TECHNOLOGY AND THE ECONOMY WHERE ARE WE NOW?

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In introduction let me state that I consider it an honour to be asked to present this year's Slade Memorial Lecture.

The work of Ralph Slade and the early founders of EDAC played an extremely important part in the development of the electronics industry in New Zealand. They were visionaries who were well ahead of their time and it perhaps unfortunate that only in recent times has New Zealand started to realise the importance of technology and even now I find many blind spots in the corridors of power which seem to divert policy makers away from the unassailable fact that innovation is the driving engine of any growing economy and technology is the most important single factor in innovation. Other factors such as finance, management quality assurance are all important but I would repeat, the one single factor which dominates innovation is technology.

During World War Two New Zealand was seen by Britain as a convenient site, well away from the threat of immediate attack, for some of the production of a very new and very secret aircraft detection device, Radar. The very word was new and many young scientists were taken from university even before they had completed their degree and set to work to build and design radar sets for use in the Pacific and Asian theatres. When the war ended New Zealand was at the forefront of electronics technology and was building radar sets and radios of world standard, as many of the old hands of the industry will tell you.

In responding to the challenge of developing a lecture as a memorial to Ralph Slade one of those early pioneers it seemed to me that an appropriate theme was

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Technology is in itself a new and an old word. Greek Tekhnologica defined the study of art. A 1958 edition of the Concise Oxford Dictionary defined Technology as "the science of the industrial arts". This definition sounds rather quaint when we consider how the word is used today.

Perhaps it is an appropriate definition for this talk.

I would like to read with quotations from "The English Saga" by Arthur Bryant. [1]

"In 1840, the population of England, Wales, Scotland and Ireland, now more than fifty million, barely exceeded twenty six million. Of these two million lived in London and another million and one half in seven cities of over 100,000 inhabitants. Scarcely more than a quarter of the population lived in towns of over 20,000. The rest dwelt as their fathers before them, among the fields or in towns from which the fields were only a few minutes walk At least half the

British race were engaged in rural and semi-rural pursuits. The overwhelming majority were sons or grandsons of farmers, yeomen, peasants and craftsmen.

Except for cotton, no textile trade had been radically affected by machinery before 1830; wool combing was still governed by skill of hand as was the hardware industry of the Midlands and the cutlery of Sheffield. The old traders were still more extensive than the new; at the time of the Reform Bill, there were more shoemakers in England than coal miners. The unit of industry was very small: apprentices frequently lived with their employers over their own workshop, and every craftsman might aspire to be a master.... They were comfortable in their silent vegetation and, but for the industrial revolution, they would never have emerged from this existence.

The social changes wrought by the English inventions of the eighteenth and early nineteenth century - themselves a product of a glorious vitality, ingenuity and disciplined activity of mind - were so far reaching that men already absorbed by the problems of an ancient, vigorous and intricate society had some excuse for not grasping their significance. For they happened with bewildering rapidity. At first they only affected an insignificant minority. At the beginning of the century factory and mine workers formed only a small fraction of the population. The speed at which their numbers increased upset all normal calculations of statecraft.

Though men often of splendid vigour, courage and independence, they were without the ruling tradition of responsibility and noblesse oblige
and the professors of economic science that scruples were in any case antiquated and useless. They had one main concern to get rich, and by every legitimate method available. ...

Machinery gave them their chance. Every new invention by simplifying the processes of manufacture and multiplying the rate of output increased their opportunities for growing rich. They took with them their boisterous energy of their race. All that was needed by the new "manufacturer," working not by his own hand but by machine and proxy, was capital enough to buy or hire a roomful of power looms, a resolve to keep his expenses and consequently his prices down against all rivals and a plentiful supply of cheap labour. The machine took the place of the domestic craftsman whose hereditary skill it rendered useless, whose price it undercut and whose ancient markets it captured.

During the period of transition from cottage to factory labour, the course of nature was reversed. The breadwinner was left idle in the home, the wife and little ones driven by want to the mill.

The result was appalling... The effect on the children can be imagined. The home to which they returned at night, often too weary even to eat, was an untended hovel. The machines to which they hurried back before dawn never tired as they did, In the country which had abolished slavery and was vigorously opposing the slave trade in every corner of the world, "strappers" were kept to flog drowsy children lest they dropped asleep at their work, and groups of pallid mites could be seen supporting each other home as they dragged their limbs up the dark cobbled lanes of Lancashire and Yorkshire valleys.

On no one did the tragedy of factory life fall more heavily than on the old craftsmen class of northern England - the finest artisans in the world.... When such simple Englishmen, feeling themselves cheated and lost, turned for relief to their rulers they received little comfort...

For economists did not see labour as a body of men and women with individual needs and rights but only as a statistical abstraction. Labour was a commodity of value on which the man of Capital, with wham all initiative lay, could draw as the state of the market demanded. And as that market - a world one - was at the mercy of accident and fluctuated unpredictably, a "reserve" of labour was indispensable.

The economic justification of all this was that the factories were giving to the country a wealth she had never before possessed and bringing within the purchasing power o.' the poor, articles which had hitherto been available only to princes. The evils that were inseparable from that system were merely transitional; the nation had only to be patient, to refrain from palliative and wasteful measures and observe the laws of supply and demand, and all would be well. The general body of the middle class accepted this comforting proposition. To any one with capital the mechanical multiplication of productive processes offered unprecedented opportunities: never had there been such a chance by the far seeing investor. The same processes by cheapening the price and multiplying the quantity of goods must surely benefit labour too. The march of progress was irresistible....

The weakness of their economic reasoning, as of all logical abstraction when applied to human affairs, lay in its lack of elasticity. It was •0o doctrinaire to withstand the shock of time and changes wrought by time 1n human ideas and circumstances. A nation, however powerful, which staked its future on a policy so rigid, might one day suffer a terrible awakening. In contrast to this quotation it is interesting to take two recent quotations from an OECD conference on Information, computer and communication policies for the 80's. [2]

We sometimes spend time in such discussions trying to determine whether we are facing a revolution similar to the industrial revolution or whether this is a fast evolutionary process. I suggest it is sufficient, perhaps, to agree that we are witnessing a radical transformation over the total fabric of our society and I insist on the word "total". This transformation is not limited to industrial, manufacturing and other similar processes. It ranges from the modifications of all highly formalised scientific knowledge to the smallest details of our daily lives. For the last ten years we have seen all aspects of our public and private lives affected 6y the new information and communication technology. [3]

There is no doubt that economic growth can help cushion the effects of change, particularly in the creation of new jobs. But many would argue that the industrialised countries are entering a period in which, on unchanged policies, growth may be accomplished by further painful restructuring accompanied by a net loss of jobs because of "new technologies", particularly micro-electronics.

Others believe that as a result of the increase in demand associated with new technologies, it is more likely that as many jobs will be created as are lost. Historically, the latter has been the case and taking the long view will probably hold good in the future. But we have to face severe stress in the short and medium term.

It must be emphasised that whatever the social and political difficulties, the new technologies are likely to be adopted eventually throughout the industrialised world as they always have been in the past, and their potential for increasing output per head will give decisive competitive advantages to those who adopt them first and to the greatest effect. That is why the debate on industrial effects of new technologies is not about whether the UK should adopt them but how and when. It is axiomatic that if new technologies are not adopted, the UK competitiveness will deteriorate further and our economy will be undermined......

The most widely publicised technologies are those based on micro-electronics, often referred to as information technologies, which include applications as diverse as computer-aided design and manufacture, industrial robotics, telecommunications, general office automation and advanced process control systems. The impact of these technologies are already quite far reaching and are likely to become more so over the next 20 years. In the office, for example, they are reducing such repetitive work as typing and billing and accounting. They are also affecting non-repetitive work by increasing decision makers independence from labour intensive information channels. As the use of visual display units, facsimiles, teleconferencing and other forms of direct communication become more widespread, memoranda, messages and designs increasingly will be circulated instantly with little or no human intervention. This is already happening not just within the office, but between offices. It is not fanciful to expect the "fully automated office" to be widespread by the end of the century.

Greater automation in the factory as a result of technologies based on micro-electronics can also be expected. The use of industrial robots is spreading and this has a compounding effect as automatic methods are used in manufacture of the robots themselves. Fujitsu Fanuc of Japan has a factory in which industrial robots, controlled by minicomputers, produce other industrial robots without human intervention. The "fully automated factory is likely to become more common over the next 20 years, though one must not exaggerate the likely speed of change. Automation can also lead to better overall quality and reliability, thereby improving non price competitiveness...

• The onset of the new technologies and in particular the unprecedented rate of change will have profound effects upon our economic and social life as we move towards the year 2000.

* Technological change, whilst it may be resisted in the short term, is inevitable in the medium and long term and it is vital for economic survival and growth.

* Technological change will cause considerable stress on the level of the individual and the effective management of change will provide an enormous challenge at the company and national levels.

*   But the new technologies offer immense opportunities for wealth creation. These opportunities must be accepted with energy and enthusiasm.

And the increase of wealth is essential if we are to achieve the overall objectives of improving general living standards and the quality of life, expanding opportunities for all groups in society, providing support for those in need and maintaining a free and democratic society.

We have no alternative but to pursue the opportunities presented by the new technologies with energy and enthusiasm, and with a real sense of commitment."

To continue the quotations Harlan Cleveland in "The Knowledge Executive" states. [4]

"In a remarkably short span of years - the 1970's and the early 1980's - the once prescient notion that industrial society was being transformed into a post industrial society was being transformed into a post industrial, "information," or "knowledge" society has become a cliché. We are already past the jaw-dropping, gee-whiz stage of technological wonder, and have internalised, even if most of us do not really understand, the prospect of trillions of transactions performed in tiny fractions of time, circling the globe at the speed of light. But we are not yet very far along in learning how to think about the implications of the technical wizardry, and especially the spreading linkage of computers and telecommunications for the way we live, work, and play."

In the last decade as well as moving through discovery and acceptance of the changes that information technology is likely to make to our way of life and to nations' international competitiveness there has been a significant change in the understanding of the effect of technical innovation in advanced capitalist economies. A number of important studies into the role of so called technology push and demand pull theories, plus the role of government technology policies have been completed and it has been suggested that the theory of industrial economics must undergo a paradigm change. It has even been proposed that it can never be the same again.

The studies have been based on international intercomparisons and a step by step study of the process of generation of technical progress, its procedures, its impact on changing industrial structures and the effect of international technological differences on trade and investment flows. Previously it was common to consider technological change or innovation as a factor external to economic theory rather in the nature of an Act. of God, or natural disaster but not a factor which needed to be included or considered. I would suggest that it is in this that there has been significant change.

The detailed studies have shown that technologies significantly alter the economies of a11 countries and also modify international relations in many ways. They provide a technological base that is more productive, more sparing in its use of resources, as well as being more relevant to modern socials needs. Technology changes countries competitive advantages, modifies the standing of individual countries and creates new trading patterns.

It is relatively easy to compare the investment in research and development as a percentage of gross domestic product or rate of economic growth, with national investments in research and development. There is a very close correlation between these two factors but this is obviously a crude measure and does not isolate the effect of technology from other forms of expenditure. It could well be argued that countries with a high GOP can afford to do more research and development and that technology is not necessarily the primary factor in economic growth. A similar relationship could exist between a number of variables where a high level of discretionary cash allows expenditure on "luxuries".

To try and isolate the relationship between technology and economic growth and also to identify how much companies or countries should spend on research and development, studies were begun on the return on investment from research and development. One of the classics in this field was carried out by Mansfield [5] starting as far back as 1961. The initial results suggested that in most cases the public rate of return often significantly outweigh the private return. The social gains in the terms of additional employment, taxation and reduced social costs can be as high as sixty per cent. In approximately one third of the cases studied by Mansfield the public rate of return was so low that in hindsight the investment did not appear worthwhile. In some cases it was evident that a return on investment was not the primary objective. Figure 1 lists some of these objectives which have been identified. From these studies it became clear that a better form of classification was needed and a more detailed understanding of why investment was made in innovation.

Models of the Innovation Processes

As an initial simplification of the process of technical innovation two approaches have been commonly defined. The first model suggests that pure market forces are the main determinants of technical change (demand-pull theories) while the second defines technology as the driving factor, at least in the short run (technology-push theories).

Demand Pull Theories

Figure 2 shows the general steps of market or demand pull process of innovation. The start of this process is the recognition of a market need which is then met by producers through the development, manufacturing and sales process. Although intellectually appealing in its simplicity, such a simplified model cannot explain "technological breakthroughs" nor can it explain why at a definite point in time an invention or innovation occurs. In general studies show that the demand- pull approach fails to produce sufficient evidence that "needs expressed through market signalling" are the prime movers of innovative activity. It is, however, almost axiomatic that most enterprises and individual innovators perceive the existence of a potential demand for their would-be products or processes. The reverse would be surprising. The perception of a market is a necessary condition for innovation but is not a sufficient condition.

'Technology Pull' Innovation Model

In this model it is assumed that an innovator has a "bright idea" which is developed and then marketed. The process is shown diagrammatically in Figure 3. It has been suggested that technical progress in this model is a process given by "God, scientists and engineers". The weakness of this model is that it does not directly include any market effects.

The Product Cycle

A new product in the market place follows a life cycle similar to that shown in figure 4. There are generally believed to be four phases, namely introduction, growth, maturity and decline. Eventually a new product is substituted for the declining product so that a firm can recapture their market share (figure 5). However a firm may often choose to resist the decline of sales of a product by a programme of improvements or extensions to stretch the product life cycle as shown diagrammatically in figure 6. Alternatively a change in technology may result in an expanded market as shown in figure 7. Another option is to extend the product by extending the maturity phase by lowering the price, (figure 8). The classic example of this is the extension of black and white television in Britain by reducing its price even though colour television had been introduced. This resulted in black and white sets being sold to an increasing number of low income consumers considerable extending the maturity phase.

As well as applying to individual products the mechanisms illustrated above apply to complete industries and it is for this reason that the simplified technology push and the market pull models are insufficient to explain the process of innovation. Many of the extension mechanisms shown above occur because of new technology but not a11. It should be clear that these innovations can occur throughout the product cycle and are generated as a result of combinations of both new technology development or new market needs.

Interactive Model of Innovation

A more representative model of industrial innovation is given in figure 9. This is the so called "interactive model". The overall pattern of the innovative process can be thought of as a complex network of communication paths, both within organisations and between organisations and linking to the market place. In general, needs affect all parts of the manufacturing process while new or innovative technology feeds into the processes improving the manufacturer's competitiveness.

Despite the increasing acceptance of the interactive model of innovation it nevertheless remains clear that many governments - many companies - continue to adhere to the technology-push model. This is reflected in the general belief that more research and development produces more innovation. There is little doubt that there is a connection between scientific advance and innovation but the relationship is not direct and can be shown to differ for different types of industry.

Cyclic Evolution of Technology

The two examples of a major transformation of society quoted above, namely the industrial revolution and the information revolution, are perhaps the best known examples of a theory of cyclic changes in the world economy first proposed by Kondratiev a Russian economist in the 192D's. This was extended to suggest that the cause might be technological innovations by Joseph Schumpeter in 1939. According to Schumpeter it was entrepreneurs who, seeing new profit opportunities, vigorously exploited the emerging techno-economic opportunities. [6] Figure 10 shows this in diagrammatic form. In the model it is normally assumed that there are four phases namely prosperity, recession, recovery and depression. The clusters of technological inventions trigger a major upswing and the resultant changes propagate very quickly internationally. It has been this international diffusion of technology which has been a crucial factor in the development and economic growth of most developed countries. Often a technological gap is an incentive for rapid economic growth.

Technology Intensive Industries

The varying level of investment in research and development for a number of industries is illustrated by figure 11. It shows the relationship between research and development investment and added value. It indicates a positive relationship between the two. We can use this relationship to indicate whether an industrial sector falls into the technology intensive grouping or not. It has been the study of the variation of industrial growth characterised by higher intensity of technology that shows the effect of technology an economic growth. For example Figure 12 shows the variation of Exports relative to imports for technology intensive goods for selected OECD countries in the period 1962 to 1977. The remarkable growth by Japan clearly stands out.

This classification can also be used to illustrate the changing employment trends in high and low technology manufacturing such as shown in figure 13. Again the growth in employment in higher technology industries is evident.

Interdependence between technologies:

One other 'important factor in the development of technology is the interdependence between various technologies. Often a major development in one field cannot progress until a development occurs in another field. For example, the development *of* the jet engine required many advances in metallurgy. Similarly the advances in large scale integrated circuits are dependent on Computer Aided Design, Figure 14 gives the relative size of design drawings using conventional draughtinq techniques for typical integrated circuits as a function of circuit density, it is clear that without Computer Aided Design it would be impossible to design modern very high density large scale integrated circuits.

It is also observed that there is strong interrelations between apparently separate fields of technology, Developments in modern computer techniques are now used by the textile and garment industry for designing and cutting clothes. Similarly development in instrumentation are often critical to the development of new processes, while many manufacturer's productivity is dependent on the makers of automatic systems and components. It is this interdependence which leads to clustering of technological developments.

Industrial Classification

By studying this interrelation and also the application of research and development Pavitt [7] suggested that industry could be divided into four categories as shown in figure 15.

The first category, namely the supply industries, are found mainly in the traditional sectors of industry such as textiles, construction and agriculture. These firms make little direct contribution to technological change themselves and normally buy in technology from suppliers. The main factor which dominates the performance of supply industries is marketing. The second category of industry is the "economies of scale" manufacturers. The factor which dominates their growth is their ability to invest in plant to achieve the economies of scale and hence capital plays a critical role in their growth. These firms generally build up a strong engineering skills related to production processes but usually also buy in the major new technological developments from equipment suppliers.

The third group of companies supply the equipment for most manufacturing processes. To achieve competitiveness they are dependent on their ability to adapt new technologies to manufacturing processes. AS a result they invest heavily in research and development both from their own sources and also under license from research and development organisations. Examples include the machine tool industry, automation suppliers and process equipment suppliers.

The final group includes the technology based companies. Examples are the electronics and aerospace industries. These companies are usually highly, specialised and founded on key scientific discoveries in electricity, electromagnetism, semiconductors, chemical synthesis, new materials etc. These firms invest the highest percentage of turnover into research and development of all the groups.

The studies of technology and innovation show that the highest proportion of innovations come from the last two industry groups. Often the first two groups do not invest in research and development directly and rely for their competitiveness on the performance of innovation by the latter two groups. It is for this reason that these latter industries are seen as "enabling industries". They play a key role in the transfer of technology from research and development into industry, and in turn directly affect the international competitiveness of most industries.

Trajectory and Diffusion Models of Innovation

Once it is recognised that the process of innovation is complex it becomes important to examine the process of introduction of technological innovation. Nelson and Winter 8 propose that there are natural trajectories for technical progress. The progress along these trajectories is determined by the interplay between the new scientific discoveries, the marketability, profitability of the products, together with special factors such as the intervention of governments or government agencies.

It seems that government intervention has usually performed a strong focusing role to stimulate the development of technology. Countries in the frontier of technology development enjoy a strong advantage over late-comers, particularly as innovations lead to more' innovations, generating a whole climate for innovation such as can be seen in the development of the semi-conductor industry in the United States. This evolutionary model for the diffusion of technology into an economy is an important development in economic theory. The specific trajectory or path by which the technology develops can be influenced by a wide range of factors including market forces, public policy, and the social and political environment. The selection environment strongly influences the path and in turn influences which areas of research and development firms find profitable to undertake.

Factors in Success and Failure

Some of the major factors which have been identified which affect the path of technology diffusion and hence successful technological innovation are shown in figure 16 and include the following:

External or Market Related Communication Factors

The ability to gather market information and relate these to the needs for innovation, and in turn to successful products in the market plate remains an important factor in successful innovation. It is critical to establish the optimum performance and price combination from the user point of view. Internal Communication Factors

The information on new technologies, the internal ideas which may be successful and the market needs must be able to permeate through a firm or an organisation so that successful products can de developed.

Internal Management Systems Factors

Innovation is a bottom up process because it is difficult to create ideas to order. A flexible, devolved management style is more likely to foster innovation rather than a highly hierarchical structure imposing planning and goals as a top down process.

Technical Factors

It is obviously important to maintain an active programme to keep up to date with technological developments in the key fields of interest.

Top Management Style

Top management must demonstrate their will to innovate new processes and products. This involves a participative, flexible management style.

Economic Resources Factors
As well as development capital and on-going supporting factors other important resources include good after sales service and user education.

Key Individuals
The existence of product champions has been recognised as a significant factor in successful innovation. Committed personnel who push a product through the complex maze of barriers to successful development are often the driving force which maintain the momentum throughout the product innovation cycle. These include business and technical innovators who identify new market opportunities or technical innovations which can be used for new product development. Working conditions and job satisfaction are often more important for retaining these personnel than financial rewards.

Government Policy Support for Innovation
Almost all of the studies of the innovation process have identified that governments play a very important role in the creation of the economic factors which influence the trajectories along which new technology diffuses into an economy. The two most successful countries in application of technology to their economic development have been the United Stakes and Japan.

The United States with about 5% of the world' population currently produces about half of the world's technology. In 1962, the United States snare of industrialised country high technology export was about 30%; in 1980 the United States share had fallen to about 24%. Over this same period Japan's share grew from about 4% to 12%. If current trends persist, market shares of the United States and Japan will be about equal in 1990. Between 1964 and 1979, R & D expenditures as a percentage of Gross domestic product fell in the United States from 3.1% to 2.4% while in Japan they grew from 1.5% to 2.0%. It is obvious that a comparison of these two countries policies provide much valuable information on the influence of "government" policy on technology development.

The United States
The United States is believed to operate a Laissez- faire, market driven policy with large corporations working internationally, suggesting that perhaps technology development can occur without any coherent technology policies. However, closer examination of the United States research and development expenditure reveals the absolute dominance of the United States Department of Defense and NASA. Dosi [9] studied the development of the semi-conductor industry and showed that the United States of Defense played its part on both the supply and demand side:

On the supply side they involved
Setting development directions and areas in which to allocate R & D efforts.
Financial incentives and support for new areas of innovation.
Support for several overlapping areas of development to allow for the investigations of more alternatives than would be possible with normal investment from the private sector.
Pressure to speed up technological development.
Development of standards for production
Lowering of entry barriers for firms wishing to develop new areas.

On the Demand Side:
A guaranteed market
The expansion of demand.
A possible subsidy element in public contracts which have helped to cover fixed costs (such as R & D).

Figure 17 indicates the importance of the United States Department of Defense in providing an initial customer for new technology. In the first few years after the development of integrated circuits the United States Government in the form of the Department of Defense and NASA were the major customers.

To give emphasis to the size of the United States Department of Defense effort in 1981 figure lb shows the employment of skilled personnel as a result of Defense activities.

Because the Defence of the United States is based on technological superiority over the USSR, the Department of Defense sets some very high targets for technological development. It has been argued that because of security classification and the relatively narrow focus on military requirements, the process may divert resources away from needs and future markets for civilian goods. There is little doubt, however, that defence research establishes many of the key trajectories for technology diffusion into industry and has many civilian spin-offs as well as providing a large national expertise in areas of advanced technology and manufacturing know-how.

Japan
Following World War Two, a decision was made in Japan to deliberately restructure industry to better match the evolving markets and technological requirements. In the early 1950's Japan's chief export industries still consisted of labour-intensive trades, where her low wages coupled with superior management techniques made her' an effective international competitor. It was clear that these advantages were transitory and Japan began to set up capacity in several large scale capital intensive industries, namely steel, shipbuilding and chemical fertilizers. In the 1960's she turned to engineering industries and by the end of the 60's her motorcar, electronics and watch and clock industries ranked with the world's leaders. Following the problems of the energy crisis in the early 1970's growth continued with further development in the engineering and technology industries. Figure 19 illustrates the transformation of Japanese industry. This chart is used by the Japanese Economic Planning Agency to demonstrate the movement towards higher value added, more knowledge-intensive industries. This transformation is the result of a coordinated (public and private) national strategy, in which technical policy h s played a key role. The main features of this policy are as follows: [10] (Figure 20)

Industrial Policy:
Japan has implemented a single-minded, continuous and consistent industrial policy. It is an active and selective approach, based on a close and continuous dialogue between government and industry. It has aimed to ensure

international competitiveness in specific industries through supporting economies of scale and to identify competitive advantage will lie or must be created. Trade policy is subjugated to industrial policy.

Financial systems
Public features of this are:

- strong tax incentives to lenders and borrowers;

- the fiscal investment end leans programme which channels `soft' loans to selected industries,

- the steering role which the Bank of Japan adopts, in the light of MITI plans, when supplying funds to commercial banks.

Engineering Education
Japan makes massive investment in engineering education which results in four times as many engineers per head of the population as in the UK. Salary and status and career prospects are all considerable for engineers, who occupy many of the top posts in industry and in government agencies concerned with industry.

Macro-economic Policy
A further example of the Japanese approach to industrial development can be seen by considering their actions after the oil shocks of the 1970's: After the 1973 oil crisis, imports and inflation were cut quickly by deflation, followed by a policy of fiscal expansion in 1975 to restore growth, profits, investment and productivity growth.

Energy Conservation
Although already much more economical [than the UK] in the use of energy before 1973 Japanese industry has since matched energy savings achieved in the UK and has therefore retained its advantage.

Competitiveness
Renewed rapid productivity of 7 per cent per annum since 1915, coupled with deceleration of earnings increases from 20 per cent to 6 per cent have improved competitiveness still further, permitting rising real incomes.

Structural Adjustment
Industrial Policy 11a: aimed at rapid restructuring away from energy and labour-intensive sectors towards knowledge-intensive ones. Intervention to ensure effective research and support for growth industries, and rapid rationalization of declining one; lids put Japan in a very strong position for the 1980's.

Innovation
Having been the world's leading importer of technology, Japan is now engaged on a large scale R & D effort. This involves very large numbers of trained personnel, large scale funding, both public and private, clear guidelines on

priority areas of innovation and national coordination and support from the highest authority.

In Japan, MITI played a key role in setting industries along technological trajectories but unlike the United States Department of Defense who initiated many new trajectories. MITI assisted Japanese companies to move rapidly along rather well defined trajectories. Japan has recognised, however, that to continue to maintain international competitiveness it will need to faster the initiation of new trajectories by undertaking research and development for itself.

Technology and National Development

Throughout the world there is a common realisation of the importance of technology for national development. It can be observed that developing countries of the present world are in fact " technologically less developed", even though same of these countries may be highly advanced in terms of arts or culture and may possess enormous amounts of naturally available resources. It now appears that technological advancement is emerging as a major criterion for measuring the level of overall national development 11 In addition the worldwide competition for technological advancement is showing an increasing trend towards deliberate specialisation. In most countries today, proper management of technology as a strategic variable for improving the quality of life and economic performance is considered most important. It is also known that useful technology is not given away free. The best deal for technology transfer is almost always obtained when there is a "mutuality of interest" for the exchange of technologies.

In many countries, no visible efforts are made for the formulation and implementation of technology policies and plans as the infrastructural mechanisms are yet to be established. It is not sufficient just to increase investment in research and development and hope that successful innovation will occur. Concentration on research alone will not produce the industrial infrastructure necessary to achieve technological innovation. If technological development is to be successful a systematic approach is essential.

The first process is to assess the national technological capability. Figure 20 shows the essential resources which contribute to the technological capabilities of a nation. There are four categories namely, trained people, current technology based products, organisations involved in research and development and natural resources.

Figure 21 indicates the first part of the process, namely the evaluation of national technological capabilities. The second part of the development of a programme for the national application of technology for economic growth is the relationship of the capabilities To national socio-economic objectives and in turn to industrial development objectives This is shown in Figure 22.

Finally the objectives and the capabilities need to be brought together to determine national needs as shown in figure 23. Both technological areas of high potential and strategic importance should be identified. As discussed above the trajectories for technological transformation of industry need to be identified. At this point the critical technologies needed are identified and at file same time policy support measures should be investigated. It should be noted that not all technologies will be available locally and nor should they be. Rational "make or buy" decisions should be made with regards to the specific technologies far development. Both Japan and West Germany who have developed their economies around technology based industries are net importer; of technology. Developing countries are more likely to be net importers as shown in figure 24.

Once technological needs nave been established it is important to develop a feedback process to cycle through the range of options available to ensure that the targets set are attainable given the financial resources available. More details are given in reference [12].

Finance Research And Development

Government Funding

In most countries governments fund a substantial proportion of national R&D activity but the degree of selectivity varies considerably between nations.

In Japan the selectivity is probably the greatest in both the public and private sectors, which collaborate closely in major national projects such as amorphous semiconductors, Very Large Scale integration and fifth generation computers. Projects are selected following an opinion sampling exercise to obtain a consensus, in which MITI plays an important coordinating role. Resources are then focused into the selected technologies in both national laboratories and the R & D laboratories of major companies, and the projects are supported both through public and private funds. It should be noted that over 60% of MITI's funds come from industry.

In the United States there is an aversion to national planning and a programme to undertake this proposed by the Carter Administration was abandoned by the Regan Administration. In truth, however, the US Department of Defense and NASA have set a de-facto policy as discussed above. 4lso market dynamics have forced the administration to devote considerable resources to bailing out problem industries rather than supporting high-technology 1ndustries (apart from working through the aerospace and defence budgets).

Private Funding

In comparing the funding of industry in the United States and Japan it is clear that the United States funds development through venture capital. Although the size of the venture capital industry in the United States is small relative to the total investments it plays a critical part in new technology development. The venture capital industry is diverse and includes both public and private sources. The industry has steadily developed since the 1950's and has accumulated sufficient knowledge so that it is we'll able to asses would-be entrepreneurs. Market assessments are based largely on the new company's business plan and there is a great deal of accumulated experience available to entrepreneurs to assist them in formulating such a plan.

On the other hand in Japan banks are intimately involved in the financing of development of industry. They offer money for a very long-term effective loan period. Even shorter term loans are usually refinanced on the understanding that the capital will not be repaid at the end of the term of the loan, but will be refinanced at its maturity date at the then prevailing interest rate. Overall the annual repayment burden for Japan is only one per cent more for Japan than Britain despite a very much higher level of investment. This availability of long term bank loans has allowed Japan to fund major programmes of industrial restructuring, including R & D and hence enjoy a high growth in its economy for the past thirty years or so.

Similar patterns can be identified in other countries and for countries undergoing industrial renewal via a technological catching up process, a financial system characterised by private and public banking institutions working in close collaboration with industry, adopting a long term view to industrial financing, and in which investment efficiency is enhanced through channelling funds, in a coordinated manner, into specific areas of technology and industry is the most appropriate funding mechanism. In the case of newly emerging and rapidly changing technologies, where both the structure of industry and its markets are in a fluid stage of development, the most appropriate form of finance is a venture capital system characterised by diversity and a propensity for risk taking.

Elements of Innovation

It is clear from the recent studies of technology and its effects on the economy that innovation and technology for innovation are key factors in economic growth. If we are to believe the cyclic theories of major re-industrialisation then the stage is set for a major phase of innovation and re-industrialisation probably based on information technology and modern digital communications. Those nations which position themselves lo, the change will benefit from economic developments just as Britain did during the industrial revolution and the United States did in the 1940's and 1950's.

It is clear that most developing countries and almost all of our near neighbours are developing programmes to apply technology towards internationally competitive economic development. New Zealand should recognise these trends and take steps to position itself to take advantage of the growing standards of living in the Asian region and the increasing application of technology for economic development.

The essential elements of innovation are shown in figure 25. Taking each element in turn we can see that New Zealand has a number of advantages Which it could exploit to change the current pattern of a stagnating economy and return to its position as a nation with a nigh degree of export trading supporting economic growth.

New Zealand is a creative nation and has shown itself, if not always the leader in totally new ideas, capable of adapting new technology to meet its needs. From the early days of refrigeration through to today's application of information technology to finance, printing and publication and the rapidly increasing growth of modern communications, New Zealand has shown that it is adaptable to change and is not restricted by cultural or religious impediments for the introduction and the application of new technology. New Zealand's record in creativity is good even though many New Zealanders have had to leave New Zealand to demonstrate their talents.

New Zealand's education system has been one of its strength in the past. There are signs that it may be losing its ability to continue to maintain its international position in technical subjects in particular. Education sets the base from which production and economic growth develops. Today most young New Zealanders look at the potential career opportunities in science and technology and see that there is little recognition of the importance of engineers and scientists to industrial development.

There is little doubt that if you want to succeed in business you will need to take a management degree, preferably with an accountancy or economics emphasis. Just study the qualifications of most directors of New Zealand companies and you will see why a science qualification is unlikely to attract high flying business oriented candidates. It is hardly surprising that our economic performance is se poor. The recognition of accountant's place as "on tap" and not "or top" is long overdue.

The problem is also exacerbated by our scientist and engineers in that they have been educated to see research or development as the prime goal and this should not be polluted by the grubby aspects of money making. This must change also.

We have had a good education system and we must ensure that we bring it back into the position where it can play its role m training our future innovators. Those nations or sections of the community that have recognised the value of education for improving both the nations economic performance and the individual's standard of living have almost always been successful when they have clearly targeted their objectives.

One advantage of the current charges in economic thinking is the freeing up of access to international sources of capital. One of the key factors which limits industries ability to enter economies of scale sectors is the availability of capital for development. There are signs that finance is available from private sources for innovative development and in sufficient amounts to enable new innovative internationally competitive industries to be established.

A disturbing feature has been the almost total dismantling of all forms of government support for technological development. It can be debated that many of the forms of government support were ineffective because they were inefficient, untargeted and overly bureaucratic. The need for government policy support measures has come out clearly in all of the studies of technology driven industrial transformations undertaken in the last decade, the debate should not be about the need for government support policies but should be concerned with establishing the most efficient and most effective support measures based on selected trajectories for technology diffusion into industry.

It is important to realise that government driven technology policies are unlikely to be successful. Government, industry, financiers and academia must all cooperate to develop of coordinated programme for the acquisition of the appropriate technologies for future development, be it by of overseas developed technology or by the invention or adaptation of technology in local research and development facilities.

Even where technology is being imported, the need for a high level of local expertise is paramount. Developing countries are littered with examples of technology forced upon them or uncritically accepted without the development of local infrastructure to make the technology effective. Research and development remains one of the most important elements in the effective use of technology to develop internationally competitive industries. It is important that the level of research and development is maintained and that a balance between pure applied and development research is attained. It must be remembered that the bulk of social returns from research and development result from the embodiment of the new technology in new products and/or services which create new jobs. The research and development process produces very small returns unless the process results in commercially successful innovation, in which case the returns can be large. For research and development to be productive it is not enough to produce an invention or an innovation that is a technical success, it must be a commercial success as well.

The studies in the last decade of economic development have shown that simple technology push or market pull models for technological economic development are inadequate for the development of technology policies. Decisions relating to the commercialisation of new technology are in fart pivotal for the future success of individual firms as well as the future economic condition of the country as a whole. Unfortunately many of our current senior managers and economists have learnt their economic theory before the studies of the importance of technology to economic development had achieved any significant degree of understanding of the technology diffusion processes. This is not to say that the theory is in a position to give clear and unequivocal directions to assist managers in their decision making processes. Much additional work is needed to fully realise the potential of the application of the current models. There is little doubt, however, that we have no alternative to pursue the opportunities presented by the new technologies with energy and enthusiasm and with a real sense of commitment. The opportunities for the development of efficient internationally competitive exporting industries based on the new technologies particularly to service the Asian and Middle Eastern markets are there. It will be a challenge to lift our economic thinking from, inward looking and focussing on the past, towards the recognition that the future lies in the successful capture of the new opportunities which are being created by technological developments.

The challenge to work together will take all our energy and should be the focal point for the actions which need to be taken if we are to realise our potential for technological advancement. I wonder if we can meet the challenge. We must not wait for government to lewd us out of the forest, We must take up the challenge ourselves and provide the direction and momentum a; we in electronics represent one of the leading technology sectors providing the key developments for future technological re-industrialisation,

Where are we? We a e at the cross roads again for our economic development just as we were when we took up the challenge of modern transport coupled with refrigeration in the economic development phase of the 1880's. We have shown that we can respond to challenges in the past but then we were able to call upon Britain to give us guidance. We are much more on our own and the future will depend on our ability to be innovative, forward thinking and economically and managerially competent to adept and adapt the new technologies to achieve economic growth. The alternatives are stagnation or a steady slide backwards towards the status of an underdeveloped country. Let us make sure that New Zealand is not seen as occupying the same position in world economies as the Chatham Island occupies in Treasury's model of the New Zealand economy.

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Figure I

Objectives of Technology Developments

Science for Science’s sake
National Prestige
Development of Efficient Technology
Political Distribution

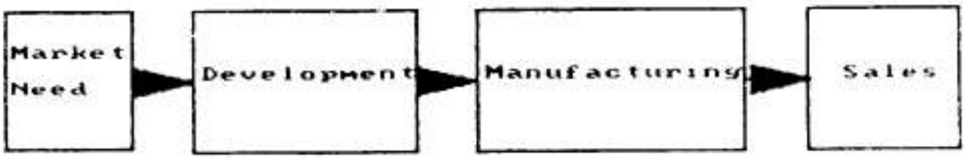

Figure 2 Demand Pull Theory
of Technological Innovation

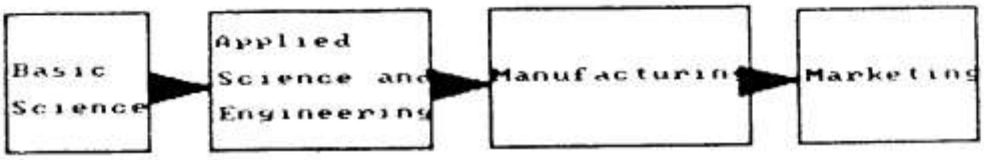

Figure 3 Technology Push Theory
of Technological Innovation

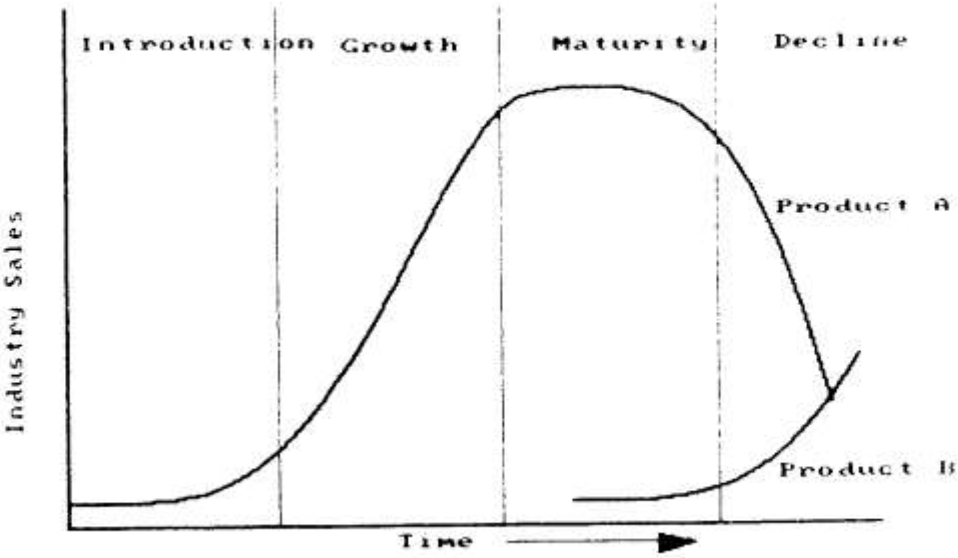

Figure 4
The Product Life Cycle - Four Phase Model

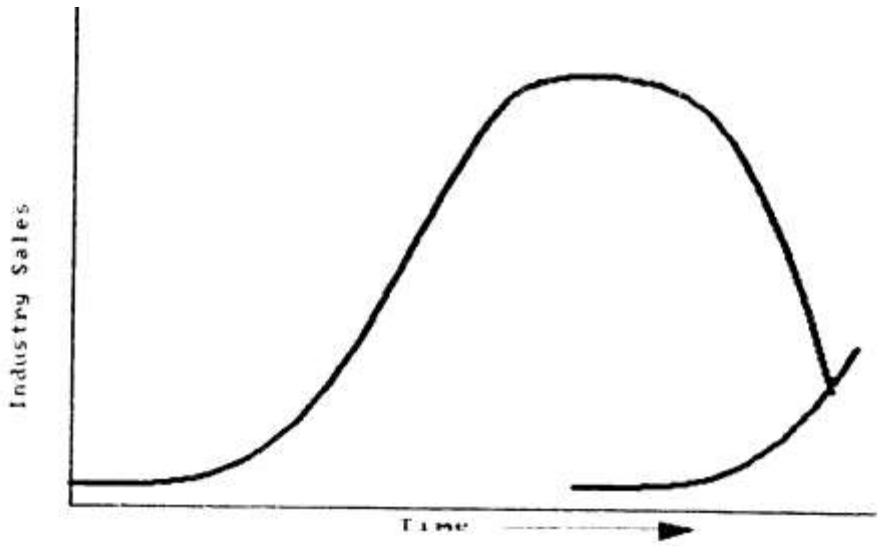

Figure 5 Substitution

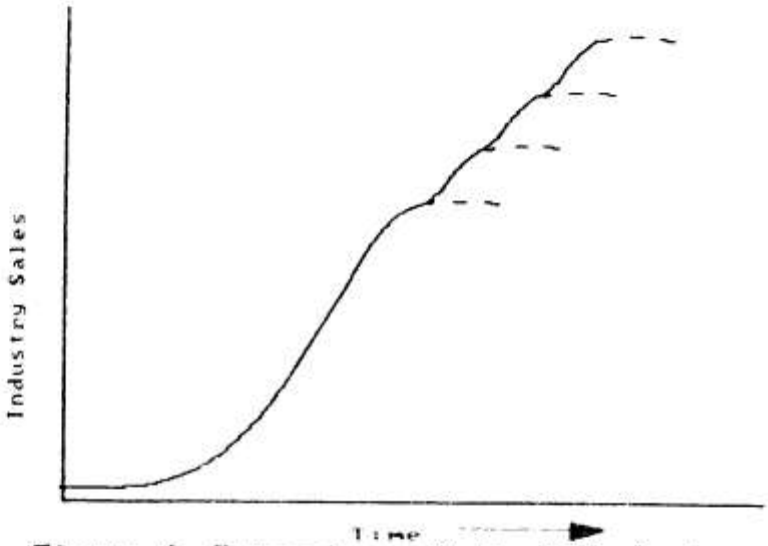

Figure 6 Extensions of the Life Cycle

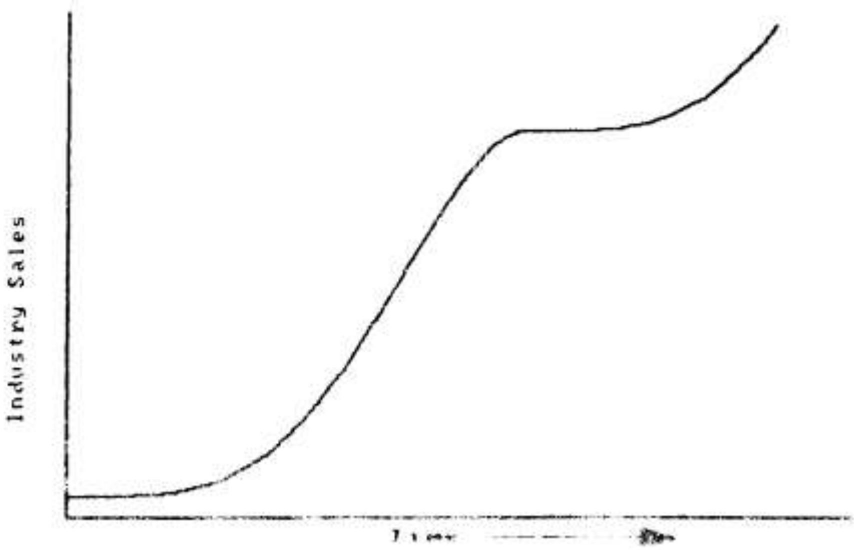

Figure 7 Change of Technology

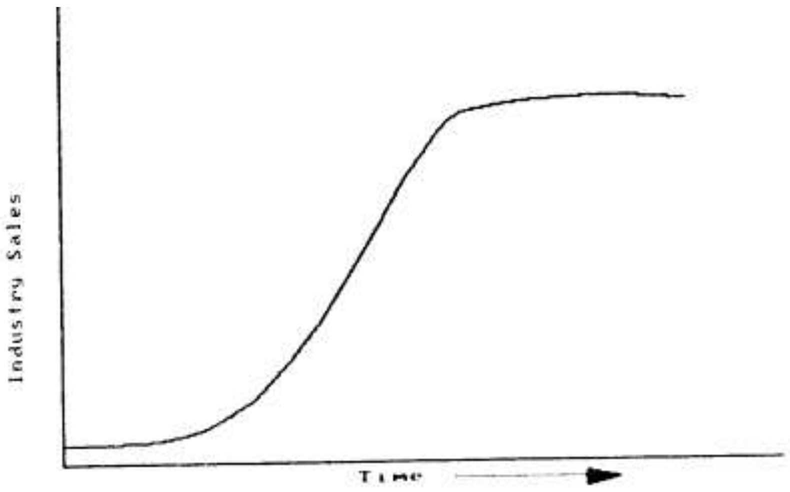

Figure 8 Extended Maturity Phase

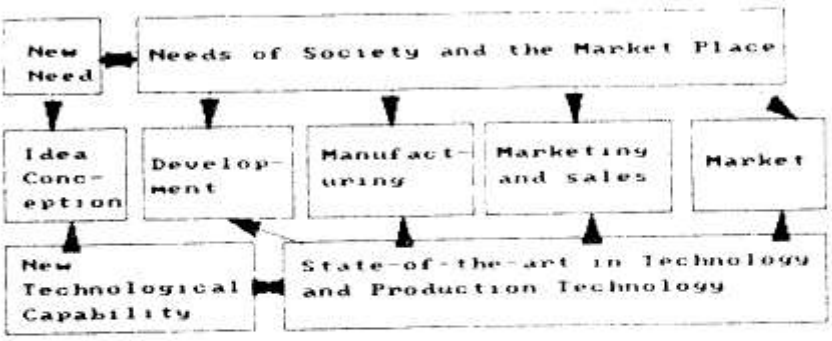

Figure 9 Interactive Model of Technological Innovation

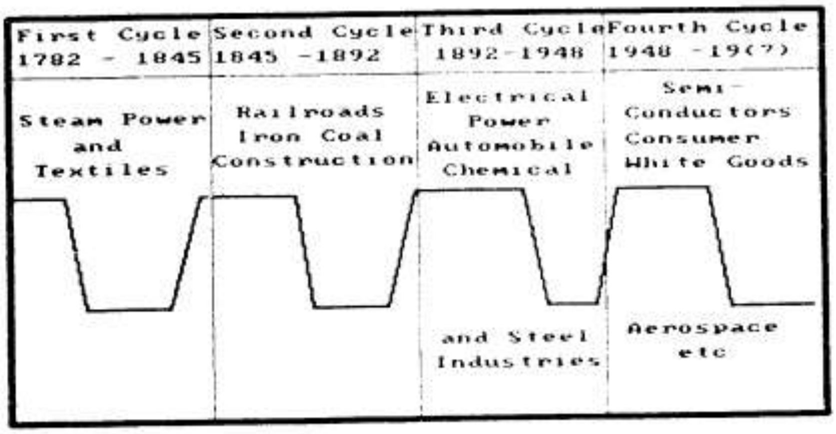

Figure 10
A Simplified Schematic of the Kondratiev Waves

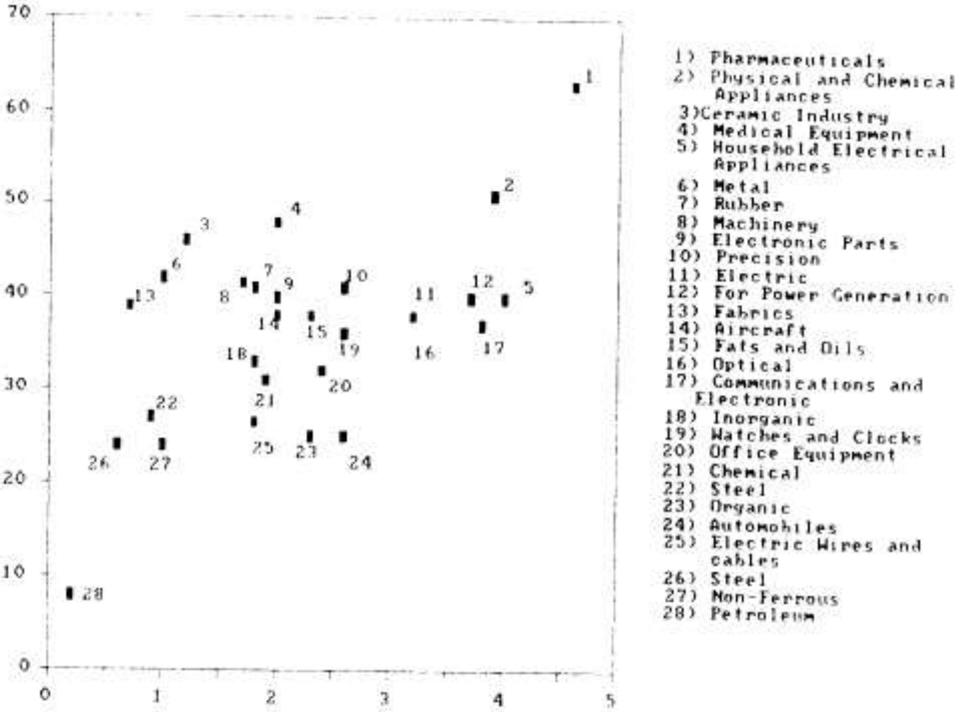

Figure 11 Ratio of R & D Investments to Sales

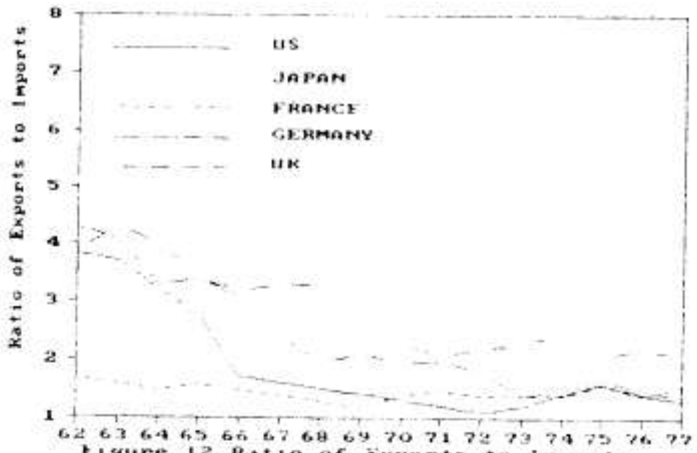

Figure 12 Ratio of Exports to Imports
For Technology Intensive Goods

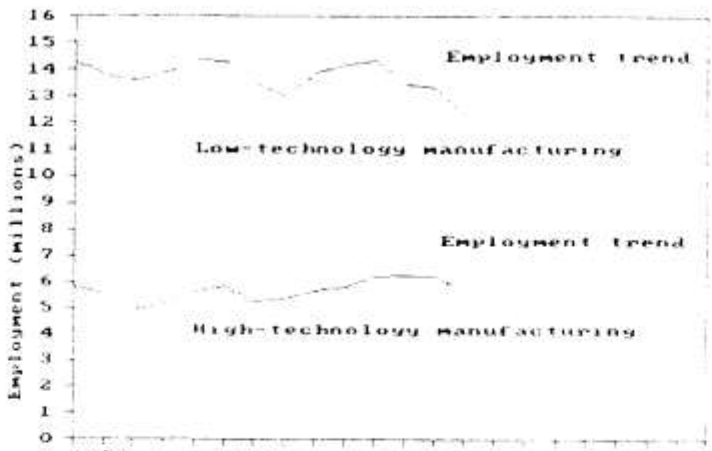

Figure 13 Employment in High- and Low-technology Manufacture

DEVELOPMENT TIME PERIOD	MINIMUM FEATURE SIZE: LINE AND SPACE	SCALE FACTOR TO MAGNIFY TO 1 CM	PAPER SIZE TO LAYOUT 250 MIL CHIP
LATE 60'S	17.5 um	340	(2m) WALL HANGING
EARLY 70'S	8 um	800	(5m) LARGE LIVING ROOM FLOOR
LATE 70'S	2 um	3150	(20m) TWO TENNIS COURTS
VHSIC I	1.2 um	5000	(30m) TWO BASKETBALL COURTS
VHSIC II	0.5 um	12300	(80m) TWO FOOTBALL FIELDS

Figure 14 The IC Design Problem

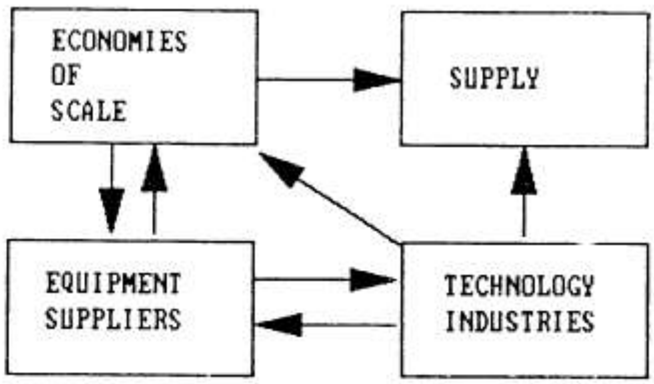

Figure 15 Industry Categorisation

- Market
- Internal Communication
- Internal Management
- Technical Factors
- Top Management Style
- Economic Resources
- Key Individuals

Figure 16 Success Factors in Innovation

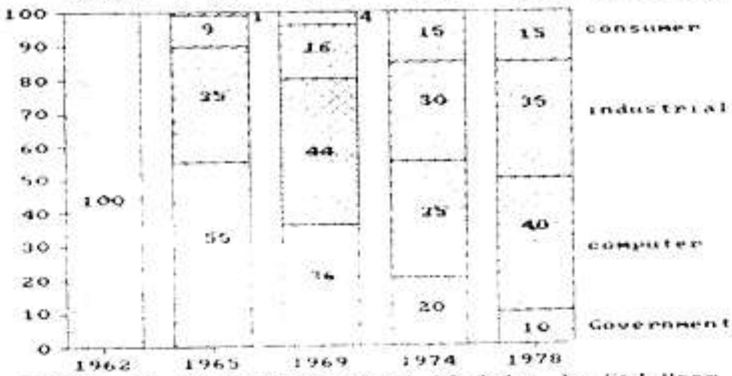

Figure 17 Percentage of US IC Sales by End User

1987

	Defence	Other	Total
Aero-astronautic engineers	40.62	46.54	87.16
Chemical engineers	3.79	52.16	55.96
Civil engineers	15.48	166.39	181.87
Electrical engineers	61.19	298.56	359.75
Mechanical engineers	39.17	188.14	227.31
Metallurgical engineers	3.48	16.63	20.10
Engineers (other)	53.28	406.42	459.70
Atmospheric and space scientists	1.04	11.90	12.94
Biological scientists	1.52	68.88	70.40
Chemists	8.84	130.10	138.94
Geologists	1.30	37.18	38.48
Marine scientists	0.60	5.14	5.75
Physicists and astronomers	7.57	18.75	26.32
Life and physical scientists (other)	1.48	5.50	6.98
Mathematicians	3.41	7.30	10.71
Statisticians and actuaries	2.24	37.84	40.08
Computer specialists	71.29	475.75	547.04
TOTAL	316.30	1973.18	2289.49

Figure 18 Employment (thousands) Resulting from Defense

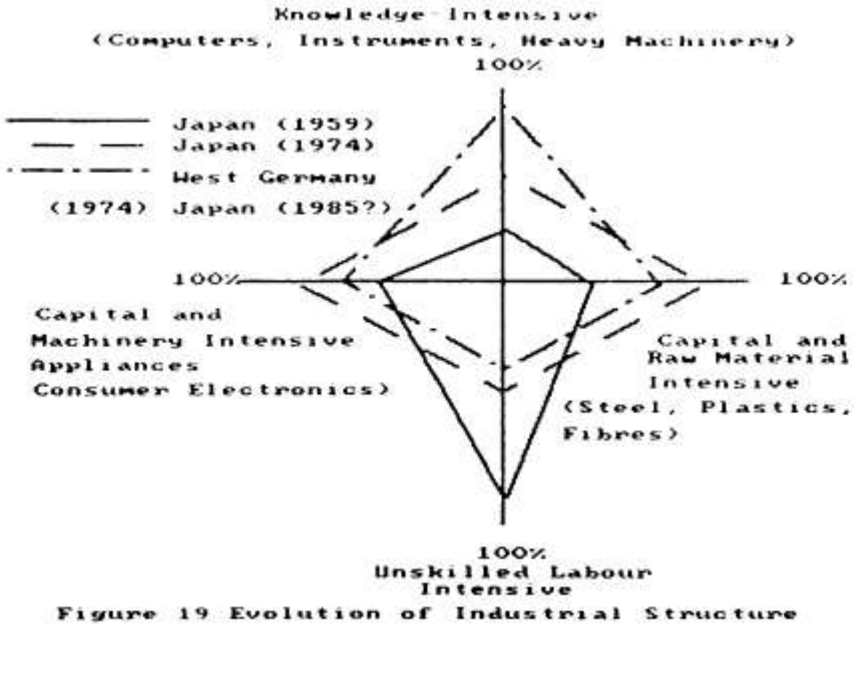

Figure 19 Evolution of Industrial Structure

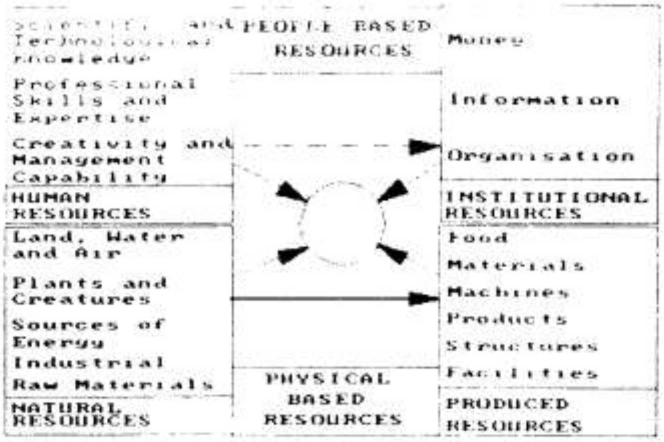

Figure 20 Resources for Technical Development

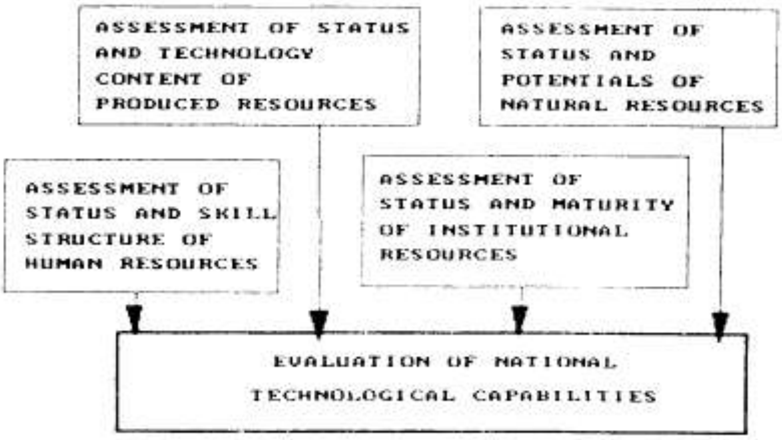

Figure 21 National Technology Assessment Model Part One

Figure 22 National Technology Assessment Model Part Two

Figure 25

Success Factors in Innovation

Market
Internal Communication
Internal Management
Technical Factors
Management Style
Economic Resources
Key Individuals