	2
Tipperary (North)	0%	0
Waterford	5%	4
Westmeath	2%	1
Wexford	6%	1
Wicklow	54%	4

The next highest concentration is in Dublin (42%), where 97 R & D performing companies received IDA R & D grants.

There are a number of factors which contribute to these high concentrations:

(1) Long well established Irish based multinational companies such as Pye and Phillips would have been based in Dublin and have maintained an ongoing level of R & D.

(2) Irish indigenous suppliers to the Post Office and telephone systems would have been based in Dublin, such as Telectron, Lake Electronics etc. and would have had to undertake some level of R & D.

(3) R & D performing US multinationals have spun off some Irish companies - Data Products, Power Technology Sources and AME.

(4) Because of its size, Dublin would have sufficient demand to allow for the development of electronics based security and building products.

(5) There are five third level colleges based in Dublin with post graduate research activity in areas of electronics though none have had the same impact on industrial R & D as the University of Limerick.

Some company R & D activity can be traced to the College of Technology, Kevin Street and more recently to Trinity College.

4.7.2.3 Companies receiving more than £50,000

Following the analysis of the distribution of companies by the total grant received over the period those who received greater than £50,000 were extracted from the list.

The companies on this list, Table 4.7, would have spent at least £100,000 on R & D and more than likely considerably more. This table, which contains most of the Irish based companies who have undertaken serious R & D over the period in question is analysed in table 4.8 by sector, ownership and survival.

Fifty five of the companies are Irish owned and 31 are Foreign owned.

4.7.2.4 Performance of Irish Companies

When one looks at the sectoral distribution no clear pattern emerges. One must look at the size of the individual companies, their dependence on R & D and their international competitiveness.

Three Irish companies from table 4.7 could be considered international leaders, with this leadership position derived in all cases from their R & D activity. Three companies manufacture test development systems. Two of them emerged from the University of Limerick (Interpro Test Systems and Ashling Microsystems) and a third (AME) started as a multinational spin off company.

Table 4.7 Distribution by Conmpany of R & D Grants (Greater than £50,000)

Company	*Total R&D Grants received over 12 year period.*	*Sector*	*Control*	*Trading*
Accuspec Ltd, Stillorgan	£ 113,725	Instruments	Irish	No
ACEC (Ireland) Ltdf	£ 54,948	Building	Irish	Yes
Acorn Automation Ltd	£ 112,434	Data acquisition/Process control	Irish	No
AEG Servo	£ 226,769	Data acquisition/Process control	Foreign	Yes
American Micro Computers Ltd Dublin 2	£ 145,214	Peripherals	Irish	Yes
Analog Devices BV	£ 1,184,345	Active components	Foreign	Yes
Anti Skid Control Ltd	£ 72,000	Automotive	Irish	No
Apparel Real Time Systems Ltd	£ 133,024	Computer systems	Irish	No
Applied Magnetics Ireland	£ 89,555	Peripherals	Irish	No
Applied Micro Electronics	£ 103,571	Test/development systems	Irish	Yes
Ashling Microsyssstems Ltd Limerick	£ 393,478	Test/development systems	Irish	Yes
AT&T	£ 1,255,338	Telecomms systems	Foreign	Yes
Aval Coorporation of Ireland Ltd	£ 71,527	Test/development systems	Irish	Yes
Beehive International	£ 133,999	Peripherals	Foreign	No
Bell & Howell Ltd	£ 70,137	Instruments	Foreign	Yes
Bontal Ltd	£ 113,057	Telecomms systems	Irish	No
Boru Electronics	£ 50,427	Boards/sub-assemblies	Irish	No
Bourns Electronics (Ire)	£ 82,029	Passive components	Foreign	Yes

Castel Electronics Ltd Dungargan	£ 51,912	Consumer	Irish	No
Centronics Ireland B V	£ 97,232	Peripherals	Foreign	No
Compucorp Ireland Ltd	£ 60,936	Computer systems	Foreign	No
Computer Automation Ireland Ltd	£ 111,559	Computer systems	Foreign	No
Connaught Electronics	£ 107,151	Security	Irish	Yes
Cornel Electronics Ltd	£ 421,095	Telecomms systems	Irish	Yes
CPT Ireland	£ 101,395	Computer systems	Foreign	No
Data Products Dublin Ltd	£ 175,525	Peripherals	Foreign	Yes
Datac Control Int Ltd	£ 189,541	Data acquisition/Process control	Irish	Yes
Digital Equipment Int. B V Galway	£ 155,706	Computer systems	Foreign	No
Digital Equipment International BV Clonmel	£ 1,297,881	Boards/sub-assemblies	Foreign	No
Donnelly Mirrors Ltd	£ 385,521	Automotive	Foreign	Yes
Ecco Ltd Louth	£ 1,151,075	Active components	Foreign	Yes
Edpac (Ireland) Ltd Carrigaline	£ 91,943	Building	Irish	Yes
Eirelec Ltd Dundalk	£ 68,316	Sensors	Irish	Yes
Elab (Ire) Ltd	£ 107,270	Instruments	Irish	Yes
Erika Ltd Clondalkin	£ 333,269	Instruments	Foreign	Yes
Farran Technology	£ 112,081	Active components	Irish	Yes
Flemmingbach	£ 453,601	Instruments	Foreign	Yes
Frese (Ire) Ltd	£ 162,892	Automotive	Foreign	Yes
Garrard Engineering Ltd	£ 69,667	Passive components	Irish	No
Glanmire Electronics	£ 80,433	Boards/sub-assemblies	Irish	Yes
Graftel	£ 76,918	Boards/sub-assemblies	Irish	No
Hitech Electronics Ltd	£ 138,055	Passive components	Irish	Yes
Hormann Security Systems Ltd	£ 85,051	security	Irish	Yes

Hyster Auutomated Handling Ltd	£ 1,719,536	Data acquisition/Process control	Foreign	No
Inland Motor Ltd	£ 730,310	Data acquisition/Process control	Foreign	*
Interpro Systems Ltd, Limerick	£ 606,217	Test/development systems	Irish	Yes
Irish Printed Circuits Ltd	£ 95,691	Passive components	Irish	Yes
ITEC Security Ltd	£ 504,886	Security	Irish	Yes
Kenny Electronics Ltd	£ 54,475	Boards/sub-assemblies	Irish	No
Kes Security Systems Ltd	£ 203,865	Security	Irish	Yes
Kollmorgen Ireland Ltd	£ 483,416	Data acquisition/Process control	Foreign	*
Lake Electronic Designs	£ 724,419	Telecomms systems	Irish	Yes
Lewicki Microelectronics	£ 53,166	Passive components	Foreign	No
Liebert Int B V Cork	£ 103,040	Building	Foreign	Yes
Memory Computer Ltd	£ 253,697	Peripherals	Irish	No
Mentec International Ltd	£ 673,110	Computer systems	Irish	Yes
Microelectronics Dev. Serv. Ltd	£ 101,120	Telecomms systems	Irish	Yes
Microsol Ltd	£ 78,614	Data acquisition/Process control	Irish	Yes
MNJ	£ 51,933	Security	Irish	No
Moog Ltd, Carrigaline	£ 355,449	Data acquisition/Process control	Foreign	Yes
National Electrical Designs Ltd,	£ 64,909	Building	Irish	No
NEC Ireland Ltd Ballivor	£ 348,414	Active components	Foreign	Yes
Nhance Development Corp.	£ 217,588	Peripherals	Irish	Yes
North Star Computers BV Cork	£ 66,024	Computer systems	Foreign	No
Northern Telecom Ltd Galway	£ 359,469	Telecomms systems	Foreign	Yes

Odenberg Manufacturing	£ 160,942	Data acquisition/Process control	Irish	Yes
Peak Electronics (Irl) Ltd	£ 227,752	Security	Irish	No
Philips Radio Comm. Systems	£ 212,000	Telecomms systems	Foreign	Yes
Power Products Ltd, Youghal	£ 420,772	Boards/sub-assemblies	Foreign	Yes
Power Tech Sources Ltd	£ 53,659	Boards/sub-assemblies	Irish	No
Promoco Ltd, Roscommon	£ 121,973	Consumer		
Reynolds Electronics	£ 145,669	Telecomms systems	Irish	No
Siemens Ltd	£ 58,674	Telecomms systems	Foreign	Yes
Solarmax	£ 113,133	Building	Irish	Yes
Southern Electronics Ltd	£ 74,418	Telecomms systems	Irish	Yes
Spectel Communications Ltd	£ 109,997	Telecomms systems	Irish	Yes
Telectron Ltd	£ 205,743	Telecomms systems	Irish	No
Tellabs	£ 1,647,591	Telecomms systems	Irish	Yes
Total Sigma Measurements Ltd	£ 81,593	Data acquisition/Process control	Irish	Yes
Tower Frame Ltd, Dublin 2	£ 150,000	Peripherals	Irish	No
Tramex Engineering Ltd	£ 54,765	Sensors	Irish	Yes
Trintech (Manufacturing) Ltd	£ 223,500	Peripherals	Irish	Yes
TT Systems Ltd Clondalkin	£ 59,526	Peripherals	Irish	No
Ventilux Ltd	£ 94,013	Building	Irish	Yes
Verbatim Ltd	£ 73,731	Active components	Irish	Yes
Videopro International Products	£ 710,424	Instruments		Yes
Waltham Electronics Ltd	£ 104,410	Instruments	Irish	Yes
Wescan Europe Ltd	£ 161,137	Peripherals	Foreign	Yes

Table 4.8 Sectoral Distribution of Most Intensive R & D Performing Companies

Sector	*Total Irish*	*Irish Trading*	*Total Foreign*	*Foreign Trading*
Computer systems	2	1	4	0
Peripherals	6	3	5	3
Boards/sub-assemblies	4	1	2	1
Active components	1	1	4	4
Passive components	3	2	2	1
Sensors	2	2	0	0
Data acquisition/Process control	5	4	3	2
Security	6	5	0	0
Building	4	4	1	1
Telecomms systems	7	4	4	4
Instruments	3	2	2	2
Test/development systems	3	3	1	1
Automotive	0	0	3	3
Consumer	2	0	0	0
	48	32	31	22

Although they manufacture similar products, these companies are not part of an industry cluster. Interpro is part of the power supply cluster while Ashling Microsystems is part of the process control/security system cluster..

The security system sector includes a number of small to medium size companies KES, at 30 people to Connaught Electronics at 60 and Hormann at 200 people. Peak electronics of Killaloe employed 250 people in 1984. The basic technology has not been developed in Ireland and these companies have developed enhancements to products they originally distributed or licensed. The availability of low cost microprocessor development systems from Ashling has facilitated this development

Computer peripherals include printers, terminal and disc drives. It is difficult for Irish companies to get a technology lead in this market and most work undertaken by Irish companies have been enhancements on basic engines. However, one company nHance has made a breakthrough in high resolution terminals but to date only employs three people. Another company, Trintech, employing thirty five people has created a technological advantage for itself with credit card readers.

The telecomm sector developed as a supplier to the Dept of Posts and Telegraphs now An Bord Telecom. The technology used is not new and the open market is making it more difficult for these companies to survive.

In the data acquisition/process control sector there are tfour small but internationally competitive companies Datac, Microsol, TSM and Odenberg Manufacturing, whose competitiveness is due to technology developed in Ireland combined with focused marketing.

4.7.2.5 Foreign Owned Companies

In general Foreign owned companies are not dependent for their success in Ireland on Irish R & D.

The exceptions to this are:

(1) Analog Devices

(2) ATT

(3) AEG (previously Inland Motor and listed also as Kollmorgen)

(4) Computer Products

Two companies that have failed because of the failure of their Irish R & D have been CPT and to some extent Hyster Automation.

Analog Devices designs and manufacturers CMOS chips in Limerick and the success of the operation is dependent on the success of the design effort. However, the design systems, development tools etc. were put in place by the US company and Irish designers simply follow the systems and operate the tools (ie CAD systems). Some CAD system development has taken place in Analog with support from the NMRC.

Inland Motor and Computer Products operate more as business entities while ATT operated on the basis of competition for corporate contracts for R & D and manufacture.

4.8 Survey of Electronics R & D Intensive Companies

4.8.1 Rationale for Survey

A survey of electonics R & D intensive (see Table 4.9) companies was undertaken to establish:

(1) Why companies undertake R & D and at what level of complexity

(2) What they see as the supporting factors

(3) What they see as the inhibiting factors

In addition to addressing these questions the survey established the size of the company, the size of the R &D facility, control and location of R & D and the control and location of company.

The survey studied 30 R & D intensive companies (those having received more that 50K in R & D grants) and a spread of large and small indigenous and multinational (in terms of R & D grant aid).

The survey was restricted to companies who were still in existence and agreed to cooperate.

Thirty companies had agreed to participate. Twenty replies were received in time to be included in the analysis.

4.8.2 Survey Findings

The survey results are listed in table 4.9 (for survey details see Appendix E).

Of particular interest in the findings are:

(1) Most MNC R & D functions report into Irish operations

(2) Process development is not considered important in Irish companies

(3) R & D drivers are similar for MNC's are driven more by growth and Irish companies

(4) Assessment of complexity was similar for both

(5) R & D support factors were very similar with both sectors rating grants at less than 4. Access to company technology outside of Ireland is one support which Irish companies obviously don't share

(6) In both indigenous and MNC's only one factor rated higher than 4 with all others rated at less than 3. This was financial constraints for indigenous companies.

Table 4.9 R & D Company Survey Findings

Survey Results Summary

Company Size

	MNC	Irish
<50	0	80%
50-150	17%	10%
150-500	50%	10%
>500	33%	0

R & D Size

	MNC	Irish
<5	17%	50%
May-15	33%	50%
15-50	50%	0
>50	0	0

R & D Budget

	MNC	Irish
<50K	0	20%
50K-500K	17%	80%
500K - £2M	66%	
>£2M	17%	
MNC R&D rporting into Irish Plant	83%	

Reasons for Doing R & D

	MNC	Irish
Product Improvement	66%	78%
Process Improvement	83%	22%
New Product Development	83%	100%
Nw Process	83%	0

Scorings

R & D Drivers	MNC	Irish
Meet customer demand	4.7	4.8
Advance Technology	1.3	1.9
Reduce costs	2.7	3.7
Increase revenue	4.8	4.3
Complexity	8.8	8.9

R & D Supporters		
Skilled people	5	4.7
Good Systems	2.8	2.4
Market knowledge	4.7	4.4
Customer interaction	4.5	4.1
Technology		
In Irish operation	2.1	2.4
In Company but not in Ireland	4.3	0.8
In Ireland but not in company	2	1.4
European Programs	0.5	0.7
Other		
Company ethos		
Technical Support	2.5	2.6
Management	3.5	2.7
Access to Government Grants	3.8	3.4
R & D Inhibitors		
Financial	2	4.4
Market Knowledge	2.7	2.2
Production Integrated	2.8	1
Materials	1.5	1.4
Technical Information	1.7	1.7
Capital Equipment	1.2	2.4
Customer Interaction	1.7	2.2
Technology Access Product	2	2.6
Supporting Technology	1.2	1.8
Simulation	1.8	2.3
Test	0.5	1.8

Process development can be viewed as a stepping stone for MNC's to full product development. It allows them develop their processes using existing staff (usually manufacturing engineers) and receive IDA funding for it. In the sample taken however, all companies have a significant level of R & D, therefore it can be assumed process development is undertaken decisively.

Process capability however, has become a serious competitive factor in the electronics industry (Seliger. 1992), and the low level of process design among indigenous companies is a factor that could reduce their long term competitiveness.

The factors supporting R & D were very similar for both indigenous and MNC's with both groups rating market knowledge, customer interactions and skilled personnel as more competent than R & D grants. There is a lot of frustration and ill-feeling among indigenous companies about the dispersion of grants and the apparently arbitrary way in which it is done. As was found in the British MC tool industry nobody who received grants complained about them but they complained about the resources they consume and the delays and complexities they introduce into projects.

The factors inhibiting R & D were significantly different for MNC's and indigenous companies.

The biggest inhibitors for MNC's were lack of market knowledge and poor production interface.

Both these factors can arise from the newness of the R & D operation in Ireland in trying to deal with established patterns of manufacture and established markets. The "R & D team" in the companies home base would have interacted much closer with its market, and more than likely driven the production processes. The R & D group in Ireland are expected to design a product that will serve a market with which they have no familiarity using a production process they are only beginning to understand.

For the indigenous sector the main inhibiting factors are financial constraints and poor access to product technology.

The overriding inhibiting factor to the indigenous sector is financial constraints (averaging over 4 where the next highest average was under 3). This in turn limits their access to capital equipment, markets and technology. One survey respondent described R & D as a dirty word in the financial sector.

The survey results suggest that if a national system in innovation in electronics is to be successful for indigenous and multinational companies it must:

(1) Maintain and develop the industry skills level

(2) Maintain and develop the level of interaction with markets and customers

(3) Improve access to product technology

(4) Include the financial sector

4.9 Science & Technology Structural Funded Programmes

4.9.1 Programmes in Advanced Technology

Under the 1989 to 1993, Structural Programme for Industrial Development twelve Programmes in Advanced Technology (PATs) were identified. There are eight PATs operating today. One of these, the National Microelectronics Research Centre (discussed under section 4.3), had been well established at the time of the establishment of the other programmes and was simply re labelled for the purposes of securing European Structural Funds.

Of the remaining seven, three of the programmes, Optronics, Power Electronics and Telecommunications are directly involved in the electronics industry and three of the remainder - Advanced Manufacturing Technology, Advanced Materials and Software Development are in related areas. Taken together, these programmes represent a significant investment in the creation of infrastructural R & D support. Their establishment was outlined in the Department of Industry and Commerce Document - Strategy for Irish Owned Electronics Industry which stated that 'the shortage of experienced designers could also be addressed by the establishment of centres of excellence in appropriate technologies Such centres may be created by drawing together expertise and facilities that already exist in the universities and "NIHE", Telecom Eireann and Eolas'. (Dept. of Industry & Commerce. 1989. P. 18).

The programmes in advanced technology were to allocate their resources, 20% to Irish owned small businesses, 40% to Irish owned medium sized businesses and 40% to overseas firms, while at the same time placing particular emphasis on creating links into the EC Framework programmes for research and development.(Gorvernment of Ireland. 1989. Para. 7.11).

The programmes in advanced technology were designed to increase the level of infrastructural technical report in the specified areas. Each programmes is managed centrally from Eolas to ensure maximum co-ordination is achieved. They are overseen by a Board consisting of academic and industrial representatives. The industrial representatives are in the majority. The programmes are intended to take advantage of the existing level of expertise and research in the colleges to build on it and through the employment of full time staff, to make it available to Irish industry. Central to the success of the PATs is the concept of industry university co-operation. The issues discussed in section 4.3.1 have not presented serious problems to the operation of the PATs.

The first PAT to be established was Optronics Ireland which was set up in 1989 (Optronics Ireland 1991). From 1989-1992, the programme was focused on the development of research facilities in its constituent colleges. It has commenced product development for Aster Ireland Ltd and Telecom Eireann and is supplying Toshiba Corporation with semiconductor wafers for optronic applications. The programme costs for 1991 was just under £1.5m and it employed 39 people primarily on full time research. At the same time, total optronics industry in Ireland consisted of 8 companies employing 100 people (Optronics Ireland. 1991).

The other two programmes directly involved in electronics were not established until late 1991. These are programmes in advanced technologies in Telecommunications and Power Electronics. An indigenous telecommunications industry has been established primarily as sub suppliers to Telecom Eireann. These companies are relatively large by Irish standards and the technology is relatively advanced but by international standards both their technology and size would not be competitive.

The Telecommunication PAT nevertheless undertook a research programme which was centred on advanced telecommunications technology. This was done under the direction of representatives of the telecoms industry and only one of its six main areas of activity was useful to indigenous industry. The result has been that the primary work of the Telecommunications PAT has been focused on European Framework Research Programmes and to a lesser extent Irish based multinational companies. The programme meets its objectives of interacting with Irish industry by providing services to users of advanced telecommunications equipment (Teltec' 1993).

The PAT in Power Electronics, the third PAT directly involved in the electronics industry was also established in late 1991. At this time Ireland already had a well established R & D record for both multinational and indigenous power electronics companies. The power electronics sector includes the power supply industry, electronic transformer industry and motion control industry. The three multinational motion control companies, AEG, Moog and SPS already had a significant R & D effort underway The power supply and transformer industries are such that to be successful the sales operation must include a significant customisation element. Both the transformers and motion control sections in this category come under electrical machinery OECD classification and as figure 4.3 illustrates, there has been steady growth in R & D expenditure in both the multinational and indigenous sectors in this sector, despite significant fall off in Government support since 1986. As discussed in section 3.2 power supply technology is an area where indigenous companies have proved competitive internationally. The result has been that within two years of its startup the PAT in Power Electronics has had a significant interaction with both indigenous and multinational companies based in Ireland and has been able to develop the technology level of these companies and improve their international competitiveness (Power Electronics Ireland 1992).

The two programmes in advanced technology partially involved in the electronics industry are - the Advanced Manufacturing Technology Programme (AMT) and the Advanced Materials Programme. The AMT programme was set up in 1987 as a manufacturing consultancy service to Irish industry and has operated as such since then. A review of this programme carried out by Technopolis Ltd in December 1992 (to be published) found that their services were of use to industry but that the programme was a consultancy service and not a research and development service. Its role should be to facilitate Irish companies in adopting best practice manufacturing systems not to develop or improve known processes. The report therefore recommended that the programme should be managed as such.

The Materials Ireland programme which includes in its brief the investigation of materials of particular relevance to the electronics industry such as ceramics and insulating materials was established in late 1991. To date it has not been able to make its technologies relevant to the electronics industry.

The software PAT has focussed its activities on applications software development and has not had significant involvement with engineering or telecommunications applicatons.

In general the programmes in advanced technology are viewed by the universities as funding mechanisms for advanced research. The industry representatives have not been able to or not been willing to redirect the research efforts towards the immediate or medium terms needs of industry and the goals imposed on the programme by

Government of self financing have encouraged the programmes to look for money where it is most readily available such as European Framework Programmes and multinational companies often not located in Ireland.

These factors have made it difficult for these programmes to have the same impact on the Irish economy as similar programmes have had in Japan , Korea, Germany and Denmark.

4.9.2 Higher Education Industry Cooperation (HEIC)

The HEIC programme was designed to promote higher education links across industry. It did not include the necessary administration infrastructure to allow this type of interaction to take place and although the original budget allocated was £20M over the four years expenditure to 1993 is less than £5M.

The programme pays 50% funding to a joint industry university research project. The work is carried out in the university and university personnel would be expected to do the marketing of their expertise followed by the processing and administration of the grant application without any additional support.

For this reason most industry university projects in electronics have gone to the PAT system where there is a more industry orientated interface. The HEIC scheme has been most active in the fine chemicals and pharmaceutical sectors.

4.9.3 Regional Technical Support

The Regional Technical Support Framework did not materialise as envisaged.

The pilot scheme in the South East (SERTEC) was not successful in encouraging and facilitating technological development and transfer. The scheme was attempting to provide technological services across a wide spectrum from a relatively weak base, ie the RTCs in Waterford and Carlow. In the electronics area it was providing computer automation support and a CAD service.

These services were not at the same level as available commercially (from PCAS in automation for example or from CAD system vendors), and although some industrial interaction occurred the service did not have the anticipated impact. The service currently runs on a budget of around £100K per annum.

In the electronics area industrial control and avionics research centres have been set up in Dublin Institute of Technology College at Kevin Street.

Even with these additional activities, the monies allocated under Regional Technical Support were not being spent.

4.9.4 Grants to Industry

The first round of structural funding from the EC is due to end in 1993.

In 1992, the government was facing a situation where a considerable amount of the science & technology element (£13M) would remain unspent and therefore be lost.

To avoid this situation in July of 1992, the Department of Industry & Commerce announced Measure 6 Grants for industrial R & D. These differed from IDA grants in that:

- (1) Projects had to be over £500,000
- (2) There were "no strings attached", ie no jobs targets, no equity or royalty payments

The companies to have received approvals in the electronics industry were:

AEG
Analog Devices
Apple Computer Ltd
Applied Micro Electronics Ltd
Ballyneety Manufacturing Services Ltd
Connaught Electronics
Cylon Controls
Datac Control
Digital Equipment Ltd
Donnelly Mirrors
Kestrel Security

Mentec

Pulse Engineering

Tellabs

Vitalograph

with a total of £8.23M approved.

The company list is divided equally between MNC's and indigenous companies. This measure represents a partial shift back to a passive outward looking approach in Government policy. It is driven primarily by a desire to find an effective means to spend structural funds, at minimum cost to the exchequer and possibly by criticism by the Industrial Review Group of the existing measures. (Industrial Review Group. 1992)

Since the money is budgeted for 1993 it is too early yet to see its impact. It is interesting to note that four of the five indigenous Irish companies selected are in the process control/sensing/security system cluster. This indicates the growing strength of this sector rather than any deliberate policy implementation by the Government.

4.10 Conclusion

R & D in the electronics industry in Ireland has been reviewed under Eolas S & T survey findings, IDA grants data, EC framework programmes, Higher education activity and technology transfer.

The progress of R & D in electronics was discussed for each of the measured sub-sections - electronics, instruments and electrical machinery. The pattern was similar for the first two where expenditure by MNC's on R & D grew from a situation in 1979 where it was approximately the same as that by indigenous to the situation in 1991 where for each it was almost 10 times as large.

In the electrical machinery sector, expenditure by indigenous companies grew from being significantly less than that by MNC's in 1979 to being twice as much by 1991.

Indigenous companies involved in R & D in these areas are in the transformer design (which is part of the power supply cluster) and electrical switch gear and motor control which is part of the industrial control cluster. The performance of MNC's in this area has been erratic.

When the three subsections are taken together there is no growth in the indigenous sector and substantial growth in the MNC sector. The growth in MNC activity is the result of more intensive R & D activity by the R & D performing companies. While the lack of growth in the indigenous side is most likely due to the unsustainable high level of R & D in the early 1980's

There was a close correlation between the establishment of R & D facilities by MNC's and the availability of Gorvernment grants, but no correlation between the amount spent and the availability of grants.

The use of technology transfer as an alternative to R & D as proposed by the Culliton Industrial Review Group was reviewed and it was found that technology transfer was effective in electronics only when accompanied by intensive R & D.

The third level sector and Government research centres were found to have a positive influence on industrial R & D in other countries. In Ireland, it was found that up to 1989 these institutes were forced to participate in European Framework Programmes in order to obtain research funding. This meant that the expertise that was available in

Ireland to support industrial R & D was being exploited by the European electronics industry and providing little or no benefit to Ireland.

With the increasing emphasis on interventionist policies by the Dept. of Industry and Commerce in promoting industrial development this situation was reversed in 1989 by the establishment of a number of Programmes in advanced technology in electronics. It was found, however, that because of their structure and funding mechanisms these programmes are restricted in their effectiveness.

A detailed review of the R & D grants scheme was completed. It was shown that the R & D grant recipients in electronics represented reasonably well the R & D activity of the industry.

The distribution of R & D activity by location and by sector of the electronics industry was presented.

The distribution by location highlighted:

(1) the impact of a "university culture and policy which supported industrial development"

(2) The impact of foreign owned R & D intensive companies in inspiring indigenous spin-off or related companies

The distribution by sector highlighted the high level of R& D indigenous activity in the identified industry clusters. These clusters are developing in areas where economies of scale are not so critical and include capital equipment, as well as product manufacturing.

The results of a survey carried out on R & D intensive companies indicated a great deal of similarity between multinational and indigenous companies with regard to R & D support factors. The differences in inhibiting factors between the two can be explained by their different sources of technology and finance.

Financial constraints is the major R & D inhibiting factor for indigenous electronic companies. Companies require financial backing and support rather than grants. For this to happen effectively the financial sector needs to take a participative role in the electronics industry.

The availability of grants is not considered a decisive factor by either multinational or indigenous companies undertaking R & D, both consider the availability of suitably skilled people, knowledge of the market and customers with whom they can interact as more important determining factors.

5 A National System of Innovation in Electronics

5 A NATIONAL SYSTEM OF INNOVATION IN ELECTRONICS

5.1 Vicious Circles

In looking at Vicious circles in the electronics industry the starting point is the industrialisation vicious circle (fig. 3.5).

In the 1980's the non-interventionist strategy in electronics became more interventionist but was still coupled with a low state capacity for policy implementation.

The non integrated structure of MNC's was further strengthened by the arrival in Ireland of their own multinational sub-suppliers who were also provided with generous privileges and who had the effect of discouraging the creation of indigenous sub-suppliers. These multi-national sub-suppliers who used home based technology, and Irish indigenous sub-suppliers who are concentrated in low tech sectors formed another vicious circle which combined with the lack of Government support for Higher Education Research forced the experts in these institutions into European national systems of innovation.

Cash flow problems combined with the availability of research grants and costly grant application and administration procedures forced indigenous companies into a grant management rather than an innovation management role, delayed innovations and sometimes encouraged the undertaking of otherwise non viable projects.

5.2 Virtuous Circles

The virtuous circles in Irish electronics have been completed only on a limited scale in specific sectors. The most complete circle is in the power supply industry.

Here there is

- (a) technology diffusion from MNC's
- (b) test equipment development by indigenous companies
- (c) strong magnetic component indigenous and MNC sub-supply
- (d) strong support from third level sector
- (e) post graduate power supply designers
- (f) willingness of MNC's to accept Irish based suppliers of power supplies
- (g) requirements for custom design in power supply industry

The cluster under development in the process control, security, building and sensor area has not yet completed its circle and in addition to a strong system of innovation will also need stronger links between suppliers and markets to ensure all elements of the circle mutually reinforce one another.

In the multinational electronics sector there have been a number of companies with strong Irish R & D centres.

These would include:
Analog Devices , Digital (Clonmel), Westinghouse, CPT, Zenith, Inland Motor (AEG), Computer Products and ATT.

The ones that have failed in general had R & D control in the home base and had no marketing in Ireland; the ones that have done best (in terms of delivering new acceptable products to the market) have had marketing and R & D controlled in Ireland - Analog Devices, Computer Products, AEG and more recently Pulse Engineering.

Among the failures are :
CPT, who had a staff of 50 engineers working in Cork on the design of their new PC. Their marketing group was based in the US. The product was delivered on time and launched in London. The product had failed within 6 months.

Zenith employed 20 people in Kells on power supply design between 1987 and 1990. they had a marketing team, based in Kells which fed into a design control group in the US which managed projects carried out by the Irish design group.

The Digital communications systems and power supply design groups based in Clonmel report to US headquarters and would not be expected to know who their customers were.

On the other hand MNC's with strong design groups that still exist are Analog Devices in Limerick, who have integrated design and marketing approach to their customers as do Computer Products and AEG and Pulse Engineering who have recently invested significantly in their R & D effort. This user producer interaction is the essential driver in a national system of innovation. Their resulting innovation process is further supported by significant Higher Education interaction and Government support.

5.3 The Electronics Design Process

Electronic products consist of assemblies of interconnected electronic components on one or more printed circuit board. The printed circuit boards, and other components are usually housed in a mechanical assembly made up of plastic or sheet metal.

The assembly interfaces with the outside world through input/output devices. There can be a CRT tube (output device), keyboard (input device), printer, microphone etc. These input/output devices usually contain their own set of electronic sub assemblies.

The electronic design process includes:

(1) System design

(2) Board level/sub-assembly design

(3) Component design

The system is supplied to meet a particular application, chemical process control, security system, or payroll system. It is the system user who very often knows best the configuration and features he needs. The system designer interprets these requirements for the board manufacturer who in turn works with the component designer.

With this process is the systems are relatively easy to design, boards and subassemblies more difficult and components can take a long time. The "core" electronic technology is very often the component.

It is in the system and board designs that the user has most influence and where user producer interaction is most important. It is also important at component level but here the basic technology, technology support systems and capital are also important. The design of electronic components requires significant investment in CAD and lithography.

The security/process control cluster where Irish indigenous industry is achieving some success is at system and subassembly level.

Sensors which are included in this cluster are component level products and represent the core technology around which the competitive advantage of this cluster could be based.

Power supplies are sub-assembly level products and the component technology is transformers.

5.4 Recommendations on the Creation of a National System of Innovation in Electronics

A number of elements of a national system of innovation are already in place in the two industry clusters discussed:

(1) Strong higher education sector performance in electronic R & D

(2) Groups of innovative R & D intensive multinational and indigenous companies

(3) An interventionist state policy to support growth in indigenous companies

(4) A highly skilled workforce in electronic R & D

(5) Good market and customer interaction by electronic R & D performing multinational and indigenous companies

However the market and customer interaction activity requires strengthening, the state interventionist policy needs to be better informed and more clearly focused and the links between all these elements needs to be strengthened in particular the links between the Higher Education and the Electronics industry.

In addition the financial sector needs to be brought into the innovation system. The resulting innovation system in electronics is illustrated in fig. 5.1 and the corresponding virtuous circle in fig. 5.2.

Policy measures discussed in Chapter 2 have been successful in promoting inter-firm technology cooperation (EC programmes) and strengthening links between Universities and industry (Japanese and Korean). State policy in Korea and Japan has also been focused in specific areas of technology. The Irish state already has R & D funding mechanisms which could be modified to meet these objectives.

The measure 6 R & D grants could be used (as ESPRIT funding is used by the EC) to

(1) Promote R & D in very narrow areas where Ireland has demonstrated some potential for national competitive advantage (Power supplies security systems, electric control in building and industrial control).

(2) Encourage user-producer cooperative innovations by limiting grants to projects involving users and producers

(3) Encourage third level participation in such projects in the same way as the EC programmes do (ie by funding it as 100% direct costs)

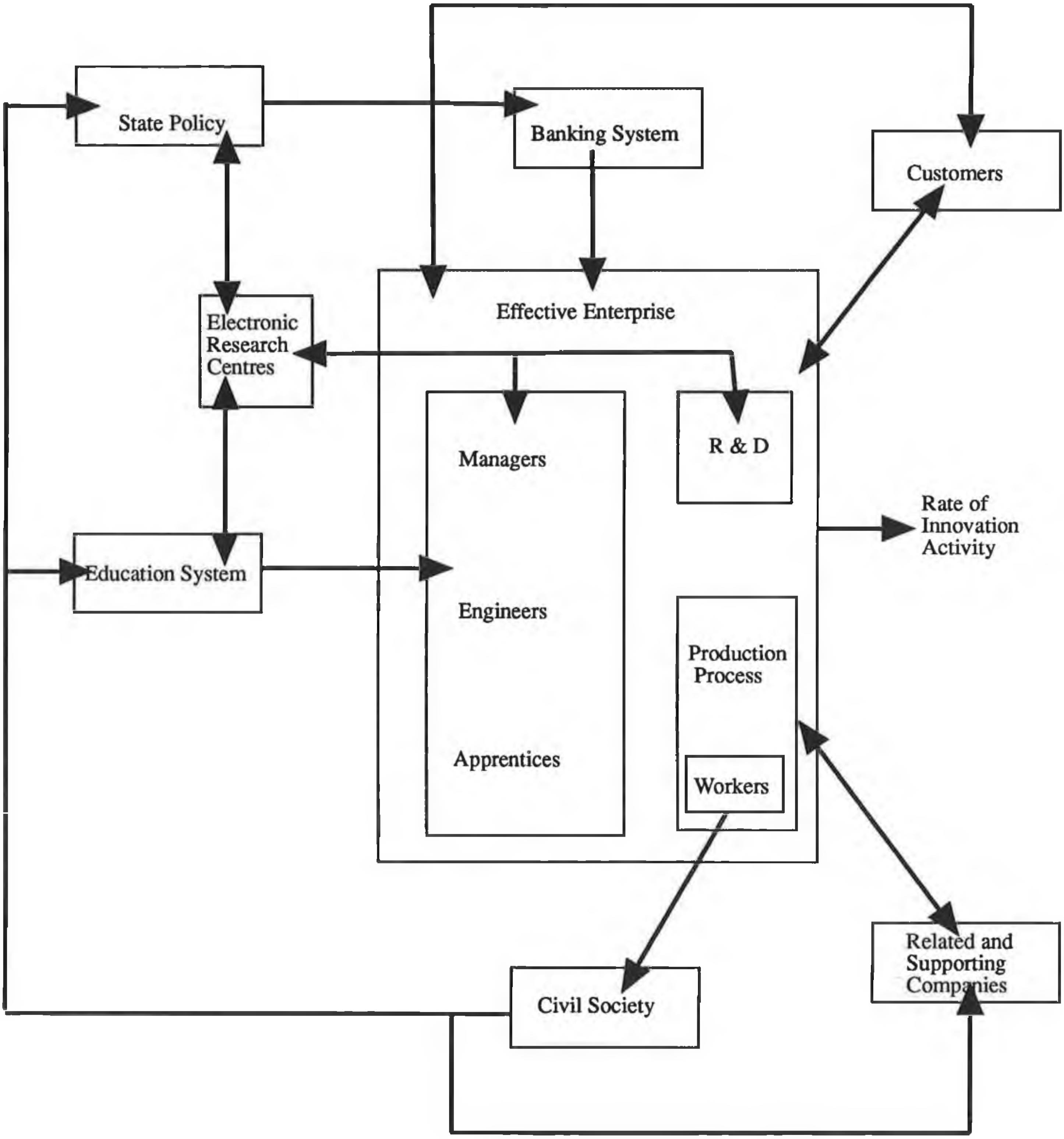


Fig. 5.1 Potential National System of Innovation in Electronics

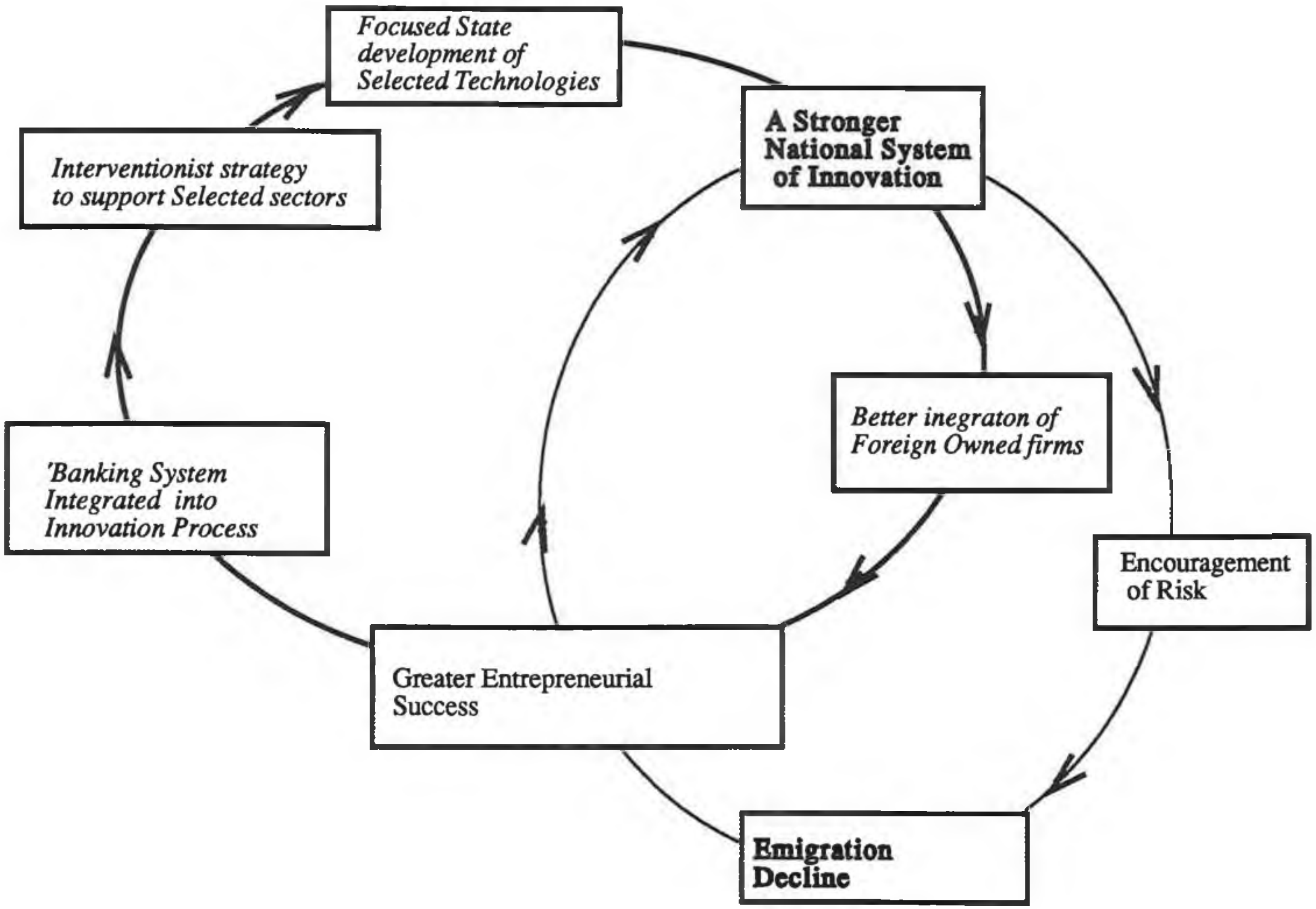


Fig. 5.2 Virtuous Circle Incorporating Proposed National System of Innovation in Electronics

> National technical competence needs to be developed in the same way as it was done in Japan and Korea. Programmes in advanced technology and higher educational industry links need to be significantly more focused.

The industry sectors they are targeted to support need to be clearly identified and representatives of these industries vested with control of the programmes.

The requirement for self financing of these programmes while it was necessary to curb academic excesses is not consistent with the creation of national competitive advantage through technology. It means the most promising technological developments will be sold to the highest bidders which are very unlikely to be indigenous electronic companies.

The sectors of the electronics industry which should be targeted have been identified. Technology objectives needs to be set for these sectors and funding needs to be made available to ensure these objectives are achieved. This funding is already available under measures 1 and 2 but it is being spent inefficiently (as described in sections 4.9.1 and 4.9.2).

Multinational companies in the power supply and industrial control sectors are already closely involved with higher education institutes. the focusing of research in these institutes will strengthen their industrial links and further integrate these MNC's into the national system of innovation.

It has been apparent that grants are not the best way to foster R & D. In fact, it is not money itself that is the problem but the loss of credibility that spending money on R &

D creates for the industrialist with his banker. Irish bankers prefer fixed assets. This is part of the vicious socio political circle of conservatism.

It is not necessary for banks to spend or risk more money but to lend credibility to the R & D process by participating in it.

This vicious circle is being undermined by the current programme on local enterprise in which the banks are committed to participate.

In the electronics industry R & D is the most costly and most important element of enterprise.

The implementation of measures to promote inter firm cooperation and focused support for sectoral technology development will see the emergence of new and bigger electronics companies in the sectors discussed.

This will lead to a demand for finance which should integrate the banking sector as partners in the R & D process.

Fig. 5.1 is derived from fig. 3.6 and incorporates some of the recommendations for the electronics industry listed above.

State funded electronic research centres and their close interaction with industry have been an important feature of successful electronic innovative economies.

The banking system needs state encouragement to become more involved in the innovation system and in the electronics industry.

It is important that customers actively participate. In the system shown this participation is encouraged by state policy.

The positive experience of wage earners in the successful enterprise is illustrated as encouraging within society the establishment of related and supporting industries. The mushrooming of the electronics industry in California was an example of this and in the electronics industry in Ireland there have been some examples on a much smaller scale (such as the cluster of indigenous printing, electronic assembly and computer add-on companies that have grown up around the Apple plant in Cork).

Fig. 5.2 illustrates this innovation system as part of the virtuous circle of self sustaining growth.

This stronger national system of innovation will lead to more indigenous entrepreneurial success and greater integration of Foreign owned firms though their participation in the innovation process. The success of indigenous companies will encourage greater involvement by the banks and will further encourage state involvement both in direct support of the companies and in support of related technology research and development leading to further strengthening of the innovation system.

The product sectors identified as having potential competitive advantage process control/security systems and power supplies already enjoy a positive system of innovation. This tightening up of all the supporting elements will accelerate their development towards international competitiveness.

Some economists have expressed surprise or disbelief (Porter 1990) at the ability of Government officials (in Japan or Korea), with little or no experience in the relevant areas to be able to choose winning industries and technologies.

The virtuous circle illustrated is a positive feedback system and provided the system remains intact it will continually amplify any industry that is introduced into it. The rate of growth and innovation activity will depend on the investment in the system. For the Irish electronics industry, sectors need to be chosen that will provide the greatest growth, for the minimum investment.

The computer industry indigenous electronic sub-supply sector is particularly weak (with the exception of power supplies) and all the supporting elements outlined above are missing (except for (3) which itself is ambiguous). It is therefore unlikely that existing or new Irish industries in this sector will become internationally competitive.

6 Conclusion

6 CONCLUSION

The Telesis Report (1982) described the electronics industry in Ireland as being a low skilled industry, dominated by multinational companies. The indigenous sector was weak. The level of R & D carried out by both MNC's and indigenous companies was generally very low.

The theoretical background on the impact of technological change on economic development has highlighted both the contribution of technology to growth and its contribution to unemployment, but the empirical evidence shows a very close relationship between electronic technology development and economic well-being.

This correlation is further supported by studies of Japan and Korea where state policies aimed at encouraging electronic technological development have resulted in rapid economic growth.

A set of specific problems related to small company innovation and of particular relevance to the Irish electronics industry, were identified.
A Porter analysis of the electronics industry in Ireland suggested that Ireland had potential competitive advantages in advanced factor conditions, demand conditions and related and supporting industries.

The analysis highlighted the existence of an indigenous industry cluster in the area of security systems, industrial control and electronic building technologies and a multinational/indigenous cluster in the area of power supplies.

The analysis also indicated that to take advantage of its potential competitive advantage in the areas of demand conditions and related and supporting industries the electronics industry needed to strengthen its R & D capability.

This underlying factor of innovative capability coupled with the experience of Japan and Korea with National Systems of Innovation in Electronics and the user as the main source of innovation in the electronics industry, suggested that a National System of Innovation Model might be an appropriate model for a review of R & D in the Irish electronics industry.

A review of the general development of the electronics industry since Telesis indicates:

(a) A significant growth in the number of indigenous companies
(b) A significant growth in employment in indigenous companies
(c) A slow growth in productivity in indigenous firms
(d) A slow growth in average size of indigenous firms

A detailed review of IDA R & D activity combined with a survey of R & D companies has demonstrated that:

(1) University R & D in electronics combined with University ethos and culture which supports industrial development is effective in promoting R & D
(2) Multinational company intensive activity in electronic R & D can lead to spin off and related companies in the indigenous sector
(3) People skills in electronics, market knowledge and interaction with customers are the most important factors in making R & D effective

(4) Grants although important are not considered a decisive factor by any of the companies interviewed

(5) The llack of interest taken by the financial community in R & D is the biggest inhibitor of R & D by indigenous electronic companies

(6) The state policy on R & D in electronics has been inconsistent and unfocused.

In a general review of R & D in electronics in the International context, the study has shown that the impact of correct R & D national policies can have more dramatic effects (as been demonstrated in Japan, Korea and on EC programmes) than even those reported by Solow in the US. Inappropriate or unfocused policies however can contribute to the decline of industries (as in the UK).

The results of the review of R & D activity have been used to develop a national system of innovation in electronics based on Mjoset's proposed Model (fig. 3.2) but incorporating specific features of importance to the electronics industry.
This model has been included as the pivotal element in a potential virtuous circle in electronics where individual elements will continually support one another leading to ever increasing national competitive advantage in the electronics industry.

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Appendix A

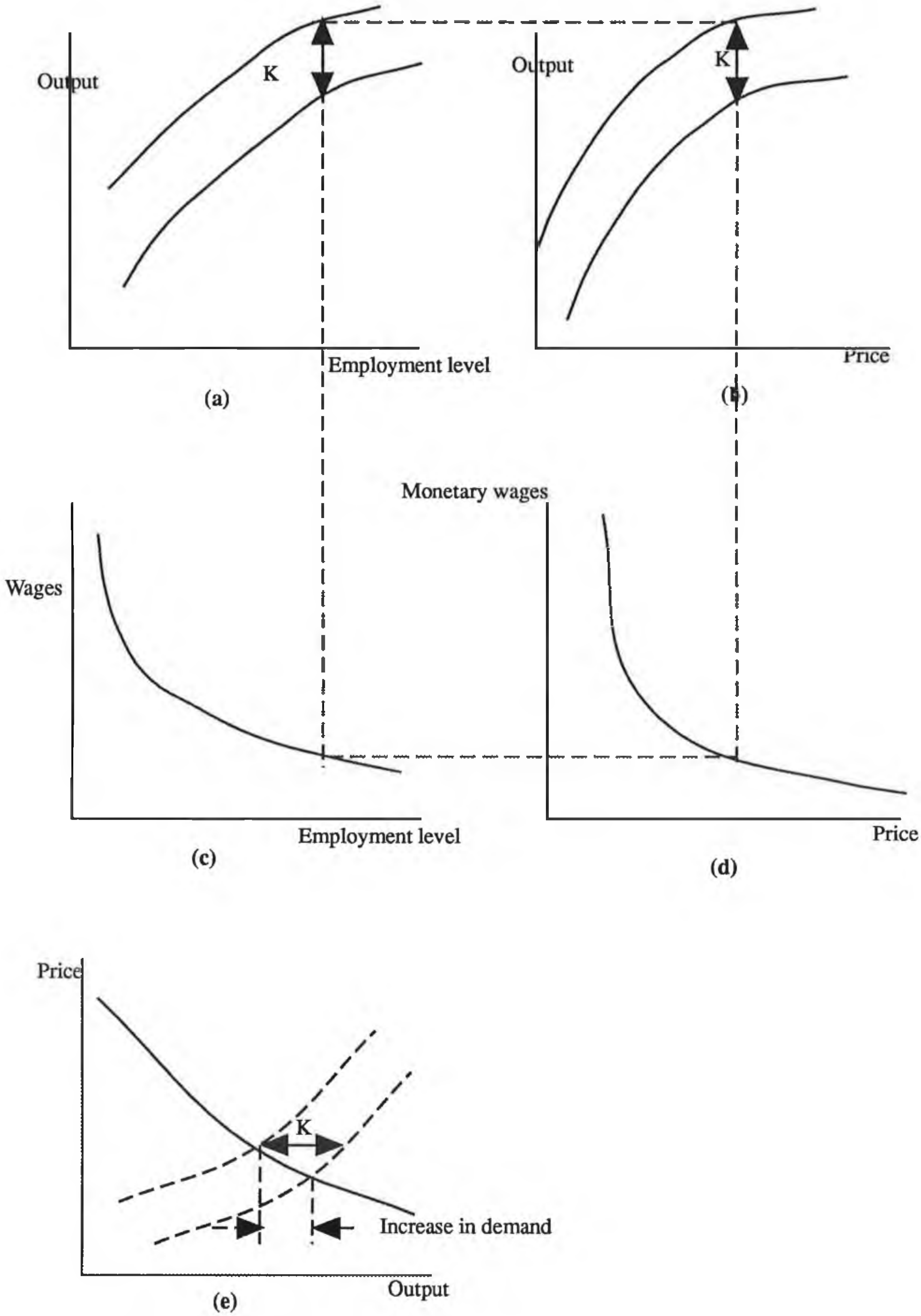
Aggregate demand and supply model of the impact of technological change

The aggregate demand and supply model of the effect of technological development is illustrated in figures A1a - A1e. For the sake of simplicity in the example chosen, the effect of the technological change is to move the production function upwards by an increment K but not to change the shape of the production function curve (figure A1a). With this type of change the marginal product of labour is unchanged (figure A.1c) and maximum profitability will equal the real wage . The relationship between the real wage and price levels is illustrated in figure A1d.

In this example, the price levels remain the same, with the aggregate supply (figure 1.1b) going from curve S to curve S1. The effect of the increase in the aggregate supply curve is shown in figure 1e, where it is plotted against a fixed demand curve. Since the aggregate demand is not infinitely elastic, the level of output will expand by less than K, there will be a fall in price. However, since the full increase in output is not taken up, there will be a consequent reduction in total employment. This model, would therefore suggest that technological improvement results in:

(a) increased output
(b) lower prices and
(c) reduced employment.

(Lovell. 1975. P. 335)



FigA1.1 Technological change and aggregate supply;
(a)Technological change moves total product curve by increment K,
(b) Aggregate supply also increases by increment K,
(c)Marginal product of labour and real wages remain constant,
(d) Prices and monetary wages remain constant,
(e)Aggregate supply and demand, demand does not absorb all of the increased supply.

Appendix B Data Tables detailing BERD in Electronics

	Total Business R&D Expenditure (Current)	Inflation Factor	Total Business R&D Expenditure (Constant 1982)	Expenditure in Electronic sector (Current)	Expenditure in Electronic sector (Constant 1982)	% Total R&D Expenditure in Electronics	% Contribution to total from Gorvernment	IDA R&D Payments	Gorvernment Contribution to Total
1979	20.5	0.59	34.7	2.5	4.2	12.20%	8.8%	3.2	1.8
1982	42.5	1	42.5	8.5	8.5	20.00%	13.6%	8.5	5.8
1984	61.9	1.16	53.5	16.5	14.3	26.66%	10.8%	7.4	6.7
1986	89.5	1.26	71.0	30.3	24.0	33.85%	13.9%	11.9	12.4
1988	105.5	1.34	79.0	31.4	23.5	29.76%	9.1%	8.5	9.6
1990	142.0	1.44	98.9	49.3	34.3	34.72%	3.7%	7.3	5.2
1991	175.9	1.48	118.8	60.2	40.7	34.22%	2.1%	6.7	3.7

	Expenditure in Electronic sector (Current)	Expenditure by Irish Companies(Electronics sector)	% Sales Revenue(Electronics sector)	Expenditure by Foreign Owned Companies(Electronics sector)	% Sales Revenue(Electronics sector)	Gorvernment Contribution to Total(Electronics sector)	% Contribution from Gorvernment(Electronics sector)	Contributation from EC Programmes(Electronics sector)	No. of Formal R&D Functions (Irish) (Electronics sector)	No. of Formal R&D Functions (Foreign owned) (Electronics sector)	No. of firms engaged in R&D(Electronics sector)
1979	2.5	1.1		1.7		0.3	0.112		5	7	20
1982	8.5	2.6		7.0		1.3	15.29%		22	19	59
1984	16.5	6.8		9.7		1.5	9.09%		35	71	127
1986	30.3	3.7		26.6		3.5	11.55%		24	30	75
1988	31.4	4.0		27.4		1.6	5.10%	0.88	19	23	81
1990	49.3	3.0	7.6%	46.3	3.0%	1.1	2.23%	0.4	21	26	67
1991	60.2	5.7	2.9%	54.5	3.0%	0.8	1.33%	0.7	23	40	64

Appendix B Data Tables detailing BERD in Electronics

	Expenditure(£, 000) in Electronic sector (Constant 1982)	Expenditure(£, 000) by Irish Companies (Constant 82)	Expenditure(£, 000) by Foreign Owned Companies (Constant 82)	% Contribution from Gorvernment
1979	4.2	1.9	2.9	11.20%
1982	8.5	2.6	7.0	15.29%
1984	14.3	5.9	8.4	9.09%
1986	24.0	2.9	21.1	11.55%
1988	23.5	3.0	20.5	5.10%
1990	34.3	2.1	32.2	2.23%
1991	40.7	3.8	36.8	1.33%

	Expenditure(£, 000) in Electrical machinery sector (current)	Expenditure(£, 000) in Electrical machinery sector (Constant 1982)	Elect Mach Expenditure(£, 000) by Irish Companies (current)	Elect Mach Expenditure(£,000) by Irish Companies (Constant 82)	Elect Mach Expenditure(£, 000) by Foreign Owned Companies (Current)	Elect Mach Expenditure(£, 000) by Foreign Owned Companies (Constant 82)	Grant payments (£,000) to electrical machinery companies for R&D (Current)	payments (£,000) to electrical machinery companies for R&D (Constant 82)	Grant payments to electrical machinery companies for R&D (% Total)
1979	397	£ 673	11	£ 19	£ 386	£ 654	£ 20	£ 34	5.0%
1982	2427	£ 2,427	458	£ 458	£ 1,969	£ 1,969	£ 633	£ 633	26.1%
1984	3230	£ 2,792	279	£ 241	£ 2,951	£ 2,551	£ 447	£ 386	13.8%
1986	2821	£ 2,238	1429	£ 1,134	£ 1,392	£ 1,104	£ 717	£ 569	25.4%
1988	4912	£ 3,678	2788	£ 2,088	£ 2,124	£ 1,590	£ 716	£ 536	14.6%
1990	7000	£ 4,875	4000	£ 2,786	£ 3,000	£ 2,089	£ 744	£ 518	10.6%
1991	8874	£ 5,993	5161	£ 3,486	£ 3,712	£ 2,507	£ 864	£ 584	9.7%

Appendix B Data Tables detailing BERD in Electronics

	Expenditure(£, 000) in Instrument sector (current)	Expenditure(£, 000) in Instrument sector (Constant 1982)	Instrument R&D Expenditure(£, 000) by Irish Companies (current)	Instrument R&D Expenditure(£,000) by Irish Companies (Constant 82)	Instrument R&D Expenditure(£, 000) by Foreign Owned Companies (Current)	Instrument R&D Expenditure(£, 000) by Foreign Owned Companies (Constant 82)	Grant payments (£,000) to Instrument companies for R&D (Current)	Grant payments (£,000) to Instrument companies for R&D (Constant 82)	Grant payments to Instrument companies for R&D (% Total)
1979	487	£ 825	£ 487	£ 825	£ 0	£ 0	£ 10	£ 17	2.1%
1982	574	£ 574	£ 66	£ 66	£ 508	£ 508	£ 29	£ 29	5.1%
1984	703	£ 608	£ 84	£ 73	£ 619	£ 535	£ 22	£ 19	3.1%
1986	2891	£ 2,293	£ 791	£ 627	£ 2,100	£ 1,666	£ 428	£ 340	14.8%
1988	5178	£ 3,877	£ 875	£ 655	£ 4,303	£ 3,222	£ 803	£ 601	15.5%
1990	8260	£ 5,753	£ 1,160	£ 808	£ 7,100	£ 4,945	£ 626	£ 436	7.6%
1991	5889	£ 3,977	£ 1,408	£ 951	£ 4,481	£ 3,026	£ 375	£ 253	6.4%

	Expenditure(£, 000) in Electronic sector (Constant 1982)	Expenditure(£, 000) by Foreign Owned Companies (Constant 82)	Expenditure(£, 000) by Irish Companies (Constant 82)
1979	5735.6	3535.6	2708.5
1982	11501.0	9477.0	3124.0
1984	17660.2	11553.2	6191.0
1986	28568.2	24305.9	4696.3
1988	31068.3	26411.0	5738.2
1990	44964.7	41436.4	5683.3
1991	50628.8	43796.4	8286.3

Appendix C Eolas, Science & Technology Evaluation Unit Survey of Business Expenditure on R & D

This survey is carried out every two years (on average) using the questionnaire included in this appendix.

The population consists of:

(1) Previous respondents

(2) IDA Grant Recipients

(3) Other Companies that come to the attention of the survey organisers as being R & D performing

The survey forms part of the wider OECD R & D statistics and uses for reference the FRASCATI Manual on "The Measurement of Scientific and Technical Activities".

The manual distinguishes R & D from innovation pointing out that R & D is one of the 7 activities in the innovation process, the others being new product marketing, tool and industrial engineering, manufacturing start up, patent work, organisation and financial changes and final product design engineering. However it identifies R & D as "the original source of inventive ideas" and which can be carried out at different phases of the innovation process.

The manual recognises the problems in identifying the cut off point between R & D and the other activities and provides many examples of what is and what is not R & D. The manual accepts that R & D output statistics would be more valuable than input statistics. It acknowledges that they are far more difficult to define and collect.

The manual notes that, "at the time of writing no up-to-date detailed standard international classifications of fields of science and technology is available and no recommendation can be made", but nevertheless classifies research areas using ISIC (International Standard Industrial Classification) codes. The manual recommends that R & D be classified according to the focus of the research or the occupational area of the research. Where there is an interdisciplinary effort it should be "prorated amongst the fields".

In Ireland the classification is made by the survey managers and it is done on the basis of the main activity of the company concerned.

In the 1992 Manual (DSTI/STII STP/NESTI (92) 4), there are 269 pages.

The contents of the manual would not be well known to industrialists completing the Eolas survey questionnaire and because "R & D" is considered "good" there will be a tendency to overstate the level of R & D activity.

Appendix D - Explanation of Marxist Concepts

1 **The Labor Theory of Value** Commodities are products of human labor which are produced for the market. When two different commodities are exchanged, one for the other, they have this and only this in common: they are both the product of the same amount of abstract human labor.

2 **Surplus Value** The laborer, who does not own the means of production, sells his labor power to the capitalist, who pays a wage equal to the value of labor power. He pays, for instance, a wage equal to 6 labor hours, if 6 labor hours are needed to produce the daily subsistence for the laborer. But the capitalist has bought the whole day's labor power (say 12 hours of labor power). The exchange value of the commodities produced by the laborer is, therefore, equal to 12 labor hours. We see that the laborer produces 6 hours' worth of commodities over and above the commodities which are needed to cover his means of subsistence. This is the surplus value, which the capitalist keeps to himself.

3 **Simple Reproductions** Production system where the total surplus value equalled "a revenue for luxury consumption by capitalists".

4 **Extended Reproduction** Production system which generated sufficient surplus value to allow for the conversion of surplus value into extra capital.

5 **The Rate of Profit** The rate of profit is the ratio of surplus value total capital: $s/c + v$. It is determined by the rate of exploitation s/v and by the organised composition of capital c/v.

6 **The Falling Rate of Profit** Since the organic composition of capital undergoes a continuous change in favor of constant capital, the rate of profit must have the tendency to fall, because only the variable part of total capital produces surplus value.

7 **The Effect of Machinery on the Rate of Surplus Value** The increased use of machinery increases the rate of exploitation, because it now takes less time to produce a laborer's means of subsistence; besides these means can now be earned by several members of the laborer's family, because the machine permits the use of laborers of slight muscular strength. It also becomes possible to lengthen the labor day or to increase the intensity of work. When the rate of surplus value increases, the rate of profit tends to rise.

8 **The Reserve Army of Labor** The most important effect of machinery is to make a portion of the labor class superfluous, to create a reserve army of unemployed men and to exert a continuous downward pressure on wages. The reserve army is also called the relative surplus population.

9 **Periodical Crises** The fall of the rate of profit and the growth of the reserve army are periodically interrupted. A crisis eliminates the smaller capitalists, concentrates capital in fewer hands, and lowers the value of constant capital. Furthermore, the reserve army grows during a crisis, and the increased rate of exploitation raises profits for the surviving capitalists. Then follows a period of

increased accumulation and increased demand for labor power. But rising wages cut again into the surplus value. This explains the phenomenon that crises are preceded by high rather than low wages.

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
Carlow																	
	Process Control & Auto Systems Ltd	R	Industrial Process Controls											£ 19,357	£ 25,252		£ 44,609
Sub-total for County				£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 19,357	£ 25,252	£ 0	£ 44,609
Total for County				£ 44,621	£ 118,238	188062	127734	£ 230,606	£ 197,759	£ 128,697	£ 20,906	£ 121,808	£ 199,627	£ 126,082	£ 1,014,722	£ 168,813	£ 2,687,675
																	£ 0
																	£ 0
																	£ 0
Cavan																	
	Elam Ltd		Electronic Regulators					£ 12,182		£ 4,443							£ 16,625
Sub-total for County				£ 0	£ 0	£ 0	£ 0	£ 12,182	£ 0	£ 4,443	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 16,625
Total for County				£ 2,775	£ 47,937	£ 22,110	£ 70,828	£ 187,479	£ 222,864	£ 250,836	£ 574,942	£ 124,989	£ 65,197	£ 45,935	£ 140,708	£ 75,251	£ 1,831,851
																	£ 0
																	£ 0
Clare	Acorn Automation Ltd		Auto-Production Linle							£ 53,597	£ 2,788	£ 38,762	£ 0	£ 10,357	£ 6,930		£ 112,434
	AEG Servo		Electrical Industrial										£ 100,000	£ 100,000	£ 26,769	£ 0	£ 226,769
	American Video Accessories		Electronic Systems				£ 19,257		£ 22,100								£ 41,357
	Assman Electronics Ltd		Electronic Components						£ 8,000								£ 8,000
	Biomedical Research		Surgical & Medical										£ 0		£ 3,419		£ 3,419
	Denver Electronics Ltd Shannon		Sonic Tape							£ 19,830							£ 19,830
	Design ID		Electronic Engineering										£ 21,672	£ 23,644			£ 45,316
	EI Ireland		Smoke Alarms										£ 44,208				£ 44,208
	Electronic Design Assembly Ltd		Electronic Equipment				£ 954										£ 954
	Electro-Mechanical Systems & Services Ltd, Ennis		Electronic Equipment					£ 10,779	£ 12,865								£ 23,644
	Iceflo System		Microprocessor Development											£ 14,992			£ 14,992
	Inland Motor Ltd	US	Industrial Motors					£ 63,431	£ 247,332	£ 254,273	£ 165,274						£ 730,310
	Kollmorgen Ireland Ltd		Precision Motion Control Systems				£ 32,827					£ 450,589					£ 483,416

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Labtech Ltd Shannon			£ 6,950													£ 6,950
	Larec CNC Ltd Ennistymon	R	Machine Tool Components			£ 7,000											£ 7,000
	Micro Processor Developments				£ 5,000						£ 19,637	£ 11,663					£ 36,300
	Minroc Ltd Shannon		Electronic Components							£ 51,266	£ 23,734	£ 103,881					£ 178,881
	Neltronic Ltd		Electronic Support										£ 9,964		£ 9,430		
	Peak Electronics (Irl) Ltd	R	Mirror System for IR Detectors				£ 60,335	£ 30,936	£ 27,079	£ 18,549	£ 11,551	£ 79,302					£ 227,752
	Tellabs		Telephone & telegraph										£ 420,914	£ 333,273	354491	£ 538,913	£ 1,647,591
	Text Lite (Ireland) Ltd		Lighting Systems					£ 23,500									£ 23,500
	Thermo-Foil Print, Ennis		Printing								£ 12,750						£ 12,750
	Tulla Electronics Ltd	Belgian		£ 5,440						£ 6,986							£ 12,426
	Tweed Audio Ireland Ltd		Microprocessor Audio Equipment						£ 25,260								£ 25,260
	Vitalograph		Medical Instruments													£ 0	£ 0
Sub-total for County				£ 12,390	£ 5,000	£ 7,000	£ 113,373	£ 128,646	£ 342,636	£ 404,501	£ 235,734	£ 684,197	£ 596,758	£ 482,266	£ 401,039	£ 538,913	£ 3,933,059
Total for County				£ 12,390	£ 16,313	£ 53,603	£ 139,653	£ 255,472	£ 484,747	£ 637,156	£ 306,870	£ 810,365	£ 710,000	£ 590,000	£ 598,632	£ 624,321	£ 5,239,522
																	£ 0
																	£ 0
																	£ 0
Cork	Allda Systems LTd	R	Wire Processing							£ 13,433							£ 13,433
	Apple Computer Ltd	US	Keyboard & Peripheral Equipment					£ 24,378									£ 24,378
	A R Electronics Ltd		Echo Sounder/Fish Finder			£ 1,377	£ 2,032										£ 3,409
	Beehive International	US	CRT Terminals					£ 90,281	£ 43,718								£ 133,999
	Bectrol Electrical Ltd														£ 11,584		£ 11,584
	Bourns Electronics (Ire) Ltd	US													£ 82,029		£ 82,029

Appendix E IDA R D Grant Payments 1979-1991

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Burgolarm (Irl) Ltd Cork		Intruder Control Systems			£ 5,000											£ 5,000
	CPT Ireland	US	Word Processors							£ 41,427	£ 59,968						£ 101,395
	Carralbu Engineering Ltd		Electro-Mechanical Test Gear									£ 6,350					£ 6,350
	Compucorp Ireland Ltd	US	Word Processors and Office Automation							£ 60,936							£ 60,936
	Comtel Business Systems Ireland, Cork												£ 89,516				
	C G Services Ltd, Bantry		Microprocessor "Queing/Service System									£ 1,914					£ 1,914
	Douglas Electronics Systems Ltd		Laboratory Equipment	£ 218		£ 5,250						£ 17,476					£ 22,944
	Edpac (Ireland) Ltd Carrigaline		Air Conditioning Equipment									£ 17,219	£ 65,402	£ 9,322			£ 91,943
	Farran Technology		Reseach Centre						£ 4,371	£ 7,169	£ 20,813	£ 51,757	£ 27,971				£ 112,081
	Forde Electronics Ltd	R	Statistical Analyser				£ 14,000										£ 14,000
	Glanmire Electronics	R	Real time Clock Peripherals					£ 10,005	£ 2,275			£ 12,851				£ 27,651	£ 52,782
	Greengate Electronics		Fuel Pump													£ 7,877	£ 7,877
	Hanimex Ireland Ltd		Movie Projectors & Viewers						£ 5,336	£ 9,424	£ 22,000						£ 36,760
	Hormann Security Systems Ltd	R	Electronic Alarm Systems						£ 59,126		£ 25,925						£ 85,051
	Irish Data Equipment Cork		Educational Microcomputer			£ 7,000											£ 7,000
	Liebert Int B V Cork	US	Environmental Control							£ 49,296				£ 53,744			£ 103,040
	McLougin Daniel, Fermoy	R	Device for Monitoring telephone Calls						£ 5,082								£ 5,082
	Marine Microsysteem Ltd		Ultrasonic Signal Processors					£ 10,148	£ 8,358	£ 13,061	£ 10,327						£ 41,894
	Mica & Micanite (Ireland) Ltd Mallow		Electronic components								£ 18,835						£ 18,835

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Millimetre Wave Technology		Schot Barrier Diodes		£ 5,076		£ 6,679										£ 11,755
	Moog Ltd, Carrigaline	US	Electric Industrial Equipment									£ 76,048	£ 57,673	£ 101,563	£ 120,165		£ 355,449
	North Star Computers BV Cork	US	Microcomputers							£ 10,919			£ 55,105				£ 66,024
	Ogenek Teoranta, Cork	IR	Data Collection								£ 10,132	£ 826					£ 10,958
	Power Products Ltd, Youghal	US	Electronic Linear Supply Products								£ 49,357	£ 137,730	£ 74,328	£ 21,340	£ 111,915	£ 26,102	£ 420,772
	P S Squared Ltd, Newmarket												£ 10,000				
	Rockwell Constructions Ltd		Air Conditioning Equipment					£ 3,363			£ 3.703						£ 7,066
	Sawafuji (Ireland) Ltd Cork		Speakers, Headphone, Telephones								£ 23,855						£ 23,855
	Ship Co Ltd	IR	Printed Circuit Boards					£ 4,615	£ 8,535	£ 10,705	£ 1,150						£ 25,005
	Southern Electronics Ltd		Communications Equipment					£ 44,846		£ 29,572							£ 74,418
	Syssgen Ltd Cork	US	Microcomputers & Storage Systems											£ 42,813			£ 42,813
																	£ 0
Sub-total for County				£ 218	£ 5,076	£ 18.627	£ 22,711	£ 187,636	£ 136.801	£ 245,942	£ 246.065	£ 322,171	£ 379,995	£ 228,782	£ 325,693	£ 61,630	£ 2,181,347
Total for County				£ 79,723	£ 178,215	£ 370,496	£ 111,857	£ 516,293	£ 510,255	£ 560,514	£ 1,040,182	£ 1,706,588	£ 983,795	£ 515,154	£ 882,985	£ 614,998	£ 8,071,055
																	£ 0
Donegal	Barry Electronics Ltd, Killybegs		Marine Electronic Equipment						£ 1,500								£ 1,500
	Byrne, Paul, Letterkenny		Electronic Theodolite							£ 6.526							£ 6,526
	Energy Electronics Ltd		Solar Powered Electric Fence				£ 2,939										£ 2,939
	Marine Electrics, Killybegs		Electronic Fish Counter							£ 4,900							£ 4,900
Sub-total for County				£ 0	£ 0	£ 0	£ 2,939	£ 0	£ 1,500	£ 11,426	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 15,865
Total for County				£ 24,406	£ 98,942	£ 19,206	£ 113,517	£ 187,351	£ 170,840	£ 567,073	£ 99,355	£ 102,978	£ 13,942	£ 0	£ 57,997	£ 1,265	£ 1,456,872
																	£ 0
																	£ 0
																	£ 0
Dublin	Accuspec Ltd, Stillorgan				£ 7,370	£ 35,025			£ 36.500	£ 26,698	£ 10,702						£ 116,295
	ACEC (Irl) Ltd		Switchgear System				£ 10,420	£ 12,208	£ 8,245								£ 30,873
	Alpine Insulation Ltd				£ 925												£ 925
	American Micro Computers Ltd Dublin 2		Small Business Computers						£ 39,378	£ 85,775	£ 20,061						£ 145,214

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Anderson Research & Development Ltd		Automatic Light Control								£ 7,945						£ 7,945
	Arner Comunications Ltd												£ 17,502				
	Apparel Real Time Systems Ltd		Computer Systems for Apparel Industry									£ 12,402	£ 36,896	£ 83,726			£ 133,024
	Applied Magnetics Ireland Ltd		Magnetic tape Heads			£ 10,539			£ 13,293	£ 16,028	£ 49,695						£ 89,555
	Applied Micro Electronics Ltd		Computer Interfaces									£ 31,181		£ 34,500	£ 37,890		£ 103,571
	Anti Skid Control Ltd		Safety Equipment					£ 18,882		£ 41,766	£ 11,352						£ 72,000
	Automatic Liquid Moritoring Systems				£ 3,500												£ 3,500
	Autotron Services		Electronic Control Equipment					£ 3,500									£ 3,500
	Aval Coorporation of Ireland Ltd		Computer Services								£ 4,361	£ 6,036	£ 56,769	£ 25,831			£ 92,997
																	£ 0
	Bell & Howell Ltd		Microfiche Readers, Overhead Projectors		£ 40,715	£ 9,285	£ 10,259				£ 4,939						£ 65,198
	Bortel Ltd		Telephone Equipment				£ 1,234	£ 81,627	£ 30,196								£ 113,057
	Computer Automation Ireland Ltd		Minicomputers						£ 609								£ 609
	Comel Electronics Ltd		Data Modems					£ 12,541	£ 17,743	£ 19,759	£ 58,973	£ 57,207	£ 91,237	£ 84,445	£ 67,133	£ 12,057	£ 421,095
	Custom Software Systems Ltd		Intelligent Point of Sale Terminal						£ 5,900								£ 5,900
	Cylon Controls		Energy Management System								£ 5,120						£ 5,120
	Data Products Dublin Ltd		Magnetic Cores		£ 46,046	£ 29,715		£ 28,599		£ 26,218		£ 43,675	£ 13,030				£ 187,283
	Datac Control Int Ltd		Data Acquisition Systems							£ 69,910	£ 57,191		£ 20,909	£ 41,531			£ 189,541
	DBSS Communications Ltd												£ 5,356				

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Digitech Systems Internatinal Ltd		Digital Communications tgransmitters								£ 1,500						£ 1,500
	DCS Computers Ltd, Tallaght		Minicomputer Systems						£ 6,148								£ 6,148
	E G & G, Ireland, Blanchardstown		Nuclear & Scientific Instruments									£ 20,502					£ 20,502
	Elab (Ire) Ltd		Electronic Actuators										£ 30,754	£ 57,688	£ 10,984	£ 7,844	£ 107,270
	Elmore's (Dublin) Ltd Dublin 8										£ 4,991						£ 4,991
	Eltech Ltd			£ 4,600	£ 6,855												£ 11,455
	Enigma tech		Computers													£ 20,000	£ 20,000
	Erika Ltd Clondalkin		Kidney Dialysers										£ 61,472	£ 134,484		£ 137,313	£ 333,269
	ETA Distributors		Electronic Air Cleaner					£ 16,800									£ 16,800
	Europlex Ltd		Alarm Control Panels							£ 6,641	£ 19,363			£ 13,000			£ 39,004
	Garrard Engineering Ltd		Transformers				£ 23,028	£ 46,639									£ 69,667
	Gildcott Associates Ltd Dublin 12		Process Control Equipment								£ 19,000						£ 19,000
	Gotec Ltd, Dublin 13		Charging Units									£ 7,400	£ 33,383		£ 492		£ 41,275
	Graftel		Electronic Data Printer					£ 4,829		£ 29,074	£ 43,015						£ 76,918
	Hickey Martin		Micro Based Milk Yield Record				£ 238										£ 238
	High Security Electronics		Monitoring System						£ 6,560	£ 4,440							£ 11,000
	Hyster Auutomated Handling Ltd		Material Handling Systems					£ 58,240	£ 713,363	£ 835,657	£ 764,012	£ 112,276					£ 2,483,548
	Incentive Marketing Ltd Portmarnock												£ 24,270				
	Ingle Engineering Ltd, Ballyboughal		Triple Power Pack Refrigeration			£ 14,500											£ 14,500
	Invotron Limited		Video Meter				£ 700	£ 6,999						£ 9,650	£ 13,350		£ 30,699
	Irish Printed Circuits Ltd Dublin 12		3 Pin Non-Rewirable Plug						£ 36,875				£ 58,125				£ 95,000
	Intrepid Ltd		Daata & voice Equipment												£ 37,796		£ 37,796
	Irish Industrial Gases Ltd		Industrial Gases				£ 10,587										£ 10,587
	ITEC Security Ltd		Electronic Analyseer Boards					£ 13,500		£ 16,622	£ 38,173	£ 171,432	£ 100,052	£ 25,605		£ 139,502	£ 504,886
	Kenny Electronics Ltd		Cable Harnesses & sub-Assemblies					£ 54,475									£ 54,475

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Kes Security Systems Ltd		Security Monitroing System						£ 14,500	£ 20,027	£ 11,640	£ 44,920	£ 100,344	£ 12,434			£ 203,865
	Kit Electronics Ltrd		Electronic Scoreboards							£ 9,795							£ 9,795
	Lake Electronic Designs		Electronic Equipment	£ 3,240	£ 9,873		£ 20,583	£ 44,655	£ 43,520	£ 160,463	£ 112,524	£ 10,967	£ 41,151	£ 16,182			£ 463,158
																	£ 0
																	£ 0
																	£ 0
	Lafla Ltd Dublin 5		Converter Systems							£ 1,291	£ 2,125						£ 3,416
																	£ 0
	Lightband Communications Ltd. Dublin 2		Opto-Electronics Projects										£ 14,198	£ 30,893			£ 45,091
	Manufacturing Management System Ltd		Microcomputer Systems							£ 26,423	£ 22,287						£ 48,710
	Memory Computer Ltd		Computer Products & Services					£ 58,283	£ 54,739	£ 102,225	£ 6,500		£ 31,950				£ 253,697
	Mentec International Ltd		Data Acquisition Unit				£ 23,205	£ 19,863	£ 36,181	£ 94,623	£ 77,590	£ 70,338	£ 66,233	£ 103,847	£ 68,395	£ 112,835	£ 673,110
	Mentec Ltd Tallacht		Microcomputer Mircoprocessor					£ 10,795									£ 10,795
	Mentor Engineering Ltd Dublin 3		Electronic Equipment									£ 8,193					£ 8,193
	Microelectronics Dev. Serv. Ltd												£ 20,531	£ 8,174	£ 46,194	£ 26,221	£ 101,120
	Microcom-Communication + electronics		Automatic Switchboard					£ 2,253									£ 2,253
	Microsol Ltd		Control Systems											£ 45,229		£ 33,385	£ 78,614
	MNJ		Anti Theft Devices						£ 51,933								£ 51,933
	National Composites Ltd Dublin 4		Vacuum Pressure System											£ 1,144			£ 1,144
	Neltronic Ltd, ublin 12		Electronnic Components									£ 4,772					£ 4,772
	Nhance Development Corp		R & D Facility						£ 49,197					£ 168,391			£ 217,588
	Odenberg Manufacturing		Processing Systems					£ 44,738		£ 18,682	£ 97,522						£ 160,942
	Optech Precision (Dublin) Ltd		Computerised Drink Dispenser										£ 8,045				
	Pelling Power Ltd Dublin 2		Car Parking Meter System								£ 1,214						£ 1,214

Appendix E IDA R D Grant Payments 1979-1991

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	PCB Controls		Anti Skid System			£ 1,565	£ 1,435										£ 3,000
	Philips Radio Communications Sys (Ire) Dublin 11		Radio Communication Equipment											£ 51,448	£ 20,069		£ 71,517
	Philips Radio Comm. Systems		Radio												£ 88,830		£ 88,830
	Phimac Computing Ltd, Dublin 5		Application Programme Generators									£ 9,860					£ 9,860
	Power Tech Sources Ltd		Electronic Power Packs					£ 12,922	£ 28,196		£ 10,291						£ 51,409
	Pye Irl Dynaphon Ltd Dublin		T V Speakers			£ 2,250											£ 2,250
	Quaestor Analytical Ltd		Machine Condition Monitor Unit					£ 20,868					£ 9,675				£ 30,543
	Reconair Manufacturing Ltd Dublin 5		Air Conditioning Equipment							£ 8,118							£ 8,118
	Sensory Instruments		Optical Test Equip													£ 10,001	£ 10,001
	Shiva Instruments Ltd		Printers for Micro-Computers							£ 4,000							£ 4,000
	Spectel Communications Ltd		Phone Line Doubling Equipment							£ 8,118	£ 19,851		£ 46,999	£ 24,109	£ 10,920		£ 109,997
	Speech Technologies ((Ire)		Speech Communicator											£ 33,791	£ 5,164		£ 38,955
	Siemens Ltd		Electricity Meters					£ 58,674									£ 58,674
	Sword Lighting Ltd		Light Fittings					£ 17,386									£ 17,386
	Tangent Company Ltd Dublin 2		Electroscanner for the Rubber Industry							£ 7,824	£ 1,086	£ 9,012	£ 1,465				£ 19,387
	Telecommunications Co Ltd		Telecommunications Equipment				£ 18,217		£ 19,419	£ 18,495							£ 56,131
	Telectron Ltd			£ 137,134	£ 256,843		£ 22,140										£ 416,117
	Tower Frame Ltd, Dublin 2		Printer Peripherals									£ 134,888	£ 15,112				£ 150,000
	Tramex Engineering Ltd		Hand Held Moisture Detector					£ 11,219	£ 14,470			£ 19,839				£ 9,237	£ 54,765
	Trintech (Manufacturing) Ltd		Credit Card Checking Device									£ 102,721	£ 117,755	£ 3,024			£ 223,500
	TT Systems Ltd Clondalkin		Computer Terminals				£ 45,587	£ 9,445		£ 4,494							£ 59,526
	Ventilux Ltd		Emergency Lighting													£ 94,013	£ 94,013
	Videopro International Products		Video Projection Equiment					£ 97,042	£ 113,878		£ 126,376		£ 246,735	£ 126,393			£ 710,424

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Voicetech Ltd Tallaght		Electronic Voice Synthesiser							£ 3,750	£ 16,300	£ 1,700					£ 21,750
	Waltham Electronics Ltd		Music Centres					£ 104,410									£ 104,410
	Wescan Europe Ltd		Computer terminals					£ 4,900	£ 38,561	£ 31,661				£ 65,120	£ 20,895		£ 161,137
Sub-total for County				£ 144,974	£ 372,127	£ 102,879	£ 187,633	£ 876,292	£ 1,379,404	£ 1,698,577	£ 1,625,699	£ 879,321	£ 1,269,948	£ 1,200,639	£ 428,112	£ 602,408	£ 10,768,013
Total for County				£ 192,760	£ 565,651	£ 369,119	£ 687,302	£ 1,461,763	£ 2,490,364	£ 3,818,675	£ 3,402,670	£ 2,745,470	£ 3,060,241	£ 2,024,407	£ 1,423,446	£ 1,680,465	£ 23,922,333
																	£ 0
																	£ 0
Galway																	£ 0
																	£ 0
	Alternative Energy Ltd				£ 19,354	£ 5,146											£ 24,500
	Civilair Ltd		Air Conditioners													£ 5,267	£ 5,267
	Connaught Electronics								£ 2,327	£ 855	£ 5,565	£ 16,304	£ 4,994	£ 30,446	£ 44,524	£ 2,136	£ 107,151
	Connemara Electronics Ltd		Extruded Synthetic Transmitter Belts						£ 3,486								£ 3,486
	Cormac Precision Instr. Ltd Tuam		Farm Weighing Scales											£ 2,359			£ 2,359
	D C Engineering Co Ltd		Water Pump Control		£ 2,825												£ 2,825
	Development Solutions Ltd		Logic Units												£ 20,705		£ 20,705
	Digital Equipment Int. B V Galway		Development Centre											£ 155,706			£ 155,706
	Geotronics Ltd			£ 2,850													£ 2,850
	Hitech Electronics Ltd		Resistor Networks		£ 29,154	£ 27,703	£ 24,945	£ 17,731	£ 2,309	£ 14,704		£ 21,509					£ 138,055
	MDB Systems Ireland Ltd		Computer Interfaces										£ 2,420				
	Micro Electronic Security Systems, Galway		Phone-Alarm						£ 4,429	£ 2,225							£ 6,654
	Micromotors Groschopp (Ire) Ltd													£ 20,880			£ 20,880
	Noctech Ltd Galway		Equipment							£ 35,859							£ 35,859
	Northern Telecom Ltd Galway		Automatic Transformer Tests			£ 27,539			£ 53,528		£ 96,782		£ 181,620				£ 359,469
	Pulse Engineering Ltd		Electronic Components					£ 2,831									£ 2,831
	Precision Management Services		VDUs				£ 29,840										£ 29,840
	Square D & Co (Ireland) Ltd		Electrical Control Equipment						£ 25,714	£ 1,193							£ 26,907

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County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
	Xon Technology Ltd, Galway		Visual Display Units						£ 4,650	£ 3,600	£ 11,166						£ 19,416
	Western Automation Research & Development Ltd Ballinasloe		Electronic Components						£ 13,914		£ 16,460	£ 3,540				£ 10,621	£ 44,535
Sub-total for County				£ 2,850	£ 51,333	£ 60,388	£ 54,785	£ 20,562	£ 110,357	£ 58,436	£ 129,973	£ 41,353	£ 189,034	£ 209,391	£ 65,229	£ 18,024	£ 1,009,295
Total for County				£ 16,943	£ 63,307	£ 141,865	£ 112,124	£ 152,164	£ 395,861	£ 148,433	£ 254,020	£ 374,663	£ 330,062	£ 487,664	£ 199,197	£ 164,940	£ 2,841,243
Kerry																	
Beru Electronics Ltd Tralee	Monitors & Switches												£ 117,543	£ 28,349	£ 53,898	£ 39,592	£ 239,382
Kostal Ireland	Automotive Electronic												£ 1,486				£ 1,486
Sub-total for County				£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 117,543	£ 28,349	£ 53,898	£ 39,592	£ 239,382
Total for County				£ 4,923	£ 46,439	£ 16,357	£ 3,700	£ 72,798	£ 48,008	£ 356,008	£ 313,855	£ 295,278	£ 145,236	£ 31,717	£ 66,596	£ 44,296	£ 1,445,211
Kildare	Aisling Lambert, Naas		Mattress with Electronic Alarm							£ 1,607							£ 1,607
	Coin Operated Amusements Ltd, Kildare		Video Games						£ 3,500								£ 3,500
	Donnelly Mirrors Ltd		Auto Rear View Mirrors				£ 42,803	£ 22,425			£ 162,985	£ 48,380	£ 19,760	£ 30,612	£ 58,556		£ 385,521
	Renley Ltd Kilcullen		Distribution Panels for ESSB									£ 11,710	£ 6,210				£ 17,920
	SPS International Ltd		Engineering Products								£ 41,085						£ 41,085
Sub-total for County				£ 0	£ 0	£ 0	£ 42,803	£ 22,425	£ 3,500	£ 1,607	£ 204,070	£ 60,090	£ 25,970	£ 30,612	£ 58,556	£ 0	£ 449,633
Total for County				£ 18,216	£ 65,304	£ 50,994	£ 188,707	£ 460,163	£ 219,288	£ 193,747	£ 656,920	£ 214,669	£ 193,298	£ 204,407	£ 201,097	£ 111,544	£ 2,778,354
Kilkenny																	
Sub-total for County				£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	
Total for County				£ 5,765	£ 0	£ 52,455	£ 24,403	£ 48,704	£ 17,567	£ 237,083	£ 96,157	£ 77,884	£ 179,372	£ 123,010	£ 250,392	£ 183,912	£ 1,296,704
																	£ 0
																	£ 0
Laois																	£ 0
Sub-total for County				£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0
Total for County				£ 5,628	£ 3,474	£ 0	£ 14,578	£ 69,794	£ 82,063	£ 33,741	£ 48,943	£ 3,582	£ 66,883	£ 0	£ 3,936	£ 14,057	£ 346,679
																	£ 0

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Appendix E IDA R D Grant Payments 1979-1991

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
																	£ 0
Leitrim																	£ 0
	Frese (Ire) Ltd		Car Mirrors												£ 162,892		£ 162,892
	National Electrical Designs Ltd.		Minature Circuit Breaker											£ 64,909			£ 64,909
Sub-total for County				£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 0	£ 64,909	£ 162,892	£ 0	£ 227,801
Total for County				£ 60,173	£ 900	£ 0	£ 5,672	£ 0	£ 0	£ 0	£ 10,525	£ 0	£ 0	£ 142,758	£ 85,043	£ 93,898	£ 398,969
																	£ 0
																	£ 0
Limerick																	£ 0
	Analog Devices BV		Electronic Components	£ 84,120	£ 124,988	£ 97,320	£ 58,073	£ 20,423	£ 88,547	£ 199,866	£ 80,430	£ 113,637	£ 123,010				£ 990,414
	Artic Environmental Ltd											£ 10,986	£ 28,415				£ 39,401
	Ashling Microsystems Ltd Limerick		Electrical & Electronic Equipment							£ 68,963	£ 84,893	£ 134,369	£ 86,176	£ 19,077		£ 0	£ 393,478
	Ballyneety Manufacturing Service Ltd												£ 49,990			£ 55,253	£ 105,243
	Colenta Ltd Limerick		Film Develoment Machines								£ 13,263	£ 7,110					£ 20,373
	Conservation of Energy (Limerick) Ltd		Automatic Dispensing Unit					£ 3,850									£ 3,850
	Electronic Design &		Power Factor Controller					£ 5,021									£ 5,021
	Electrotek, Limerick		Electronic Components									£ 2,293					£ 2,293
	Elverex Ltd, Limerick		Computer Services									£ 9,732					£ 9,732
	Flemmingbach		Medical Instruments										£ 157,165	£ 188,747	£ 25,385	£ 82,304	£ 453,601
	GTI Ireland Ltd Abbeyfeale		Diode Leads							£ 15,000							£ 15,000
	IAC Ltd Limerick		Alternator Voltage Regulators			£ 6,700											£ 6,700
	Industrial & Scientific Imaging Ltd		Automatic Visual Instruments							£ 20,436		£ 4,376					£ 24,812
	Interpro Systems Ltd.		Test Equipment						£ 45,886	£ 105,703	£ 85,172	£ 125,030	£ 120,965	£ 67,705	£ 41,206	£ 9,600	£ 601,267
	Location Technology Ltd			£ 12,522													£ 12,522
	Microprocessor Development		Domestic Heaters				£ 13,500										£ 13,500
	Monroe Manufacturing Ltd		Car Sequurity Systems					£ 1,822									£ 1,822
	Plassey Technology		Electronic engineering										£ 0				£ 0
	Seagull Electronics		High technology					£ 1,872		£ 2,491							£ 4,363
	Verbatim Ltd		Magnetic Storage Media					£ 5,700			£ 68,031						£ 73,731
	ViP Microelectronics Production Ltd		Design & Development of Test								£ 9,088		£ 38,280				£ 47,368

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County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
Meath	Beta Electronics Ltd, Ashbourne		Electronics							£ 2,109		£ 5,600					**£ 7,709**
	Bndisco Sire) Ltd		Electric Accessories													£ 11,506	**£ 11,506**
	NEC Ireland Ltd Ballivor		Integrated Computer Circuits							£ 273,414	£ 75,000						**£ 348,414**
	Software Interface Ltd, Ashbourne		Telecommunications Equipment								£ 3,070	£ 2,218		£ 4,016			**£ 9,304**
Sub-total for County				**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 275,523**	**£ 78,070**	**£ 7,818**	**£ 0**	**£ 4,016**	**£ 0**	**£ 11,506**	**£ 376,933**
Total for County				£ 27,353	£ 18,865	£ 55,381	£ 94,320	£ 113,969	£ 105,302	£ 501,659	£ 163,681	£ 72,211	£ 40,380	£ 79,233	£ 37,638	£ 169,195	£ 1,479,187
																	£ 0
																	£ 0
																	£ 0
Monaghan																	**£ 0**
Sub-total for County				**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**
Total for County				£ 84,144	£ 13,860	£ 70,258	£ 232,526	£ 105,665	£ 110,024	£ 97,717	£ 158,781	£ 94,967	£ 164,754	£ 95,967	£ 295,013	£ 300,976	£ 1,824,652
																	£ 0
																	£ 0
																	£ 0
Offaly	Lewicki Microelectronics		Advanced Hybrid Circuitry					£ 53,166									£ 53,166
Sub-total for County				**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 53,166**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 53,166**
Total for County				£ 30,491	£ 29,523	£ 82,571	£ 110,951	£ 102,616	£ 83,508	£ 68,949	£ 80,288	£ 65,626	£ 50,983		£ 44,239	£ 0	£ 749,745
																	£ 0
																	£ 0
																	£ 0
Roscommon	Promoco Ltd, Roscommon		Microwave Cookwaare							£ 42,364	£ 8,567	£ 34,717	£ 36,325				**£ 121,973**
	Urovac Ltd, Athlone		Medical Engineering									£ 4,153					**£ 4,153**
Sub-total for County				**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 42,364**	**£ 8,567**	**£ 38,870**	**£ 36,325**	**£ 0**	**£ 0**	**£ 0**	**£ 126,126**
Total for County				£ 18,160	£ 17,000	£ 12,000	£ 62,879	£ 113,646	£ 42,626	£ 310,992	£ 303,281	£ 139,032	£ 170,109	£ 57,194	£ 79,341	£ 83,617	£ 1,409,877
																	£ 0
																	£ 0
																	£ 0
Sligo	Hanson		Scales			£ 4,464								£ 34,428			**£ 38,892**
	Tenco Design Engineering Ltd		Design										£ 16,135				
	Solarmax		Solar Energy												£ 74,020	£ 39,113	**£ 113,133**
Sub-total for County				**£ 0**	**£ 0**	**£ 4,464**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 16,135**	**£ 34,428**	**£ 74,020**	**£ 39,113**	**£ 168,160**
Total for County				£ 5,307	£ 7,225	£ 15,173		£ 34,414	£ 36,195	£ 70,337	£ 24,384	£ 79,235	£ 25,778	£ 105,668	£ 107,431	£ 61,019	£ 572,166
																	£ 0
																	£ 0
																	£ 0
Tipperary (South)	Digital Equipment International BV		Computers						£ 18,841		£ 128,615	£ 637,324	£ 136,559	£ 376,542			**£ 1,297,881**
	Evans Dev & Manu Ltd		Voltage Converters											£ 14,010			**£ 14,010**
Sub-total for County				**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 18,841**	**£ 0**	**£ 128,615**	**£ 637,324**	**£ 136,559**	**£ 390,552**	**£ 0**	**£ 0**	**£ 1,311,891**

County	Company	Nationality	Product	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
Total for County				£ 18,894	£ 6,823	£ 2,704	£ 78,566	£ 12,627	£ 79,332	£ 34,664	£ 256,474	£ 918,217	£ 321,717	£ 443,936	£ 144,087	£ 78,130	£ 2,396,171
Tipperary																	£ 0
Sub-total																	
Total for County						£ 3,011	£ 28,065	£ 27,126		£ 11,645	£ 106,671	£ 120,701					
																	£ 0
																	£ 0
Waterford	ACEC (Ireland)					£ 19,584	£ 4,196		£ 14,181	£ 15,183	£ 6,000						**£ 59,144**
	Boru Electronics		Electronics													£ 50,427	**£ 50,427**
	Castel Electronics Ltd		Televisions									£ 49,135	£ 2,777				**£ 51,912**
	Veelite Foundry Ltd		Cast Iron Stoves & Cookers									£ 8,422					**£ 8,422**
Sub-total for County				**£ 0**	**£ 0**	**£ 19,584**	**£ 4,196**	**£ 0**	**£ 14,191**	**£ 15,183**	**£ 6,000**	**£ 57,557**	**£ 2,777**	**£ 0**	**£ 0**	**£ 50,427**	**£ 169,905**
Total for County				£ 41,707	£ 6,970	£ 31,138	£ 156,937	£ 150,277	£ 202,926	£ 97,228	£ 245,715	£ 345,235	£ 306,840	£ 99,987	£ 1,078,688	£ 307,225	£ 3,070,873
																	£ 0
																	£ 0
																	£ 0
Westmeath	Ericsson LM Ltd Athlone		Relay & Relay Sets							£ 11,737							**£ 11,737**
																	£ 0
Sub-total for County				**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 11,737**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 0**	**£ 11,737**
Total for County				£ 74,404	£ 73,399		£ 127,773	£ 271,477		£ 75,180	£ 61,625		£ 36,269	£ 14,804		£ 26,810	£ 761,741
																	£ 0
																	£ 0
Wexford																	£ 0
ABS Pumps			Electric Pumps				£ 20,881		£ 17,932		£ 5,734		£ 33,068				**£ 77,815**
Sub-total for County				**£ 0**	**£ 0**	**£ 0**	**£ 20,881**	**£ 0**	**£ 17,932**	**£ 0**	**£ 5,734**	**£ 0**	**£ 33,068**	**£ 0**	**£ 0**	**£ 0**	**£ 77,615**
Total for County				£ 37,345	£ 61,367	£ 38,806	£ 42,424	£ 55,674	£ 39,181	£ 19,684	£ 164,152	£ 96,445	£ 105,578	£ 209,512	£ 162,259	£ 271,169	£ 1,303,596
																	£ 0
																	£ 0
																	£ 0
Wicklow																	**£ 0**
																	£ 0
Industrial Print Ltd						£ 1,225								£ 13,610			**£ 14,835**
Lumex Ltd			Microwave Equipment		£ 4,765			£ 5,058			£ 79,535						**£ 89,358**
Microwave Radio Ltd							£ 8,679							£ 674,944	£ 273,192	£ 227,667	
Tembour Engineering								£ 3,821									
Sub-total for County				**£ 0**	**£ 4,765**	**£ 1,225**	**£ 0**	**£ 8,879**	**£ 0**	**£ 0**	**£ 79,535**	**£ 0**	**£ 0**	**£ 688,554**	**£ 273,192**	**£ 227,667**	**£ 1,288,675**
Total for County				£ 70,250	£ 37,892	£ 38,850	£ 0	£ 167,461	£ 53,543	£ 62,577	£ 122,290	£ 105,938	£ 113,435	**£ 850,370**	**£ 444,237**	**£ 306,619**	**£ 2,373,462**

Appendix F IDA R & D Grant Recipients as a Proxy for R & D Performing Companies.

Table 4.1 illustrates the proportion of companies in 3 NACE codes covering the electronics industry that were IDA grand aided in 1990.

Table 4.1 Companies receiving IDA Grant Support

<table>
<tr><th></th><th>Office & Data Processing Machinery</th><th>Electrical Engineering</th><th>Instrumentation</th></tr>
<tr><td>IDA grant aided</td><td>49</td><td>237</td><td>67</td></tr>
<tr><td>Not IDA grant aided</td><td rowspan="2">7</td><td>16</td><td rowspan="2">14</td></tr>
<tr><td>Not classified</td><td>38</td></tr>
<tr><td>Total</td><td>56</td><td>291</td><td>81</td></tr>
</table>

(In office and data processing machinery and instrumentation the numbers not receiving IDA grant assistance were too small to be classified separately).

This table indicates that over 90% of companies in these sectors are receiving IDA grant support. They would be made aware of the possibility of R & D grant support if they were undertaking or planning to undertake R & D projects or setting up an R & D function. Their first R & D project would put R & D jobs in place so they would also meet the IDA jobs criterion.

To receive IDA funding a specific project must be identified costed and commercially justifiable. Since 1987, it also has had to undergo a technical assessment by Eolas to ensure it was legitimate R & D.

The funding is paid only after technical and commercial reports are written, and these reports approved b;y the IDA.

Thus the IDA data represents payments made to support planned R & D projects that have been technically and commercially evaluated. Over the 12 year period in question it should capture 90% of the companies undertaking R & D. From reviewing the companies, their apparent level of R & D and the level of funding provided there would appear to be a good correlation between the two.

The companies receiving the largest grant funding are clearly those who are (were) undertaking the most R & D - Analog Devices, ATT, Digital, ECCO and AEG/Inland Motors on the multinational side and Mentec, Lake Electronics and Interpro on the indigenous side.

The total amount paid has fallen significantly as a percentage of the total spend on R & D in the sectors, so to get a truer picture it might be necessary to weight late eighties payments heavier than payments in the mid eighties.

Because the IDA funded projects are of "assessed quality", cover 90% of the industry and are independently assessable (since company names and project titles are published), they represent a more valuable source of data than the Eolas statistical reports which are more extensive.