THE ROLE OF RESEARCH AND DEVELOPMENT IN NEW ZEALAND'S INDUSTRIAL GROWTH

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ABSTRACT

The conceptual background to this thesis involves an examination of the interrelationships between technological change, innovation and research and development, and the impact that they can have upon national economic growth and development. Research and development investigations can be translated into product and process innovations and these can cause short and long term structural changes. Such impacts are differentiated temporally and spatially because of the selectivity of the innovation diffusion-adoption process.

These relationships can be examined in a more concentrated way by looking at the role of research and development upon New Zealand's industrial growth. Research and development has already contributed significantly to agriculture and, if manufacturing industry is to become a major component of New Zealand's growth, the potential implicit in the greater application of industrial research and development must be considered. The analysis of research and development involved looking at two groups of organisations; individual manufacturing firms and research associations. It was hypothesised that manufacturing firms in New Zealand are essentially concerned with adopting and adapting overseas technology, and that research associations are primarily concerned with improving the efficiency of their industry.

Research and development in manufacturing firms was firstly examined generally, with a look at staffing and expenditure figures and the variation in programme emphasis

among firms. The sectoral perspective of research and development activity looks at interindustry variations and the influence of firm size upon the type of work undertaken. A four-fold classification of firm organisation was proposed and it is possible to see how the programme emphasis and the criteria for project selection and research and development expenditure varies accordingly. The linkage impacts generated by research and development are also examined. Examples of growth impacts generated by technological and capital goods linkages and the phenomenon of spin-off firms are also discussed. At all times the spatial dimension of these processes is presented so that some idea of the diffusion of the impacts associated with research and development can be gained.

The analysis of research and development activity in the research associations proceeded in a similar manner. The particular emphases of the research and development programme were examined, along with the sources of project ideas and the criteria considered in their selection. Any locational and linkage impacts that may be generated were also examined. Emphasis was given to the nature of the interaction that occurs between member firms and the research associations, and to the accountability that the associations have to the industry they serve. Once again the spatial dimensions of the processes examined have been presented.

In conclusion, it was determined that the industrial research and development activity carried out in individual manufacturing firms and in the research associations does make a positive contribution to New Zealand's industrial growth. Product ranges can be diversified, production techniques can become more efficient, new firms may be created and general industrial growth ensues. Research and development, as part of the more general phenomenon of technological change, can certainly contribute to New Zealand's industrial and economic growth and development.

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Chapter One :

TECHNOLOGICAL CHANGE, INNOVATION AND REGIONAL DEVELOPMENT

Technology, and the nature and rate of its change, is accepted as a significant factor influencing national and international welfare and economic progress. The concept of technology is central to this thesis because of its critical interrelationships with the processes of innovation and of research and development. A typical dictionary definition describes technology as 'the science of the industrial arts'. Other interpretations, such as that of Galbraith (1967), suggest a practical emphasis. Galbraith sees technology as 'the systematic application of scientific or other organised knowledge to practical tasks'. (Galbraith, 1967, 13). This definition is useful for it points to a distinction between science and technology. Science represents the objective body of knowledge which has been accumulated and organised by systematic study and, as such, is concerned with understanding. Technology is concerned with practicalities and utility, and can be therefore regarded as the embodiment of science in a set of techniques.

This interpretation can be extended further to relate technology more closely to production. Technology can be seen as delimiting the spectrum of available techniques that define the various combinations of inputs which will yield any given output. Thus technology is included, along with labour and capital, as a component of the production function. This gives some indication of the multidimensional nature of technology and the impacts that any changes in its state may have. Technological change can cause positive or negative fluctuations in production output and general economic growth as a result of its influence upon demand patterns and/or productivity levels.

Technology is never constant because of its direct dependence upon the state of knowledge. As knowledge is extended, the potential for new technological developments is enhanced and, from these, short or long term economic growth forces may ensue. The growth of technological knowledge is essentially an increase in knowledge about useful goods and how to produce them. This increase will be in one of two forms: either what was known before becomes more widely known or knowledge never known before is provided.

This suggests a basic dichotomy about the nature of technological change. Change may be 'evolutionary', consisting of gradual improvements over time, or it may be 'genuinely innovative', creating quite unexpected and unanticipated opportunities. The first type of change allows the production of the same good at a lower cost, or more of the same good at the same cost. This means that technological change might result in improved cost efficiencies and profitability levels, at least in the short run. The second type of change may result in the introduction of a hitherto unknown product, possible culminating in the establishment of a new singleproduct industry. In this case, technological change has altered the industrial composition of the economy concerned and caused major structural changes.

This distinction in the intensity of technological impact is an important one. In the short run technological change may induce a 'round-of-growth' as a result of changes in cost efficiencies similar to those proposed by growth pole theorists. In the long run technological change is responsible for deeper structural changes within the economy. (Kuznets, 1966; Thomas, 1969, 1972, 1976). In both instances productivity levels have been altered in a positive direction. From this it can be seen that technological change has important ramifications for the competitive position of economic activities of all scales, ranging from an individual plant to the national economy.

It must be recognised, however, that the impacts of technological change relating to, say, the firm's competitive position need not necessarily be beneficial. Burns (1934) acknowledged this when he suggested that technical progress is 'Janus-faced'. Technical progress, or technological change, causes changes in relative competitive strengths and increases the possibilities for industrial growth. Such improvements in a given firm may tend to stimulate development. However, improvement in a competing firm will have the effect of checking the development of the original organisation. Burns contends therefore that the progressiveness of general industry has caused retardation in the growth of particular industries. It is important to realise that technological change may have such second-phase consequences. (Bauer, 1969; Bright, 1968).

Technology is an important variable in the process of economic growth and development. (Solow, 1957). Internationally there are two different attitudes to technology, depending on the particular country's level of development.

In so-called 'developed' countries technology is designed to be labour-saving, as labour represents a major factor in the cost structure of any economic activity. By contrast, the emphasis in 'developing' countries is on other attributes of technology. Labour is a comparatively free resource. Any technological changes introduced are required to be conservative of such production factors as capital and entrepreneurial skills. These differences in technology requirements are reflective of an international technological gap, and they also show the need for careful integration of the general characteristics of technological change into the peculiar local environments.

The process by which technological change effects structural changes and thereby alters industrial growth has been outlined. This type of process represents the way in which technology can affect economic growth and development at both national and subnational levels. Once again technological gaps, differences between actual and potential production capacity, are present. The more rapid and the more efficient the process of technological transfer, the greater will be the benefit that might accrue to the adopter of the new technology. This idea can be more readily appreciated by examining the related concepts of innovation and innovation diffusion.

INNOVATION AND INNOVATION DIFFUSION

Innovation represents the process by which new products and new techniques are introduced into the economic system. It is the application of an invention, where invention is defined as a new combination of available knowledge designed for practical use in production. The two significant features of an invention therefore are its novelty and its potential utility. The relationship exists such that an invention causes, or is caused by an advance in the state of technology and, on application in a technical and economic environment, the invention is transmuted into an innovation. The advance in technology can be either a result of evolutionary improvements in production techniques, perhaps within an individual firm, or it can be due to the creation of new knowledge. It is as a part of these causes that research and development can be integrated into the overall framework of technological change and innovation.

Innovations are of three basic types. They may involve a technological change in the form of a new product or a new process, or they may involve an organisational change, perhaps in the form of new management practices within a particular economic entity. Product and process innovations are by nature capital embodied forms of technological change. They require capital investment before they can have an impact economically. A new product innovation may in the long run stimulate the development of a single-product industry, while a process innovation may influence a number of technologically linked industries. Rosenberg (1963) has examined this type of phenomenon in the capital goods industry of the nineteenth century. Process innovations in this industry led to related technological responses in the form of product, process and organisational changes in a number of industries. This is conducive to a process of technological convergence.

Organisational innovations are a disembodied form of technological change. They represent alterations in the organisational structure or management practices of the firm or industry and, even though they do not necessarily require capital investment, serve as an important means of enhancing the efficiency of production and permitting further productivity gains. Innovations, therefore, represent new contributions to existing products and processes bring about productivity gains, and may even be expressed in the creation of completely new industries, thereby creating important structural changes within the economy at large.

Any impact that an innovation may have is directly determined by its rate of diffusion and adoption. Innovations need to be accepted into production systems for them to realise any actual benefits. An innovation has a number of characteristics which influence the ease of its adoption. (Rogers, 1962). Firstly, the relative advantage of the innovation over the present product or technique must be established. Secondly, compatibility of the innovation with existing values and the previous experiences of the adopters can influence the speed of adoption. The complexity and the divisibility of the innovation are two further considerations. Divisibility may be interpreted as the degree to which an innovation can be tested on a limited basis. If the innovation requires large scale capital investment before the relative advantages can be appreciated, this is likely to inhibit the rate of adoption. Finally, the communicability of the innovation can be important. In 'developing' countries, for example, the visibility of results, perhaps of new high-yielding rice varieties, can be a significant factor in determining the adoption rate of the innovation.

Apart from the characteristics of the innovation itself, the external economic and social environments are also relevant. The state of the overall economy may effect adoption rates. If an industry is operating at full capacity during a boom period there may be little incentive for management to make introductions.. If a trough situation is prevalent, however, pressure to innovate may be strong. (Mansfield, 1968 b). The market structure of the firm or industry involved is also important. It is generally accepted that there is a threshold effect implicit in the diffusion process, whereby organisations below a certain size will find it uneconomic to become adopters. Similarly, social variables, such as the educational level of the people and their attitudes to change, also exercise some influence upon the rate of innovation diffusion.

The diffusion process varies both temporally and spatially. Temporally, an innovation is initially adopted by only a few. With improved information accessibility the numbers will increase until a saturation point is reached. Eventually the users of the innovation will decrease. This is due either to diminishing returns from the innovation, perhaps as a result of cost increases in one or a number of its inputs, or to diminishing utility, a response perhaps to changes in demand.

The spatial component of the diffusion process is dependent upon the particular type of innovation. Pedersen (1970) categorises innovations as household or entrepreneurial. Household innovations, such as consumer durable goods, spread among private households and might be accepted equally by all groups of the population. They tend to diffuse in a wavelike, spreading motion across space. Diffusion occurs from one point to the next with distance and relative location being the critical variables.

Entrepreneurial innovations differ from household innovations in three basic ways:

1) Entrepreneurial innovations usually involve a higher risk, economically, socially and politically.

2) The adoption of an entrepreneurial innovation is competive and subject to a threshold effect in terms of town size.

3) Entrepreneurial innovations are often only adopted once and diffuse from town to town in a discontinuous fashion.

According to evidence presented by Pedersen entrepreneurial innovations tend to diffuse in a pattern similar to the structure of the urban hierarchy. It is suggested that the largest urban centres tend to be exposed to the innovation first because they have 'the highest exchange of ideas, people, and products with other cities in the country and with cities in other countries' (Pedersen, 1970, 207). Progressively the entrepreneurial innovation is transmitted from these largest centres and channelled through the urban hierarchy until it reaches a threshold level. (Berry, 1972).

Such an hierarchical diffusion pattern does not appear to be as applicable when considering product and process innovations in the manufacturing sector. Diffusion of a manufacturing product or process will almost certainly be concentrated in the urban areas because, apart from some primary processing activities, this is where the majority of manufacturing enterprises are located. But diffusion does not necessarily occur down the urban hierarchy. Instead the pattern is more closely tied to other variables such as industrial distribution and organisational structure. (Thomas and Le Heron, 1975). If a process is developed and is applicable to only a narrow range of industries, then the extent of its diffusion will be limited and will probably take place independent of the urban hierarchy. Similarly, a new product may be developed in a branch plant located in a secondary urban centre. This product will diffuse through the other divisions of the firm's organisation, located probably in both secondary and metropolitan centres. Further, adoption or adaption of the product may occur among competitors and further diffusion waves will be set in motion. Thus, the patterns outlined for household and entrepreneurial innovations do not appear to be relevant, for the diffusion of manufacturing products and processes is better related to industrial and organisational structure. Developments of new products and processes within the manufacturing sector leads to a consideration of research and development activity.

RESEARCH AND DEVELOPMENT

Research and development is an activity designed to ascertain the feasibility of prospective innovations and thereby to plan the adoption of new technology. It covers a broad spectrum of activity that can be subdivided into three distinct, although not definitive, categories. Research, the process of adding to total, or advancing the limits of, scientific knowledge, can be either basic or applied. Basic research refers to those projects which are original investigations for the advancement of scientific knowledge and which do not have any commercial objectives. Their technical and commercial outcome is quite unpredictable and any investment will be repaid only in the long term. Basic research cannot be readily integrated into the goals of an individual firm because of the high degree of uncertainty involved. There is therefore little incentive for the firm to engage in this type of activity as no immediate competitive advantages can be gained.

Applied research projects are those investigations, for either products or processes, having specific commercial objectives in mind. It is in this area that much of the firm's competitive strength lies. The quicker the technical and commercial feasibility of the new product or process is established, the sooner the firm can introduce such an innovation into its production system. This will give it a 'lead time' advantage over other firms, during which it may be in a temporary monopoly position. This ability to take advantage of the lead time factor is related to the differential scientific or innovative receptivity of various firms and industries. An innovation may not be as readily applicable to the production environment of one firm as it is to another.

Applied research selects those projects which have the greatest perceived potential and it is development, a more carefully directed and supervised process, which translates this potential into economic reality. The development process is important in bridging the gap between the technical side of the innovation and the management of its adoption. Irrespective of the inherent potential of an innovation, its commercial introduction must be carefully timed and managed. This 'coupling' process between the technical and marketing divisions of an organisation is critical. (Ansoff and Stewart, 1967).

Any research and development activity must eventually be integrated into the overall goals of the organisation. Accountability for the expenditure of finance on research and development is necessary and the general economic welfare of the organisation must always be considered. Research and development, therefore, is an activity that provides opportunities for investment in different products and processes that have evolved from changes in technology. Once the research and development phase has been translated into an innovation then, through its sectoral and spatial diffusion, potential for growth is created.

INNOVATION AND INDUSTRIAL STRUCTURE

Now that the interrelationships between technology, innovation and research and development have been examined, it is necessary to integrate the three concepts into a spatio-temporal framework. Technology, and hence technological change, is a universal phenomenon which is apparent in varying degrees depending on the prevailing social, economic and political environments. For any given country the present state of technology, a factor critically influencing its level of development, is a combination of that which has been produced internally and that which has been introduced from overseas. External forms of technology can either be adopted per se or adapted in some manner to facilitate better compatibility with the local environment. Innovation is the key factor in this process of development because it represents the embodiment, either with or without the expenditure of physical capital, of technological change and/or research and development. Thus, a more explicit examination of the role of innovation in the development process, at both national and regional levels, is important for the conceptual background of this thesis.

Perhaps the first writer to assign innovation a positive role in the process of development was Schumpeter. (Ruttan, 1971). His ideas formed the basis for Perroux's work and, hence, for the theories of growth pole literature. Perroux claims that economic development resulted from the adoption of innovations. (Perroux, 1971). An innovation in one dominant industry can be followed by innovations in several subsidiary lines. Such a group of related innovations can be manifested in the clustering of industrial organisations within geographic space, which means that spatial or regional imbalances are created. This type of process implies that there are interrelationships between the process of technological change, including any subsequent economic growth impacts, and the geographical use of space. Because the innovations resulting from technological change are not diffused uniformally, either over space or time, geographical space will be differentiated in accordance with the selectivity of the diffusion - adoption processes. It is in this way that innovations are seen to create or cause regional imbalances within the national growth and development process.

It is suggested that innovations have caused industries to cluster in geographical space. The presence of these so-called 'sectoral clusters' is the result of a preceding innovational cluster. Innovations, it has been established, are discontinuous in nature. If, in terms of Perroux's ideas, an innovation in a major industry or firm caused subsequent minor innovations within related establishments, a group of industrial units could quite feasibly cluster at the same locational point. This is because production complementarities and indivisibilities will soon develop between the various establishments. Thus sectoral clusters are seen to have been preceded by innovational clusters. As the rate of technological change is accelerating, it is possible that future innovations will occur in faster and tighter clusters, meaning that the spatial landscape will become increasingly differentiated. (Lasuen, 1973).

The organisational component of industrial structure has also been subject to the impact of innovations. Organisational innovations, which are disembodied forms of technological change, may include features such as new structural relationships within firms, new operating processes, and new planning and policymaking procedures. Technological changes in communication and transport techniques have resulted in the greater integration of business units at all levels of economic activity, regionally, nationally, and internationally. The increase in complexity of corporate company structure reflects this reorganisation that is taking place in the business world. Small regional companies are amalgamating with others, thereby broadening their range of activities. National companies may become multiplant operations, with the administrative functions tending to be concentrated in the largest centres and the manufacturing operations dispersed among the secondary centres. Further, the multinational corporation will have its headquarters in a large international centre, while ~~their~~ its various subsidiaries are operating with differing degrees of autonomy among the secondary centres of the world. Communication and transport innovations are occurring at a faster rate and, with the closer integration of organisations throughout the world, their rate of diffusion and adoption is also accelerating. This suggests that the multinational corporation and its subsidiaries might, at least in the future, play an increasingly significant role in determining the industrial structure of 'technologically-adaptive' countries such as New Zealand (Deane, 1970).

Research and development activity is increasingly becoming an integral part of corporate activity. Product ranges are continually being extended and diversified and production processes are becoming more efficient. The need for these corporations to remain competitive means that they must keep abreast of the latest technological advances. However it is still not easy to anticipate exactly what impacts such changes in organisational structure will have. In the words of Tornqvist (1970, 129-130):

> The organisation of today lives in an environment which is changing very rapidly and which promises to become increasingly complex. As the different parts of the economy and of society become more and more interwoven it is extremely difficult to predict the exact effect of technological progress.

From this discussion it is suggested that the two basic effects of innovation upon industrial structure have been in the development of sectoral clusters and in the changes in organisational patterns typically associated with the industrial scene. Because the activities involved in industrial processes are primarily urban phenomena, it is now possible to outline the way in which innovation diffusion and adoption have influenced the process of development and the system of cities that evolves in any one country.

ECONOMIC DEVELOPMENT AND URBANISATION

While technological change is a continuous phenomenon, innovation is not. It is discontinuous and tends to occur in clusters. An innovation in one situation may cause 'spin-off' or demand responses which can accumulate in a number of second order, subsidiary innovations. These clusters of innovations occur both in space and over time, and it has been suggested that development and urbanisation patterns represent the spatial and temporal traces of the process of innovation adoption (Lasuen, 1973). The process of development, like that of technological change, is continuous and international, and the extent of development can be related to the rate of innovation adoption. A 'developed' country has a fast rate of innovation adoption, while lesser developed countries find adoption a much slower and more difficult process because of constraints that exist in their social, economic and political systems. Over time the level of development of any country is closely related to their ability to integrate innovations into their individual environment and to adapt quickly to the accelerating rate of technological change. For a country such as New Zealand, where indigenous sources of innovation appear to be comparatively minor, a clear understanding of the international process of innovation generation and diffusion is vital.

By contrast the urbanisation process is a national one and its pattern varies according to a number of factors, such as history, size and characteristics of the population, and the extent of government influence. Nevertheless the process of innovation diffusion-adoption has exerted some influence on the development of a country's urban system. The process of urbanisation began in response to a number of technological changes particularly within the agricultural system, until gradually a system of cities has evolved in each country, each city developing in response to a specialised function or some other initial advantage resulting from peculiar site-situation characteristics. (Pred, 1966). The city system has developed as part of the general process of technological change and, more specifically, each component of the system is differentiated from the others according to the selectivity of the innovation diffusion-adoption process. Hence, the relative position of an individual city within this urban hierarchy structure is a result of the extent of its participation in past innovational clusters. This relative position, plus the particular industrial composition, will also determine future participation. Once an urban system is established it conditions the acceptance of new innovations and the introduction or expansion of sectoral clusters. Hence the conclusion that 'technology's main impact has been to strengthen the preexisting hierarchical and functional order of the urban system'. (Lasuen, 1973, 176).

The geographical concentration of firms and industries has always been an obvious feature of the economic system. Sectoral clusters, developed in response to preceding innovational clusters, have caused the concentration of economic activity in spatially differentiated geographical clusters. These clusters have exhibited differential rates of growth, have different structural characteristics, and have eventually stabilised into the formation of an urban hierarchy or system of cities.

The pattern of city development will in the future probably be increasingly affected by the second type of change in industrial structure caused by innovation; that is, by the expansion of companies having a corporate structure. A significant locational characteristic of these corporate organisations is that they are, at least for their administrative functions, concentrated in the largest cities (Tornqvist, 1970; Pred, 1973, 1975). Such a multiplant, multiproduct corporation is part of the 'quaternary economy' and access to highly specialised services and their specialised information requirements restricts the diffusion of these administrative functions lower down the urban hierarchy. Such concentration means that the largest centres will be able to benefit from the new organisational innovation while the smaller, more peripheral centres are again at a disadvantage. These administrative functions depend upon the employment of 'contact-intensive' personnel, which can create important multiplier benefits for the larger centre, both in terms of income and employment (Tornqvist, 1970).

It must also be recognised that other rounds of multiplier impacts are also involved. These are associated with the manufacturing operations of the corporation which are not necessarily concentrated but tend to be dispersed among a number of regional centres. These activities provide employment and income multipliers for the regions concerned. Any expansion in the level of general activity, whether it originates from the headquarters or from a manufacturing plant, will promote growth in both types of centres. For example, a new product or process development that occurs in a branch plant will mean that non-local multipliers may also arise from the adoption and diffusion of this growth-inducing innovation by the other divisions of the organisation. Consequently, economic interdependencies between cities may be extended which helps to increase the integration of the overall space economy (Friedmann, 1966, 1973).

The structure of a geographical cluster, in terms of its industrial composition and its position in the urban hierarchy, obviously affects the degree of its involvement in the innovation process. Because innovations are being generated at an accelerating rate, and because the time lag between diffusion and adoption is being reduced, the process of growth and development is becoming increasingly differentiated. Growth appears to be occurring most rapidly in the largest centres where international contact levels are densest and the spatial biases associated with specialised information are favourable. (Pred, 1973, 1975). However, in the smaller centres lower down the urban hierarchy the rate of innovation adoption is thought to be slower and consequently the extent of development comparatively less.

An understanding of the regional imbalances implicit in the innovation process, and which develop from the differential receptivity of both industry and region, is critical if any attempts are made to alter the present patterns and processes of regional development in countries such as New Zealand.

REGIONAL DIMENSIONS OF INNOVATION

Such imbalances exist on two different levels within the national context. Unbalanced growth occurs in the interregional and intraregional systems. Both these differences have developed as a result of spatial and temporal variations in the innovation diffusion process. A region's ability to generate innovations and to adopt those introduced first elsewhere is dependent on its industrial and organisational structure. Manufacturing innovations diffuse according to the industrial orientation of firms, and follow the diverse patterns of intraorganisational and interorganisational communication channels. Some firms act as 'technological gatekeepers' (Allen, T.J. 1971) and participate actively in the innovation diffusion-adoption process, while others are content to assume a more passive role. (Carter and Williams, 1957).

The diffusion of the innovation can be constrained by threshold limits; after a particular city size is reached adoption of the innovation may be no longer feasible. Perhaps the size of the market is too small to offset the costs of introducing a new product or the scale of economic activity may not be large enough to justify the alteration of, say, a production process. Further constraints ~~to the~~

to the diffusion of an innovation can be expected. For example, there may be a lack of the entrepreneurial or technical expertise so vital for the introduction of an innovation. Bottlenecks may arise within the production or distribution systems. The extent of diffusion may also depend upon the origin of the innovation. Developments within a government sponsored research organisation tend to be more widely disseminated than those issuing from private companies. Such a range of factors reduces the ability of a region to accept external innovations and it is in this way that a region's industrial and organisational structure so critically affects its participation in the national development system.

Perhaps the greatest positive advantage that a region can have in relation to innovation adoption is the existence of agglomeration economies. (Richardson, 1973). These economies can enhance the rate of productivity and technical progress of an area, attract new industries and capital, and influence the migration decisions of individuals. They are an important element in regional growth because they explain the reasons for spatial concentration in certain regions and, further, in cities within those regions. Such economies affect the concentration both of people and of firms, which is of obvious importance in the innovation diffusion process.

Agglomeration economies for people attract those individuals more concerned with innovating. Technologists, research and development specialists, entrepreneurs, all tend to concentrate in the largest centres where the availability of specialised information is greatest and the communication and information networks most efficient. Agglomeration economies for businesses attract the firms, the research and development institutions and other corporations that all serve to increase a region's capacity to absorb innovations. The scale of these agglomeration economies within a region is closely related to its industrial structure. Hence, there is a complexity of interrelationships between agglomeration economies, the urban hierarchy, and the innovation-diffusion process.

Agglomeration economies are a direct function of population size and, being invariably urban in character, promote the hierarchical diffusion of innovations. (Richardson, 1973). The national distribution of the people involved in innovation appraisal and adoption, and the flow of physical capital necessary for the embodiment of technological change are also hierarchical in nature. So too are the formal communication networks and information channels so vital to the process of innovation awareness and acceptance. All this suggests that the industrial structure of a region, particularly the development of agglomeration economies, and the innovation diffusion-adoption process, are two vital determinants in any process of regional growth.

Thus far, a conceptual framework has been developed outlining the interrelationships between technological change, innovation and research and development, and the impacts that these may have, by means of the innovation diffusion-adoption process, upon national development and economic growth. Such interrelationships and impacts generate questions as to the extent of New Zealand's participation, both present and future, in these processes. In a more restricted context this conceptual background can be operationalised in the New Zealand context by examining the role of research and development in New Zealand's industrial growth. The impact of research and development upon industrial structure and growth will be investigated as the basic hypothesis of this thesis and, as such, it represents one part of the more general interaction between technological change and economic growth.

RESEARCH AND DEVELOPMENT IN NEW ZEALAND

> If the growth of manufacturing industry is to be a major component of a balanced programme of national development, the application of scientific principles will form an essential part of this plan.
>
> (Brooke, 1968, 38)

DEFINITIONS

In looking at research and development in New Zealand, the first qualification necessary is that concern is with industrial research and development and not with the agricultural component. Research and development has made obvious contributions towards improving the productivity and efficiency of New Zealand's agricultural sector and this thesis attempts to determine what impacts industrial research and development might have for the manufacturing sector. New Zealand's technological capacity is a composite of what is produced internally and what is introduced from overseas, by means of patents and various licensing agreements. The contribution of overseas technology to the development of New Zealand's economy, particularly in the manufacturing sector, has been vital. However, the application of overseas techniques to local conditions is often not a routine matter due to differences in raw materials, length of production runs, labour and market conditions. Thus, in the long run the most desirable alternative is to develop a more adequate internal research and development programme.

Interest in the potential benefits that might accrue from research and development for the manufacturing sector seems to have been stimulated by the findings and suggestions of the National Development Conference, May 1969. The report of the Committee on Education, Training, and Research states the case quite succinctly:

> In order to expand industrial exports and at the same time develop a higher level of productivity in the local market, it will be necessary to make a considerable increase in the application of science and technology to improve the quality of products, to increase productivity, and to develop new processes, new products, and new markets. For this purpose greatly improved scientific services to industry are required.
>
> (Report 12, paragraph 57, p.30)

Further, in paragraph 67, p.34,

> A basic objective is to encourage industry to initiate more research, through research establishments, in individual firms, in industry research associations, and also by commissioning Government and university research organisations for specific research projects.

Research and development, when applied to industry in New Zealand, can certainly answer many questions and supply the background information for quite new developments. It can provide information on the better use of locally available raw materials. It can improve the efficiency of present process technology and the quality of existing products. It can promote the development of new materials, new processes and new products. All this is possible from a fuller application of scientific and technological knowledge to current manufacturing operations.

A formal definition of industrial research and development has been provided by the Department of Trade and Industry in their booklet, Guidance Notes for Applicants. Industrial Research and Development Grants Scheme, (1974)

> Industrial research and development (I.R. and D.) is defined as systematic experimentation or analysis in the fields of science, engineering, and technology carried out by a company, corporation, or person - or on their behalf by approved research organisations - with the object of acquiring knowledge that may be used for the purpose of devising or developing new or improved industrial products or processes or with the object of applying knowledge for that purpose.

This definition describes the organisations that engage in research and development and the expected results of such work. Companies, corporations and individuals undertake research and development in the hope that, when applied commercially, the new or improved product or process that has been developed will bring them a return of enlarged markets and an increased level of income.

OVERVIEW OF NEW ZEALAND RESEARCH AND DEVELOPMENT ACTIVITY

For the purposes of this thesis, two categories of organisations engaging in industrial research and development have been delimited. Firstly, there are the individual manufacturing companies or corporations that carry out independent research and development activities as part of their overall operation. Certain of their staff members are responsible for developing new products, making modifications to the existing product range, and for alterations to the process technology used by the firm. Research investigations, development work, testing and trials are all carried on in the research and development department, whether this be defined formally or informally, and the results are then integrated into the firm's more general production and marketing operations.

The second category can be broadly described as research associations, and are all supported to some extent by government finance. Within the Department of Scientific and Industrial Research there are four divisions engaging in research and development work that is in some way applicable to the manufacturing sector. These are the Auckland Industrial Development Division, the Christchurch Industrial Development Division, the Chemistry Division, and the Physics and Engineering Laboratory. In addition there is a Science in Industry Unit whose main role is to co-ordinate such activities and facilitate liaison with industry.

This second category also includes the research associations that have been jointly established by industry and government. These associations are of two types:

1) Three are concerned with the processing of primary agricultural products:

i) Dairy Research Institute.

ii) Wool Research Organisation.

iii) Meat Industry Research Institute.

2) The other seven are concerned more particularly with manufacturing industries:

i) Building Research Association.

ii) Coal Research Association.

iii) Fertiliser Manufacturers' Research Association.

iv) Leather and Shoe Research Association.

v) Pottery and Ceramics Research Association.

vi) Concrete Research Association.

vii) Research Institute of Launderers, Drycleaners, and Dyers.

Excluded from the survey is the work on industrial research and development that is carried out within the universities, any work that individuals may undertake, plus the activities of the Cawthron Institute. This latter organisation was founded in 1920 and is the only independent research institute in New Zealand. Its activities are organised in two sections. There is a research section which carries out basic research in microbiology, and a chemical services section which offers fee-charging analytical services in chemistry and bacteriology. After communication with the director of the institute it was felt that their activities could not readily be analysed within the terms used for the other organisations and so the omission was made.

Central in the operation of research and development activities anywhere is the role played by the government. The government of any country must assume some responsibilities in encouraging general technological innovation and hence growth of the national economy. Technologically advanced countries with a high degree of scientific expertise typically spend a reasonable percentage of their Gross National Product on research and development. Omitting military and defence expenditure, United States and Netherlands spend 2.2 percent and 2.15 percent of their Gross National Product respectively on research and development, as compared with New Zealand's level of 0.5 percent (New Zealand Year Book, 1974, 239).

Although direct correlations between the proportion of Gross National Product invested in research and development and the national level of technological and economic progress are difficult to establish, any significant increase in the former is likely to positively affect the latter. (Philpott, 1973; Thurow, 1971). In a country such as New Zealand, the government can certainly play an important role. This may be done by investing directly in research and development, or by providing financial and other incentives for individual firms to carry out their own research and development. In New Zealand both these strategies have been adopted. Direct investment in research and development obviously occurs in the case of the industrial divisions of the Department of Scientific and Industrial Research and in the research associations, while the second alternative is evident in the operation of the Industrial Research and Development Grants scheme. Precise details about the amount of expenditure by the government in these two categories can be seen in the accompanying table. (Table 1.1). Increasing awareness of the importance of investing in research and development is reflected by the fact that Government expenditure has increased by more than 300 percent from 1970 to 1974.

The Industrial Research and Development Grants Act, 1970 was incorporated to promote increased industrial re-

Table 1.1: Government Expenditure on Research and Development, 1970-1974.

	YEARS				1970 - 1974	
	1970-71	1971-72	1972-73	1973-74	TOTAL EXPENDITURE	PERCENTAGE INCREASE
Grants to Research Associations	1,048,499	1,385,000	1,527,500	1,631,400	5,592,399	55.6
D.S.I.R. expenditure on manufacturing	-	1,573,000	1,829,000	2,149,700	5,551,700	36.6
I.R. & D. Grants Scheme	202,108	749,175	1,156,506	1,246,799	3,354,588	516.9
TOTAL EXPENDITURE	1,250,607	3,707,175	4,513,006	5,027,899	14,498,687	302.03

Source : Annual Reports, Department of Scientific and Industrial Research; Industrial Research and Development Grants Advisory Committee.

Note : D.S.I.R. is Department of Scientific and Industrial Research;
I.R. & D. is Industrial Research and Development.

search and development in New Zealand industry. Grants are made to the companies or corporations that show an increase in research and development expenditure on salaries, wages and related payments over such expenditure in a base year, two years previous. In assessing grant payments above a certain level, particular consideration is given to the effect of research and development on such factors as the better use of indigenous resources, growth in exports and/or savings in imports, the development of internal sources of technology, and general improvements in the productivity of New Zealand industry. Thus the scheme is designed to provide incentives for companies in a range of industrial groups to engage in research and development activities, and thereby to become more active in both national and international markets.

New Zealand's ten research associations, an example of direct government investment, constitute a joint effort by industry and government to foster research and development programmes relevant to the problems of industry and for the purposes of increasing productivity, profitability and trading competitiveness. Those research associations dealing more directly with the agricultural sector are comparatively well established, having high levels of accommodation facilities, equipment and qualified personnel. The manufacturing associations are often of more recent origin and are certainly operating on a smaller scale. This is reflected by the fact that the first three associations accounted for 71 percent of the government's 1972-1973 grant to research associations while the other seven shared the remaining 29 percent. Possibly this ratio might alter over time as New Zealand's industrial structure broadens and becomes generally more developed.

The establishment of a research association depends upon obtaining the agreement of a group of companies with similar interests to combine in the support of research and development for their common good. The prime objective of an association is to see that its research and development findings are translated effectively for the use and benefit of its industry. Indirectly, member companies may be encouraged to expand their own technical staff and facilities, thereby becoming more scientifically competent themselves and hence more capable of absorbing their association's results. The productivity or effectiveness of a research association is essentially a function of its degree of involvement with industry. Although industry sets up the research association it sometimes fails to become fully involved with the work of the association. This is unfortunate for without adequate interaction between the two parties the absorption of new ideas and the willingness to innovate may well be inhibited.

Definite advantages can result from the decision of firms to promote research and development co-operatively rather than individually. Work can be conducted on a broader and deeper range and quite likely of a higher quality. Duplication of work can be more easily avoided, resulting in a saving of valuable scientific and technological resources. Continuity of longer term projects can also be better guaranteed, as the research association is able to operate more independently of external economic fluctuations.

One of the disadvantages inherent in the formation of research associations is that they serve only established industries, for it is often the newly established industries that require most assistance. A certain amount of difficulty also exists when determining the particular balance needed in an association's research programme. It cannot become overloaded at the basic end of the research and development continuum as companies are not usually concerned with investigations having no prospect of a fairly immediate payoff. At the other extreme, the research association needs to avoid delving too closely into the final product or process for it is in this area that firms become commercially sensitive.

Despite these potential disadvantages the contribution that the research associations can make to industry, in terms of improvements in profitabilities and efficiencies, cannot be denied, and it is likely that this will continue in the future. Such an expectation is apparent in official circles, as can be seen from the following statement from the National Research Advisory Council Annual Report, 1974, p.7:

> The council is convinced that the associations have a vital role to play in the seventies; and that in the almost complete absence of large-scale private enterprise research of the type that exists in larger countries, continued Government financial support of the associations is warranted.

This represents an outline of the way in which research and development is organised in New Zealand and categorised according to two groups, individual firms and research associations. Now that the subjects for the study have been identified, attention can be directed to the method by which the investigation was carried out.

METHODOLOGY

Research and development can be regarded as a component of economic growth and, as such, it can be expected to exhibit sectoral and spatial impacts. It is apparent that research and development has been able to make positive contribution to the efficiency and competitiveness of New Zealand's agricultural sector, so the problem remains to determine what impacts it might have upon New Zealand's industrial growth.

This thesis is concerned with research and development activity that is carried out within the manufacturing sector. Using the Department of Statistics criteria, manufacturing includes registered factories employing at least two persons (including the working proprietor) engaged in the manufacture, assembly, repair, or treatment of articles. The Department of Trade and Industry definition of research and development is followed, whereby functions such as market research and routine quality control are excluded. Finally, two categories of organisations involved in research and development are delimited.

Work has been carried out deductively, with relationships being derived from the theory and, on the basis of these, hypotheses being developed to be tested in the empirical situation. The basic premise for the thesis is that research and development has industrial impacts. For each research and development category a central hypothesis can be formulated. Firstly, it is hypothesised that manufacturing firms in New Zealand are essentially concerned with adopting and adapting overseas technology. The main stimulus for New Zealand's technological, and hence economic, growth comes from overseas rather than being generated internally. Similarly, it is hypothesised that the individual research association is primarily concerned with improving the efficiency of its industry. In accordance with the basic premise and from the established theory, different sets of relationships are examined for the two research groups and evidence compiled by means of questionnaire and interview surveys. (Appendices 1 and 2).

METHODOLOGY FOR FIRMS

In order to determine which firms actually carried out research and development activity in New Zealand written approaches were made to the following organisations:

Department of Scientific and Industrial Research.
Science in Industry Unit.
Industrial Research and Development Grants Advisory Committee.
National Research Advisory Council.
New Zealand Invention Development Authority.
New Zealand Manufacturers' Federation.
& the four Manufacturers' Associations.

From the suggestions given, a list of 88 firms was drawn up within which research and development work was thought to be conducted. The survey and subsequent analysis was conducted on a firm basis rather than at the company level for, in some instances, both a parent company and a subsidiary firm were included in the survey and analysis. From these 88 firms, 47 returns were gained from personal visits, 15 returns were received by mail, 12 firms proved to be not concerned with research and development, 5 firms declined to provide information, and returns from 8 firms were rejected primarily because the information provided was too sketchy. Analysis is therefore based on information from 62 firms, a 70 percent response rate. Included among the 8 rejections are two firms whose activities are wholly concerned with providing analytical services, which may or may not be industrial in nature. These firms do not fulfil the criterion of being a manufacturing firm and so were omitted from the study.

In a supplement to November 1974, Monthly Abstract of Statistics returns from the 1972-3 Census of Manufacturing showed that 7.8 percent of establishments included in the survey employed research and development staff. A total of 1,183 people were involved fulltime in such work, which was defined as 'research into and development of existing and/or new products, excluding market research and similar work on the selling and distribution of products'. From the 62 firms analysed in the sample for this thesis there was 490 people employed which represents a coverage of 41.4 percent. Further evidence as to the degree of representation can be gained from the 1975 annual report of the Industrial Research and Development Grants Advisory Committee. Grants approved by this Committee to individual firms in the year ended 31 March 1975 totalled 127.[1] The thesis

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1 Government policy dictates that the names of firms receiving grants cannot be disclosed. Hence, it was not possible to gain any information from this source when determining the firm population for the survey.

survey covered approximately 49 percent of this figure.

From the thesis' basic premise certain hypotheses concerning the characteristics of the firm's research and development activities can be inferred. For example, it can be proposed that the bulk of research and development carried out by the firms is relatively safe from a technical viewpoint. (Hamberg, 1963). To determine the validity of this, it is necessary to know about the relative importance of basic research, applied research, and development activities; the importance of developing new products and processes as compared with modifying existing ones; and the typical temporal dimensions of a firm's research and development projects. Such questions will provide some indication of the research intensity of New Zealand's firms, their degree of innovativeness, and their willingness to accept the long term risks involved in research and development activity. These characteristics may in turn vary in relation to other firm traits such as the type of ownership, the particular industry group to which the firm belongs, and firm size.

A further hypothesis is that the nature of the research and development activity undertaken may vary according to firm organisation. A four-class organisational structure for New Zealand firms is outlined in the next chapter and the results of the questionnaire suggest ways in which organisational structure can affect research and development. This is achieved by looking at the origins of research and development projects, by finding out how decentralised research and development activity is in New Zealand firms, and by looking at what factors are considered when determining the levels of research and development expenditure and the selection of particular research and development projects. The proportion of successful projects in the market situation will also give some indication of the degree of integration between different functional divisions of the one organisation.

There have been a number of investigations in the overseas literature examining the effect of firm size on research and development activity. (Mansfield, 1968a; Comanor, 1967). Such a relationship is examined specifically in one question, while other factors such as level of expenditure, length of time before projects are completed, and the research intensity of the company can be related to firm size. From this some idea of the role of large, medium and small firms in the innovation process in New Zealand can be gained. The questionnaire for firms also tries to evaluate the intensity and direction of the growth impacts emanating from research and development. Hence, a consideration of the various linkage connections of the firm, forward and backward technological linkages, capital goods linkages and linkages with competitors, was carried out.

Research and development activity that is conducted in individual manufacturing firms can also be examined within a spatial context. Various sectoral and organisational characteristics have been suggested and the spatial dimensions of these provide the third viewpoint for firm analysis. The particular spatial frame adopted for this thesis has been to differentiate between metropolitan and all other centres. In the conceptual framework developed the interrelationships between the innovation process and urban and regional development were discussed. By introducing a spatial dimension into the analysis, some indication of the role of urban centres may be gained. Are manufacturing innovations typically urban in character and how does the significance of overseas sources of technology differ for the different centres studied? The geographical distribution of the 62 surveyed firms is summarised in Table 1.2. Forty-eight of these firms are in the metropolitan centres while the other 14 are distributed throughout the rest of New Zealand.

METHODOLOGY FOR RESEARCH ASSOCIATIONS

The methodology for the research associations follows the same principles as those described in relation to manufacturing firms. The population of research associations is more clearly defined for there are ten incorporated research associations, four industrial divisions of the Department of Scientific and Industrial Research, and one independent research organisation. All of these organisations were approached, either personally or by mail, and returns were received from 7 of the research associations. The basic premise behind the analysis of the research associations is that the organisation's primary concern is with enhancing the efficiency of its industry.

This focus suggests an initial consideration of the nature of the programmes of research carried out by the associations, and this is followed by a treatment of a number of key questions. They are: How does the association's orientation differ in comparison with industry in terms of the degree of innovativeness of their projects and their particular emphasis? How much is the research association

Table 1.2: Location Distribution of Surveyed Manufacturing Firms.

LOCATION	Number Surveyed
Auckland	20
Christchurch	11
Dunedin	4
Hamilton	1
Hastings	3
Invercargill	1
Marton	1
Masterton	1
Nelson	1
Palmerston North	4
Temuka	1
Timaru	1
Wellington	13

Source: Field Survey, 1975.

serving as a 'technological gatekeeper', channelling the receipt of overseas sources of technology and commenting on its applicability to the New Zealand context? What factors assume most importance when determing the balance of the research programme and how does this differ from the choices made by firms?

It is additionally hypothesised that the demands made by firms of its research association will vary according to firm characteristics. Large firms may be more concerned with the basic aspects of the association's research programme, while smaller firms may have a greater demand for more routine service functions. The type of firm ownership may also cause some variations. Such considerations could give some indication as to the degree of complementarity and substitutability between private research and that conducted by the associations.

A further group of relationships concerns the particular impacts that may be generated as a result of the organisation's research and development activities. Market impacts may be in the form of greater domestic sales or an increase in export earnings. Industrial linkages may exist with the capital goods industry or member companies. There is also the possibility that locational impacts may develop in response to the benefits of agglomeration in the costs of acquiring technology. These are the general hypotheses that will be investigated in the analysis of industrial research and development activity conducted in New Zealand's research associations.

The foregoing sections described the methodological procedures utilised in this thesis. Several additional points of interpretation must, however, be discussed. Analysis is directed toward assessing the role of research and development in New Zealand's industrial growth. Research and development itself is an embodied form of technological change. The thesis examines only product and process innovations and does not concern itself with disembodied forms of technological change. Moreover, the thesis is a study of only a part of the phenomenon of technological change and concentrates upon the interrelationships between research and development and industrial growth in New Zealand. Thus, it is not only disembodied forms of technological change which have been omitted, but also research and development concerned with agriculture.

Technological changes of different intensities are examined. The introduction of a completely new process causes the establishment of a number of firms, while changes of a more evolutionary nature induce short term rounds of growth in the individual firms. The second phase consequences that may be inherent in specific technological developments are not examined in any explicit way, but the phenomenon of spin-off firms is discussed. Further, the distinction between technological change that is labour-saving and capital-saving is not pursued.

Finally, the study does not treat specifically the diffusion of innovations developed as a result of research and development investigations. This is an area in which future detailed investigation could be carried out. It would be valuable to have some understanding of the degree of technological gaps that exist among different firms of the one industrial group. Similarly, it is important to understand how an innovation diffuses spatially, the nature of constraints involved in the diffusion process, and the role of the urban centres in the overall innovation adoption-diffusion process. These, then, represent a summary of the limitations and qualifications implicit in the methodological procedure adopted for this thesis investigation.

THE ORGANISATION OF RESEARCH AND DEVELOPMENT IN NEW ZEALAND'S MANUFACTURING FIRMS

> Yet technological progress has become of vital concern for the individual firm in many industries, and the increasing pace of innovation makes it inevitable that the firm provide more and more support for research and development as a condition of its own survival.
>
> (Burns & Stalker, 1961, 33)

Manufacturing firms in New Zealand are becoming increasingly aware of the potential contribution that research and development can make in the improvement of pro- efficiencies and profitability levels. As competition becomes more intense nationally and internationally, a greater amount of time and effort needs to be invested in improving the quality of existing products, extending the present product range and bettering the productivity of the various production processses. These actions may require complete research and development investigations in which formulations are tested, prototypes are developed and exploratory production runs are introduced. New Zealand's manufacturing firms are becoming more aware of research and development and, it is therefore becoming increasingly integrated into general manufacturing processes.

The survey on which this analysis is based covered a wide range of industrial groups and includes firms employing from 5 to 8000 people. The analysis of data has been carried out in four sections. Firstly, research and development is considered as a general activity and interpretation of expenditure and staffing figures plus the general orientation of the research and development effort is undertaken. In the second part research and development is examined from a sectoral perspective, with some interpretation of interindustry and firm size variations. Thirdly research and development can be interpreted from a organisational viewpoint. A four-fold classification of New Zealand manufacturing firms is proposed and the way in which research and development might vary accordingly is examined. Finally, some interpretation of the linkage impacts of research and development in New Zealand manufacturing firms is attempted.

RESEARCH AND DEVELOPMENT AS A GENERAL ACTIVITY

Staffing

From the 62 firms covered by the survey, there was a total of 490 people involved full time in research and development work. Of these 280 (57 percent) held recognised scientific or engineering qualifications. Three-quarters of the firms have qualified staff constituting at least half of their total research and development workforce, which suggests a reasonable standard of technical expertise and ability. The distribution pattern of qualified: total research and development staff, plus the ratio of research and development: total staff is given in Table 2.1.

When the research and development staff are related to total employees, the average ratio is for 3.6 research and development staff per 100 employees. Fifteen firms have ratios of less than or equal to 1:100, which could be due to one of two reasons:

1) Research and development has not yet become ful-

Table 2.1: Research and Development Staff as a Percentage of Total Staff, and the Percentage Qualified.

	Percentage of Research and Development Qualified						
	0-10	11-25	26-40	41-55	56-70	71-85	86-100
Number of firms	6	4	8	5	16	11	12
	Research and Development Staff as a percentage of total Staff						
	0-1.00	1.01-2.0	2.01-4.0	4.01-6.0	6.01-8.0	8.01-10.0	10.01 +
Number of firms	15	12	14	9	6	3	3

Source: Field Survey, 1975.

ly integrated into the firm's general functioning.

2) The firms are large by New Zealand standards and the research and development staff, while critical, are minor in relation to the total staff required in the production process.

At the other end of the scale are three firms where research and development staff account for 80, 27.7 and 12.5 percent of the total employment figures of 5, 18 and 80 respectively. These are high ratios and obviously the three firms are intimately concerned with research and development work.

Such a contrast suggests a continuum of activity along which firms may be classified. Those at one end may be regarded as 'development intensive' with work being closely directed and supervised, and factors such as increased output being given greater consideration than innovation. By contrast 'research intensive' categories tend to be less directive in particular work assignments and value innovativeness over efficiency. (Ansoff and Stewart, 1967). It is probable that such a continuum of research and development activity exists for manufacturing firms in New Zealand, and it is also probable that the specific position of a firm along that continuum will be affected by such factors as industrial classification, firm size and organisational structure.

Further understanding of the distribution of research and development staff can be gained from Table 2.2 where firms have been categorised according to the size of their research and development unit. Nearly half of the firms fall into the first group, suggesting that research and development in many manufacturing firms is, as yet, carried

Table 2.2: Distribution of Research and Development Staff among different Sized Units.

Number of Staff per Unit	Units		Research and Development Staff			
	Number	% of total	Qualified	Other	Total	% of total
1-4	28	45	53	31	84	17
5-9	19	31	65	49	114	23
10-14	7	11	51	26	77	16
15-19	3	5	23	26	49	10
20+	5	8	88	78	166	34
TOTALS	62	100	280	210	490	100

Source: Field Survey, 1975.

Table 2.3: Spatial Concentration of Research and Development Staff.

Geographical Area	Location Quotient
Auckland	0.85
Wellington	2.07
Christchurch	0.48
Dunedin	4.00
Others	1.05

Source: Field Survey, 1975.

out on a small scale. This group is decidedly underrepresented in terms of its overall share of research and development staff while, by contrast, 13 percent of the firms have 44 percent of the research and development workforce. There would appear to be a concentration of research and development staff in firms having the larger research and development units. These firms, however, are not necessarily those having the largest total employment numbers, as has been pointed out by the previous table. It is also interesting to note that in all but one of the categories, the numbers of qualified staff outweigh the unqualified, showing a good filtering of recognised expertise throughout all sizes of research and development units.

It is also interesting to examine the spatial distribution of research and development staff. The relative concentration of such workers varies for the different areas (Table 2.3). This concentration is measured in terms of a location quotient, whereby the area's share of research and development staff is divided by its share of total employment within the firms surveyed. From the table it is seen that research and development workers are relatively over concentrated in Wellington and Dunedin, while in Auckland and Christchurch they are unimportant when related to total employment figures. The secondary centres show no real degree of overconcentration and, as such, can be regarded as having their share of research and development workers.

These patterns can probably be related to other variables such as firm size and industrial classification. For example, the Dunedin firms are comparatively small in size and belong to industrial groups that are more research than development intensive. Similarly, in Wellington there are two of the three firms where research and development staff account for the highest proportion of total staff, and these are both electronics firms, a research and development conscious activity. The Auckland and Christchurch figures are prejudiced by firms of large size (8000 people are employed in one Auckland firm), and a concentration of firms that are less research oriented, such as the Food, Beverages and Tobacco industry group.

Expenditure

Expenditure figures are another indication of a firm's involvement in research and development. The amount spent on research and development in relation to the total expenses of the firm gives some indication of the extent to which research and development is integrated into the overall functioning. Unfortunately, because expenditure figures appear to be a sensitive matter, only 49 of the 62 firms gave answers to the question concerning the amount of expenditure on research and development, while there were 53 responses relating expenditure to total sales. Total expenditure on research and development for these 49 firms in 1975 is $4,290,000, giving an average of $87,551 and a median of $51,500. These figures for expenditure can be analysed in two ways; firstly in relation to firm size and secondly in relation to total sales.

Economists such as Galbraith (1967) advance the thesis that the greatest amount of technological change and innovation takes place in big firms, that innovativeness requires bigness. Other economists are not convinced about the validity of this relationship and see small firms as important sources of innovation also. (Adams, 1970). Table 3.1 shows the distribution pattern of research and development expenditure among the firms of different sizes. The average amount spent on research and development for the largest firms is between three and four times greater than that spent in firms of small size. Of the ten firms spending at least $100,000 each year, only one was not in the largest firm size category. These ten firms are responsible for 59 percent of the total expenditure while the remaining 41 percent is shared by 84 percent of the firms. This suggests that, in absolute terms at least, research and development activity might be more important and carried out on a greater scale in the largest firms, for 33 percent of the firms are responsible for 71 percent of the expenditure.

By relating research and development expenditure to total sales it is possible to get some idea of the importance of research and development to the firm's general activities without any size bias. On looking at these proportional figures research and development can be seen to be at least as important to some small firms as it is to larger ones (Table 3.2).

Thirty-two percent of the firms have research and development expenditure contributing a proportion less than 0.5 percent of their total sales and, of this, half are firms employing more than 250 people. Also, in the last category, three of these four firms employ 5, 18 and 80 people with research and development expenditure representing respectively 70, 15 and 13 percent of total sales.

Table 3.1: Relationship between Research and Development Expenditure and Firm Size.

Firm Size	Number of Units	Total Group Expenditure	Average Expenditure
1-50	4	$ 168,000	$ 42,000
51-100	9	$ 397,000	$ 44,177
101-150	6	$ 289,000	$ 48,167
151-200	5	$ 194,000	$ 38,000
201-250	4	$ 197,000	$ 49,250
251+	21	$3,045,000	$145,000
TOTALS	49	$4,290,000	

Source: Field Survey, 1975.

Table 3.2: Research and Development Expenditure as a Percentage of Total Sales.

Research and Development as a Percentage of Total Sales	Number of Firms	Percentage of Total
0- .5	17	32
.51-1.0	9	17
1.01-1.5	6	11
1.51-2.0	5	9
2.01-5.0	8	15
5.01-10.0	4	8
10.01+	4	8
TOTAL	53	100

Source: Field Survey, 1975.

Interestingly these three firms are the same three that had the highest ratio of research and development: total staff. Thus, for the data collected on expenditure it seems reasonable to conclude that while large firms may be more important in absolute terms, essentially because of the scale of economic activity at which they operate, their relative involvement in research and development is not necessarily any greater than that in many small firms.

When Table 3.2 is spatialised (Table 3.3) it is seen that the four firms where research and development expenditure represents the greatest proportion of total sales (70,15,15 and 13 percent) are all located in the three metropolitan areas. The concentration of these firms in the higher order urban centres is possibly reflective of their specialised requirements in terms of information accessibility and services required. This is further supported by the fact that Dunedin and the secondary centres have only one out of a possible 17 firms where research and development accounts for more than 5 percent of total sales. It is also interesting to note that 44 percent of Auckland's firms spend less than 0.5 percent on research and development. This is probably reflective of the concentration of firms of very large size in this area.

Product and Process Emphasis

Within this examination of research and development as a general activity, it is possible to look at the particular emphases of the firms' research and development programme. The particular distribution of firm product/process emphasis can be seen in Table 4.1. In 75 percent of the cases concern for developing new products or modifying

Table 3.3: Spatial Concentration of Research and Development Expenditure as a Percentage of Total Sales.

Research and Development as a Percentage of Total Sales	AUCKLAND	WELLINGTON	CHRISTCHURCH	DUNEDIN	OTHERS
0- .5	7	3	3	1	3
.51- 1.0	2	1	1	-	5
1.01- 1.5	1	2	2	1	-
1.51- 2.0	1	2	-	1	1
2.01- 5.0	3	-	1	1	3
5.01-10.0	1	2	-	-	1
10.01+	1	2	1	-	-

Source: Field Survey, 1975.

Table 4.1: Firm emphasis on products and processes.

	Percentage Distribution of Research and Development Projects			
	0-10	11-40	41-70	70-100
Develop new products	5	22	23	12
Modify existing products	15	38	6	3
Develop new processes	43	15	3	1
Modify existing processes	39	21	2	-

Source: Field Survey, 1975

Table 4.2: Spatial Concentration of Product/Process Emphasis.

	Average Percentage Distribution				
	AUCKLAND	WELLINGTON	CHRISTCHURCH	DUNEDIN	OTHERS
Develop new products	46	47	49	36	48
Modify existing products	34	22	28	43	18
Develop new processes	9	21	9	15	15
Modify existing processes	11	10	14	6	19

Source: Field Survey, 1975

existing ones was greater than the interest in processes. Thirty-three firms spent at least half of their research and development effort in developing new products while, by comparison, only four spent half their time in developing new processes. Only two firms did not engage in new product development but 20 did no new process development. Thus the emphasis is on product development and, furthermore, on the development of new products.[1] The lesser importance of process development possible reflects New Zealand's position in the international system of technological change. Process technology is more basic and more long run than is product technology, and is therefore adopted from overseas rather than generated internally. This is further supported by the fact that modification of processes is more important than new processes. Presumably the technological principles need modification and adaption to fit the peculiar set of conditions involved in the New Zealand production process. Production is carried out in shorter runs and on a smaller scale, with the degree of capital investment being less intensive.

When the particular product/process orientation for firms is examined for different areas some interesting features become apparent. (Table 4.2) For all five areas the emphasis on product development is greater than that for

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1 In a survey of business firms carried out in the early 1960's in the United States, 47 percent of firms indicated that the main purpose of their research and development was to develop new products, while a further 40 percent were most concerned with improving existing products. Only 13 percent gave greatest emphasis to the development of new processes. (Cited in Mansfield, 1972, 480).

processes. In the Dunedin area, however, development of new products is relatively less important and the modification of products is of greater interest. It is possible that there may be some relationship between Dunedin's slower rate of growth over the past few years and its relative lack of new product innovations, a factor which is an integral part of the general innovative quality of an area.

The nonmetropolitan area group spends comparatively less time on product modifications. This area has a greater concentration upon processes than the other four areas. Probably this is a result of firms which are peripherally located and concerned with the processing of raw materials, either mineral or agricultural. In these instances process development would be more important than it would be to, say, a firm involved in the manufacture of electrical appliances. The Wellington area has also a relatively high concentration on new process development, as its figure is boosted by an 80 percent emphasis in one electronics firm, and 50 percent in one firm in each of the nonmetallic minerals and metal products groups.

SECTORAL PERSPECTIVE

This discussion of staffing, expenditure, and product/process orientation represents the examination of research and development in general terms. The second stage is to look at it from a sectoral perspective. Research and development can be more or less important as an activity depending upon the particular type of industrial group to which the firm belongs. Some firms are obviously involved in highly sophisticated technologies and require intimate research and development involvement to remain competitive and successful. For other firms basic product and process technology has not changed for many years and research and development might therefore receive relatively less attention. On the basis of the data collected from the questionnaire comments can be made about the sectoral dimension of research and development in New Zealand's manufacturing sector.

Industrial Classification

The 62 firms analysed can be usefully categorised into eleven industrial groupings. Table 5.1 gives the distribution of firms among these groups, the expenditure pattern for each, and the distribution of research and development staff. From this sectoral perspective it is possible to see that some industry groups are more involved in research and development activity than others. Electronics is obviously the industrial group that is most intensively involved, with research and development expenditure representing an average of 20.6 percent of total sales. This figure is upwardly biased to some degree by the 70 percent figure for one of the firms, but even omitting this exceptional amount the overall average is still greater than eight percent. The research and development intensity of the electronics firms is also indicated by the fact that research and development workers account for an average of 22.6 percent of the total workforce, nearly five times as large as the second largest category.

Mechanical and electrical engineering are two other categories where research and development appears to be a relatively important item of expenditure and a reasonable proportion of the workforce are involved in such activities.

Table 5.1: Research and Development Activity classfied according to Industrial Groupings.

	Number of Units	Total Industry Group Expenditure	Research and Development as a Percentage of Total Sales	Total Research and Development Staff	Average Percentage Research and Development: Total Staff
Food, Beverages, Tobacco	10	$ 433,000	0.83	72	1.4
Textiles, Apparel, Leather Products	3	$ 130,000	1.66	9	1.0
Wood and Paper Products	2	$ 527,000	0.18	23	0.75
Metal Products	5	$ 329,000	0.66	25	1.5
Non-metallic minerals	5	$ 400,000	1.12	34	2.9
Mechanical engineering	4	$ 211,000	5.83	19	3.5
Electrical engineering	8	$ 231,000	4.30	107	4.2
Electronics	7	$ 549,000	20.60	57	22.6
Plastics	4	$ 105,000	2.17	19	2.1
Chemicals	13	$1,295,000	2.31	121	4.7
Miscellaneous	1	$ 80,000	1.00	4	1.0
TOTALS	62	$4,290,000		490	

Source: Field Survey, 1975.

In the chemicals industry expenditure on research and development in relation to total sales is, on average, not particularly high. This is essentially because there is such a range of firms involved in the chemical industry operating at different scales of economic activity. Expenditure ranges from over $500,000 down to $18,000, but in all cases there is a fairly high proportion of total staff (average of 4.7 percent) involved in research and development work.

The wood and paper products group has the second highest level of absolute expenditure but this figure is exaggerated by the large size of one of the firms concerned. A truer indication of the role of research and development in this industry group is given by the figures relating research and development to total staff and total sales. Other sectors such as Food, Beverages, Tobacco and Textiles, Apparel, Leather Products do not appear to be involved in research and development to any real extent. This is in contrast to the research and development intensive groups such as engineering, echmicals and electronics. However there does appear to be some changes in awareness and attitude taking place. The more traditional industrial groups are gradually becoming more conscious of the potential contributions of research and development to their firm in terms of improving their product range and the general efficiency of their production processes.

Table 5.2 gives an indication of the distribution of research and development performances according to industrial groups for British industry. Figures are for 1967/1968 and are for firms employing less than 200 people.

Table 5.2: Expenditure per Employee on Research and Development Performed within Small Firms: Industrial Distribution in 1967/68.

	Estimated expenditure on Research and Development £m	Percentage	Total Employees ('000)	Expenditure on Research and Development per employee £
All manufacturing	21.3	100.0	2,441	9
Food, drink and Tobacco	0.4	1.9	191	2
Chemical and allied Industries	2.8	13.1	101	28
Engineering:				
Total	15.0	70.5	850	18
Mechanical	7.3	34.3	646	11
Electrical	1.1	5.2	67	17
Electronics	3.8	17.9	38	100
Vehicles (including aerospace)	2.8	13.1	99	28
Metal manufacture	0.2	0.9	88	2
Textiles, clothing, etc.	0.6	2.8	575	1
Other manufacturing	2.3	10.8	637	4

Source: Cox, 1971, 13.

Again the research intensity of categories such as electronics, general engineering and the chemical industries is evident.

Basic Research, Applied Research and Development

A further component of the sectoral perspective on research and development is to examine the way in which firm size and industrial classification influences the orientation of the research programme. Research and development can be subdivided into three categories - basic research, applied research, and development - and the definitions of these were discussed in the introductory chapter. In the New Zealand scene very little basic research is carried out within individual firms. This is because of the smaller scale of local economic activity. The scientific facilities and resources necessary to support a large scale, long term programme of basic research do not exist to any real extent in New Zealand firms.

The relative orientation of research and development programmes is described in Table 6.1, with responses coming from 61 firms. 54 out of the 61 firms spend 10 percent or less of their effort on basic research, with 67 percent of these firms doing no basic research at all. This suggests support for the basic premise proposed for manufacturing firms; that they are more concerned with adopting or adapting overseas sources of technology. At the other end of the scale there were 48 out of the 61 firms (78 percent) where development accounted for at least 50 percent of research and development work, while eleven firms were engaged in only development work.

By introducing the spatial frame it is possible to

Table 6.1: Orientation of Firms' Research and Development Programme.

	Percentage Distribution of Research and Development Activity			
	0-10	11-40	41-70	71-100
Basic Research	54	7	-	-
Applied Research	26	21	5	9
Development	4	8	18	31

Source: Field Survey, 1975

Table 6.2: Spatial Concentration of Basic Research, Applied Research and Development.

	Average Percentage distribution of projects				
	AUCKLAND	WELLINGTON	CHRISTCHURCH	DUNEDIN	OTHERS
Basic Research	1.8	2.3	6.3	2.5	5.4
Applied Research	29.8	29.8	31.4	36.75	19.7
Development	68.4	67.9	62.3	60.75	74.9

Source: Field Survey, 1975

see if there is any areal concentration of basic research, applied research or development. (Table 6.2) Christchurch firms appear to spend a greater proportion of their time on basic research. This figure is boosted by one firm in the metal products industry group which spends 20 percent of its effort in basic research work. The basic research proportion is also relatively high in the nonmetropolitan centres which is explained by research investigations into minerals and other such raw materials. This is a situation where overseas findings are not readily applicable because of the unique qualities of the raw materials involved. The greatest concentration upon applied research in the Dunedin metropolitan area. It is quite probable that there is some positive relationship between this figure and the high proportion of time spent in this area on the modification of existing products. Finally, development activity is most concentrated in the secondary centres. This emphasis may be reflective of the lesser degree of integration of these centres into the national process of innovation diffusion - adoption.

To determine the relative importance of applied research and development, the variable of firm size can be introduced (Table 6.3). For every size category development received greater emphasis than applied research. Again this reflects New Zealand's dependence on overseas technology, for not even the majority of the largest companies are more involved in applied work. This is because many New Zealand firms are subsidiaries of larger overseas organisations and depend upon their parent companies for the supply of technical information of a more fundamental

Table 6.3: Relationship between Firm Size and Research and Development programme.

	Applied Research more important than Development	Development more important that Applied Research	Applied Research equally important as Development
1-50	-	5	-
51-100	1	10	-
101-150	2	5	-
151-200	3	4	-
201-250	-	4	-
251+	6	19	2
TOTALS	12	47	2

Source: Field Survey, 1975.

nature, while they themselves carry out any modifications or adaptations required to fit the local context.

It is also possible to see how this orientation varies according to different industrial groups (Table 6.4). Surprisingly, it is the nonmetallic minerals group where applied research is relatively of most importance. In these firms investigations are carried out into the physical and chemical properties of the raw materials with which they are involved. The local raw materials have unique properties and qualities, which means that the transfer of overseas technology is not easily facilitated. Two of the electronics firms and three of the chemicals firms are also more concerned with applied research. In such fields local production and marketing conditions are quite different from those experienced overseas and therefore adaptation of the basic research knowledge must take into account the peculiar characteristics in New Zealand.

An indication of the emphasis on these different research categories within overseas countries can be seen in a table, for United States firms, that has been adopted from Mansfield (1968a, 58). Although the industrial classification is somewhat different, general comparison is still possible. (Table 6.5) From the table it can be seen that industry in general is not really concerned with basic research. Some industries such as the chemicals and electronic components group are more conscious of basic research than others. The general trend is for development to be more important than applied research with two interesting exceptions being textiles and food products. According to Mansfield (1968a, 59): 'For all industries combined, about 4 percent of the total is basic research, 20 percent applied

Table 6.4: Relationship between Industrial Classification and Research and Development.

	Applied research more important than Development	Development more important than Applied research	Applied Research equally important as Development
Food, Beverage, Tobacco	2	8	-
Textile, Apparel, Leather Goods.	-	3	-
Wood and Paper Products	-	1	1
Metal Products	-	5	-
Non-metallic minerals	3	2	-
Mechanical Engineering	1	3	-
Electrical Engineering	-	6	1
Electronics	2	5	-
Plastics	1	2	-
Chemicals	3	10	-
Miscellaneous	-	1	-

Source: Field Survey, 1975.

Table 6.5: Percent Distribution of Funds for the Performance of Basic Research, Applied Research, and Development, by Industry, 1964.

Industry	Basic Research	Applied Research	Development	TOTAL
Food and kindred products	9	47	44	100
Paper and allied products	3	36	62	100
Chemicals and allied products	13	n.a.	n.a.	100
Industrial chemicals	13	n.a.	n.a.	100
Drugs and medicines	16	49	35	100
Other chemicals	n.a.	23	68	100
Stone, clay, and glass products	5	35	59	100
Primary metals	6	37	57	100
Fabricated metal products	3	23	75	100
Machinery	2	14	84	100
Electrical equipment and communication	5	14	81	100
Communication equipment and electronic components	8	16	76	100
Other electrical equipment	2	12	86	100
Motor vehicles and other transportation Equipment	3	n.a.	n.a.	100
Textiles	3	50	47	100

n.a. not available.

Source: Adapted from Mansfield, 1968a; 58.

research, and 76 percent development'. Respective figures for the firms surveyed in this thesis are 3.4 percent, 28.2 percent and 68.4 percent, so that there is a slightly greater emphasis on applied research locally than for those firms in the United States.

From this sectoral perspective it can be seen that different industrial groups are more or less concerned with research and development as part of their general activities. Generally, firm size is seen to have little effect on the type of activity that is carried out, although the largest firms are responsible for spending the greatest absolute amounts on research and development. Sectorally we have also seen some indication of the importance of overseas sources of technology and the emphasis, locally, on the development aspects of research activity. The significance of overseas technology can be elaborated further by examining the sources of the firms' main technology component, as it is described by Table 7.1.

External Sources of Technology

For the majority of firms surveyed, overseas sources represent the major supply of technology and techniques. The New Zealand stock of technology was considered more important than that available from overseas for only four firms. Such figures give further credence to the hypothesis that New Zealand's manufacturing firms are concerned primarily with adopting or adapting overseas technology. But this is not to deny the innovativeness of the New Zealand firms. In many cases these overseas techniques are adapted to the New Zealand context, modifications and investigations are undertaken on their more basic qualities and, as a result,

Table 7.1: Major sources of technology for New Zealand Manufacturing firms.

	Use technology available in New Zealand	Adopt/adapt overseas technology	Both sources equally important	Do develop 'new' technology
Food, Beverages, Tobacco	1	8	1	2
Textiles, Apparel, Leather products.	-	3	-	-
Wood and Paper Products	-	2	-	-
Metal Products	-	3	2	2
Non-metallic minerals	-	3	2	1
Mechanical Engineering	1	2	1	2
Electrical Engineering	-	6	2	2
Electronics	-	6	1	5
Plastics	1	1	2	2
Chemicals	1	8	4	3
Miscellaneous	-	1	-	1
Percentage of Total Firms	6	70	24	32

Source: Field Survey, 1975.

quite 'new' forms of technology may eventuate.

New Zealand's manufacturing firms have been able to develop important inventions internationally particularly in the engineering and electronics fields. Local knowledge and expertise has been applied in specialised fields and important discoveries have resulted. Similarly, in the food industry new advances have been made by local firms in areas such as meat processing technology. While overseas technology is a major factor in determining the degree of industrial development and competitiveness of New Zealand's manufacturing firms, this does not necessarily mean that local innovativeness is completely lacking but rather that new technology is not, understandably, the major source of technological advance.

It is also possible to examine how the importance of overseas technological sources varies spatially (Table 7.2). For the majority of firms in all areas external sources of technology appear to be the most important. This is least the case in the nonmetropolitan areas where significant reliance is placed upon the supply of indigenous technology. Wellington and Christchurch are the two areas where the highest proportion of firms develop new forms of technology, while the other three areas show no real variation. Possibly the Auckland area is integrated to the greatest degree into the international process of innovation diffusion, while Dunedin and the secondary centres are less concerned with the generation of new technological forms and are more involved with the adoption/adaption process. Hence, Wellington and Christchurch appear as comparatively more important.

Table 7.2: Spatial Concentration of Technology Sources.

	Use New Zealand Technology	Adopt/Adapt overseas Technology	Both Sources equally important	Develop New Technology	
				Number	Percentage of firms
AUCKLAND	-	13	7	4	20
WELLINGTON	1	11	1	6	46
CHRISTCHURCH	-	8	3	6	45
DUNEDIN	-	4	-	1	25
OTHERS	3	7	4	4	28

Source: Field Survey, 1975.

Firm Size

It is interesting to note how the size of the firm affects its ability to use external sources of technology. Opinion is divided, with some firms regarding large size as a prerequisite for research and development and a definite advantage in assimilating external technology, while others regard small size as being an equal advantage.

For a firm to be large, this implies that it has reasonable capital strength. Because of this, it will be able to support a large research and development department and may be able to sustain research and development projects of a more basic and long term nature. In many cases the larger firms covered by the survey are subsidiaries of overseas companies or have overseas technical agreements. Such connections can be an advantage in gaining access to the latest technological advances and in learning about the various problems that may arise with application into the production system. In one case at least, large size was a prerequisite for research and development work to even begin. A meat processing firm was unable to engage in research and development work until several mergers had taken place creating an organisation of sufficient size and scale to make their 'own R. & D. become effective'.

The advantages of small size are flexibility and personal involvement. As general production is undertaken on a small scale such a firm is able to introduce new products or new techniques very quickly into the general system. Their production process has greater flexibility and is able to respond more quickly to changes in market conditions, with the firm therefore gaining the advantages implicit in the 'lead time' concept. In the words of one firm manager, "A small company is able, because of low inertia, to jump quickly on to any new technology".

Small size also means that the degree of personal involvement on the part of employees is greater. Each member of the firm can realise the part he is playing in overall firm growth and expansion, and because of this his value as an employee is often enhanced. One pharmaceutical firm made an interesting comment. Since they are small in the international sense, they employed a wide range of disciplines with the individuals all working closely together generating an important cross fertilisation of ideas. It is from this close contact that the innovative character of the New Zealand firm has developed to an extent where it is often superior to its overseas counterparts.

Disadvantages can also arise for different firm sizes when engaging in research and development. If a firm becomes too big it loses some degree of personal involvement, a sense of direction, and production systems can become inflexible. If a firm is too small this can cause quite serious problems when assimilating overseas technology. Overseas technology is designed for multiproduct lines with long production runs and often requires heavy capital investment. Such characteristics are not typical of industrial production in New Zealand's small firms, so new techniques must be scaled down to fit the particular level of economic activity. A further consideration, probably independent of size, is the quality of the workforce. Unless the firm has employees of sufficient expertise and adaptability the successful introduction of many overseas techniques will not be possible. Behavioural factors such as these are also quite important when considering the process of research and development.

This section has considered the sectoral dimension of research and development. It has shown that research involvement in research and development work varies in relation to firm size and industrial classification. The particular orientation of the firm's research and development programme plus the importance of external sources of technology has also been examined. From such a background comments can be made about the typical growth-inducing impacts and linkages that might evolve from research and development investigations. However, before this is done it will be useful to consider the organisational perspective of research and development in New Zealand's manufacturing firms.

ORGANISATIONAL PERSPECTIVE

Any firm can be regarded as an 'organisation' carrying out a number of economic activities within a particular economic system. Obviously different firms operate with different degrees of success and profitability, and it is possible that the level of performance may be in some way related to the organisational structure of the firm. It also seems reasonable that attitudes and expertise in research and development can be examined in the same way. Various classifications of organisational structure have been proposed in the overseas literature (Chandler, 1962; Stopford and Wells, 1972). The model developed by Stopford and Wells divides firm organisational structure into the following four stages:

Stage 1: Firms 'usually small enough to be administered by a single man, typically the owner and founder'

(Stopford & Wells, 1972, 11).

Stage 2: Firms that have established functional departments, such as sales, production and finance.

Stage 3: Firms that have a divisional organisational structure based usually on product or area lines and as such operate as quasi firms.

Stage 4: Firms which have a global organisational structure.

If this classification system was to be adopted for analysing the firms surveyed in this thesis, there would be 7 firms in the Stage 1 category, 51 Stage 2 firms, 4 Stage 3 firms and none of the Stage 4 group. This concentration of firms in the Stage 2 group is the result both of the different degree of industrial development in New Zealand as compared to some overseas countries, and of the fact that inquiries were carried out at the firm rather than the company level. Thus, say, for one Auckland company that would be of the Stage 3 group, questionnaires were received from two of its autonomously operating firms rather than from the company's administrative headquarters.

Organisation Structure

Because of these differences, the Stopford - Wells model has been modified to better fit New Zealand's industrial structure and to make the interpretation of results within an organisational perspective more meaningful. The first firm class is the same as the Stage 1 group; that is, New Zealand owned and operated firms that are small enough to be administered by a single person. Classes 2, 3, 4 represent essentially a rearrangement of Stages 2 and 3 in the Stopford - Wells model. Firms of Class 2 and 3 are the larger manufacturing firms which have a varied product range and operate in a number of centres throughout the country. Class 2 of these multiproduct, multiplant firms are subsidiaries of another New Zealand firm and may also have subsidiaries of their own. Class 3 are New Zealand owned and independently operated firms that may also have subsidiaries, either locally or overseas. The fourth class of firm organisation is those firms that are subsidiaries of overseas organisations. Their New Zealand operation may be multiproduct and multiplant in nature but they have direct ownership affiliations to an overseas company.

After arranging the firms surveyed into these organisational classes, there were 7 representatives in Class 1, 14 in Class 2, 24 in Class 3 and 17 in Class 4. The spatial distribution of these different classes can be seen in Table 8.1. The Auckland area appears to have a concentration of firms of Class 3. These are the larger of New Zealand's firms and the predominance of firms of large size in the Auckland area has been previously mentioned. In the Wellington area the greatest representation is of Class 4 firms, those that are subsidiaries of overseas companies. There is some tie up between this emphasis and the major importance that overseas sources of technology held for the Wellington area, as outlined in Table 7.2. Christchurch, like Auckland, seems to have some concentration of Class 3 firms and again this is reflective of the number of firms of large size that were found in this area. For Dunedin and the secondary areas representation appears to be fairly spread with no real concentrations.

Research and Development Programme

Table 8.1: Spatial Distribution of Firm Organisational Classes.

Firm Class	AUCKLAND	WELLINGTON	CHRISTCHURCH	DUNEDIN	OTHERS
I	1	2	-	1	3
II	5	2	3	1	3
III	9	2	8	-	5
IV	5	7	-	2	3

Source: Field Survey, 1975.

It is possible to consider how the way in which research and development activity is carried out might vary with respect to firm organisational structure. It is suggested that the different nature of the research and development programme varies according to organisational structure. This aspect is examined in Tables 8.2 and 8.3. Basic research seems to be more important to the small independent New Zealand firms than to the firms of other organisational structure. These tend to be the research-intensive firms that undertake work of a highly specialised and technologically sophisticated nature which may be quite new to the New Zealand industrial scene. While applied research is comparatively of little significance, the development phase is quite dominant within the overall programme. The need to get the new project applied to the market situation is essential as it directly affects the survival of these small firms.

Firms of Class 2 and 3 exhibit little difference in their programme emphasis. Invdvement in basic research does not exist on any great scale. Applied research represents a reasonable proportion of activity with attention being paid to getting the new product and process ideas adapted to fit New Zealand marketing and production conditions. Such work, which generally involves scaling down production systems to New Zealand's short run conditions, is vital to the successful assimilation of external technology. Once the applied research has been undertaken the development phase can occur more quickly and easily.

Firms of Class 4 do very little basic research, not particularly much applied research, and concentrate more

Table 8.2: Relationship between Organisational Structure and Research and Development Programme.

Firm Class	Number of Units	Average Percentage distribution of Research and Development activity		
		Basic Research	Applied Research	Development
I	7	5	9.3	85.7
II	14	3.7	34	62
III	24	4.3	33	62.7
IV	17	1.9	22.2	75.9

Source: Field Survey, 1975.

Table 8.3: Relationship between Organisational Structure and Length of Research and Development Projects.

Firm Class	Length of Time Before Project Completion Percentage Distribution					
	TECHNICAL			COMMERCIAL		
	-2 years	2-5 years	5 + years	-2 years	2-5 years	5 + years
I	81.5	17.1	1.4	80	20	-
II	83.8	15.3	0.7	88.3	11.6	-
III	78.2	20.1	1.7	68.9	26.8	4.3
IV	83.4	15.6	0.9	70.6	23.1	6.2

Source: Field Survey, 1975.

upon development work. This is almost certainly a result of their particular organisational structure. These firms are subsidiaries of overseas companies, from which they get considerable technical backup. The basic and applied research is carried out by the overseas company and all that is required is some development work involved in the commercialisation process. Consequently, the innovativeness of Class 4 firms is certainly much less than, say, some Class 1 firms.

It is also possible to see how attitude towards risk-taking varies with firm organisation. Risk and uncertainty are part and parcel of any research and development work, but the willingness to accept these risks varies considerably. One way of measuring this is to examine the typical length of time before the technical and commercial phases of projects are completed. Naturally the longer term projects involve a greater degree of risk and uncertainty. From Table 8.3 it is seen that, technically, the majority of projects are short term ones. In the case of Class 1 firms, this is because the organisation is small and does not have the capital strength to sustain projects over too long a time period. The larger New Zealand firms are the ones most prepared to do this with over one fifth of the Class 3 firms' projects taking longer than two years before completion.

From a commercial point of view interest in longer term projects is least in firms of Class 1 and 2. Class 1 firms do not operate at a scale large or diversified enough to be able to wait long periods for a return on their capital investment. For Class 2 firms the projects of a more speculative nature are possibly carried out by their parent company. Firm classes 3 and 4 spend a reasonable proportion of their time on projects that take a long period to be commercially applied. Once again these are the firms involved in economic activities of a greater scale and are therefore able to sustain low immediate returns on capital in anticipation of greater long term benefits.

Thus, it is reasonable to conclude that organisational structure does to some extent affect a firm's attitude towards research and development projects and their willingness to accept risk and uncertainty. Possibly too, it may have some influence upon the ability to successfully control this risk. An indication of this is possible from the proportion of commercial and market successful projects for the different firm types.

Success at handling the risks implicit in research and development does not appear to vary very much, as seen in Table 8.4. Generally the commercialisation rate is equal for all types of firms, with Class 1 firms being slightly higher, probably because of their need to identify with the market more quickly in order to survive. However, their market success rate is lower than the other three groups, often because the product they have developed is so specialised technically that it is regarded as a 'oncer' in the market situation. Classes 3 and 4 have the highest market success rate. This may be a result of their more divisionalised operational structure within which functions such as market research assume more importance than they would in a small firm.

While the rate of commercial and market success varies

Table 8.4: Relationship between Organisational Structure and Success of Research and Development projects.

Firm Class	Average Percentage of Research and Development projects that are:	
	Commercialised	Market Successes
I	79.7	64.0
II	77.1	69.5
III	72.6	73.0
IV	78.3	73.5

Source: Field Survey, 1975.

a little, the reasons for the failures are fairly constant, Non-commercialisation of projects can be a result of an unfavourable cost-benefit ratio, the excessive degree of capital investment required, problems of raw material supplies, and various technical or production inadequacies and incapacities. The failure rate also appears to be greater for projects involving the development of a totally 'new' product or process technology, rather than just innovation improvements. Market success can be prejudiced by inadequate market research, poor timing of the project introduction, distribution bottlenecks, unfavourable competion or unforeseen technical difficulties that develop when the technology is applied to mass production conditions.

Thus far it has been shown that organisational structure can have some affect upon a firm's attitude to research and development, its innovativeness and willingness to accept the risks and uncertainty inherent in research and development, as well as influencing its successfulness in dealing with these issues. Organisational structure may also influence the relative importance of sources of research and development projects and ideas.

<u>Sources of Projects</u>

In Table 9.1 the typical sources of project ideas for the various firm types are shown. The major source for the small independent firms is from the research and development staff. In some firms however, it is quite likely that these personnel overlap with those termed 'higher management' or 'marketing and production staff'. Considerable reliance is also placed upon external sources. These small, research-intensive firms often have important interaction

Table 9.1: Sources of Research and Development project suggestions.

Source of Suggestions (Percentage)	Firm Organisational Structure			
	Class I	Class II	Class III	Class IV
Research and Development Staff	36.4	36.8	24.5	27.2
Marketing/Production Staff	23.6	30.2	22.9	42.2
Higher management	17.7	17.9	26.3	16.6
Branch Plants and/or subsidiaries	3.6	2.6	7.1	2.5
External Sources	18.7	12.9	19.2	11.5

Source: Field Survey, 1975.

Note:- In comparison, work done by Mansfield et al., (1971) gave the following distribution pattern:

60 percent - research and development staff

17 percent - marketing staff personnel

9 percent - 'management' sources

8 percent - sources external to firm.

with other research organisations of government departments. In fact two of the firms surveyed are 'spin off firms', one from the Physics Department of Auckland University and the other from the Department of Scientific and Industrial Research in Lower Hutt.

Class 2 firms have most weight placed up on research and development and marketing/production staff. The equal importance of these two groups points to the necessity for close interaction between the research and development and marketing functions of the firm for the process of innovation adoption and diffusion to be successful. A technically complete product will not be successfully diffused if the marketing functions are not conducted properly vice versa.

For class 3 firms no one category assumes much more importance than another, but there is a larger comparative contribution from branch plants and subsidiaries. Nineteen out of the 24 firms have at least one subsidiary plus a number of branches, from which a certain amount of feedback must arise about possible product improvements and modifications to processing techniques. Branch plants and subsidiaries are not as important for the Classes 1, 2 and 4, because they do not have such a multiplant organisation.

In Class 4 firms marketing/production staff act as the most important source for project ideas. People working in such positions in the New Zealand firm probably engage in frequent trips overseas to the parent and other associate companies, viewing any new developments and evaluating their potential in the New Zealand context. Thus, the various types of organisational structure do, to some extent, place different emphases upon possible sources of ideas for research and development investigations.

It is interesting at this stage to note that not many firms carry out research and development in their branch plants or subsidiaries, supporting the idea that research and development is a centralised activity. Branch plant work tends to be supportive in nature, limited by the amount of equipment available and often concerned with practical trials and testing rather than more innovative matters. In the subsidiaries work tends to be of a specialised nature, perhaps into a particular product or process that is important within their operation but is not important to the parent company. However it is the firm headquarters that are in control and make the major decisions.

Criteria for Research and Development Expenditure

Possibly, too, firm organisational structure will affect the way a company evaluates research and development. Two questions about firm attitudes were included, one concerned with the determination of overall expenditure levels and the other with the selection of individual projects. Some general comments are possible but it is difficult to be precise in many cases, for the factors were often considered to be so interrelated and interdependent that any attempt to separate their relative importance was invalid.

Expenditure on research and development within the firms is, at least in the background, controlled by the general economic climate. At present, expenditure levels in many firms were low compared with sales down and firm profitability levels not as high as those normally experienced. These were perhaps the most important constraints on the amount of research and development expenditure and appeared to operate independent of firm organisational structure or industrial classification for all firms were affected to some degree. Research and development as an activity is carried out initially because it is past of the firm's business philosophy. It is recognised as an important tool in the firm's growth strategy and, once the firm has been involved, commitment to such expenditure is usually inevitable.

The direction of the expenditure is mostly controlled by the market situation. Conscious evaluation of market potentiality, of vacuums that exist and the feasibility of filling these, is carried out by all firms. Project feasibility includes evaluation, not just of the amount of capital investment required, but also of the availability of raw materials and the abilities of the workforce. Thus, once the more immediate constraint of current firm profitability has been overcome, closer consideration is given to firm growth strategy and firm competitiveness. What fields does the firm want to become involved in; should it concentrate on those in which it already has recognised expertise; and what new products are going to be most beneficial when added to the present product range? These considerations seem to operate for all firms independent of organisational structure.

When deciding what particular projects to work on a number of further factors come into consideration. These seem to vary, not so much with respect to organisation structure, but according to the particular industrial groupings. For example, the pharmaceutical firms prefer to avoid 'me-too' products, opting instead for more innovative developments. Similarly, electronics firms prefer to get involved in projects of a more complex technological nature, feeling that greater benefits will accrue to the firm if they are able to make the necessary technological advances. One particular firm in the textile industry places emphasis upon those research and development projects that have the greatest 'deskilling' component. With the introduction of equal pay and the high content of female labour in this industry, they are looking for process advances that can reduce the labour intensity of the firm's operations.

Projects must also be selected with close reference to the present resources and capacity of the firm. As one manufacturer phrased it, the firm has a 'bias towards extending our manufacturing and commercial activities in those fields in which we already have expertise, raw materials and experience'. Firms also appear to bear in mind the various institutional incentives, such as those provided by the Inventions Development Authority and the Industrial Research and Development Grants Scheme. Thus it would seem that differences in firm organisational structure do not really act as determinants for the amount of expenditure on research and development. Further, in the case of individual project selection it appears that industrial classification is a more useful explanatory variable of the decisions firms make.

This represents the discussion of the organisational perspective of research and development. A typology of firm organisation was established and it has been seen that the innovative quality of the firm and its willingness and ability to deal with the uncertainties involved in research and development varied for these different classes. Different sources for research and development suggestions were also examined with respect to firm organisational structure. Finally an examination of the role of organisational structure in research and development expenditure decisions showed that it was not really a critical factor and that industrial classification is probably a more useful explanatory variable. The final stage in this analysis of manufacturing firms is to determine what linkage effects might be associated with their research and development activity.

LINKAGE DEVELOPMENT

Linkages evolve from industrial activity as a result of the interdependent nature of production processes. A firm often requires inputs from other firms and may supply inputs to other firms, giving rise to forward and backward technological linkages (Hirschman, 1958; Thomas, 1972). Likewise, the firm has an impact on the market in which it operates either in the immediate geographical area or diffused throughout the country. Linkages can also be generated to firms involved in the capital goods industry. Changes in production process techniques may provide a capital goods firm with the opportunity to manufacture a new machine or carry out alterations to present production systems. When looking at these types of linkages discussion can only be general as the questionnaire was not designed to examine such connections in a quantitative manner.

Market Impact

Any research and development project, if it is applied successfully, usually causes an increase in sales and income generation. Even if the project is a product substitute, the sales volume of the new innovation is hopefully greater, at least after a reasonable time period, than the replaced product. Often employment figures are not affected with reallocation of labour occurring rather than more or fewer people having to be employed. This is especially the case for those technological changes which are evolutionary rather than innovative in nature.

The more innovative advances can often have dramatic effects upon the firm's growth. For example, one Christchurch electronics firm began production eight years ago with a staff of 12. The introduction of their first research and development project was successful, providing them with increased income and enabling the staff to expand to eighteen. On the basis of this first product further research and development investigation was undertaken and the product range was extended and diversified. This diversification has been directly responsible for the firm's growth, to the extent that staff numbers are now 130, sales are $1.6 million per annum and exports account for 15 percent of production. For a firm such as this, participation in the process of research and development has been concommitant with the total process of firm growth and expansion.

Research and development can also have positive market benefits to a firm if it becomes involved in a new product area or line. One firm, for example, had an established and successful product range when it elected to manufacture bicycles. This was a completely new development for the firm in which it has since been able to exhibit technical leadership to other manufacturers. New plant and equipment was introduced for the bicycle manufacture, production has now expanded to account for 50 percent of the firm's income, and employment figures increased by about 40 percent. This radical departure from established product lines has realised considerable benefits to the firm in terms of its overall market expansion.

Technological Linkages

Research and development not only has impacts for the firms in which it is carried out, but generates important growth-inducing impacts within firms to which it is technologically linked. The improved outputs of one firm may, in turn, represent improved inputs for another. For example, a chemical firm produced a new form of hot-melt adhesives which, almost immediately, had important advantages for the construction industry because of improvements that will be induced in the efficiency and productivity of their processing operations.

Similarly, major advances have taken place in packaging technology in New Zealand firms. New methods and new products have been introduced, often in response to changes in hygiene regulations. These new techniques have important ramifications for New Zealand's export trade because it is in the sale overseas of meat, fruit and other perishable products that the advances have shown most impact. Thus research and development carried out in the packaging firms, while increasing their own sales, has also enhanced the exporting opportunities for a number of linked firms. Further, the innovations involved in the introduction of frozen foods into New Zealand has lead to rapid expansion in commercial and domestic freezing equipment and in flexible packaging companies. Thus growth impacts can be induced from research and development via technological linkages that move backward to suppliers and forward to customers.

Technological linkage impacts also result from the system of subcontracting. A particular manufacturing firm may be unable or unwilling to make all the components which it requires. A useful way of dealing with this is by subcontracting. The subcontracted firm is required to develop a particular product, often following specifications drawn up by the original firm. To attain a reasonable standard of accuracy and quality the subcontractors may need to introduce a new piece of machinery into their production process. This, in turn, has improved their own technological capacity and has resulted from their linkages with a research and development oriented company. It is not just from improved technical capacity that the firm benefits, but this can also have multiplier impacts upon its own sales, its employment figures and general firm growth.

In some cases this idea of subcontracting may cause the establishment of a new firm. For example, with the introduction of television there was an increase in consumer demand for vinyl coated cabinets, a concept which is based on Japanese technology. The response has been such that two firms were established in Auckland and one in Wellington to fulfil such a demand. Once again the linkage connections involved in research and development have caused significant growth impacts. It must also be recognised that research and development advances in one firm are likely to have some impact upon that firm's competitors, for they will obviously undertake activity in some direction to maintain their share of the market.

Capital Goods Linkages

A further type of linkage connection is with the capital goods industry and benefits here can result from improvements in either product or process technology. A change in the state of either form of technology may necessitate the introduction of new machinery and equipment into a firm's production process. If this is done by an outside company growth inducing forces may come into operation.

From the firms in the survey it appears that the majority of capital goods, not just those used in the research and development department but also for general production, are imported from overseas. This is because of the highly specialised nature of the equipment, reducing the viability for any one firm in New Zealand to make such machinery for a small market. Also, any modifications that are needed on firm plant are often carried out by their own workshop staff. In this instance any benefit from the capital goods linkage would be internalised. But, while the capital goods linkages appear to be comparatively weak, there are still instances of positive benefits. For example, an engineering firm in Wellington has bought twelve pieces of equipment over the past five years, valued at a total of $300,000, all of which have been manufactured by the same Auckland company.

'Spin off' firms

Research and development can also have an impact in terms of the establishment of 'spin off' firms, either from other firms or from other research organisations. Two examples of this phenomenon have been previously mentioned.

The firm which evolved from the Physics Department of Auckland University was established to produce one particular product. The total output of this product is exported, as its highly sophisticated and technical composition is not oriented to the New Zealand market. The income that has been gained from this product has enabled the firm to support further research and development investigations, which are essentially offshoots of the original product. Its growth as a firm has snowballed because of the successful application of the original research and development project.

New firms may also spin off from existing firms and this has happened twice in the case of one Auckland plastics firm. In two instances a member of the research and development staff has carried out research and development work into a new product, developing the dyes required and producing a technically successful product. Unfortunately the main firm did not pursue the marketing function as vigorously as it could have, with the result that the individual concerned left the main firm, established one of his own, and markets the product concerned. In both cases the establishment of the new firm has been successful and marketing has been extended to include a sizeable export component. Such linkage impacts can occur in a variety of industrial groups. In a Wellington chemical firm six employees have left to form two separate firms. A pharmaceutical firm developed a new process for utilising a hitherto wasted by product of the meat industry, resulting in the establishment of a new firm.

These spin off firms may become of increasing importance to New Zealand industry. One feature of such firms is that their initial research and development costs are relatively low because most of the work has been done in the firms from which the new organisation has evolved. (Freeman, 1971). These firms also indicate the beneficial effects of personnel mobility. The transfer of research and development workers from one firm to another must be an important means of information diffusion. Although this mobility factor might seem immeasurable, its importance cannot be denied. It certainly represents a valuable growth inducing linkage connection, even though its form is rather intangible.

Spatial Dimension

The linkages as described have been sectoral in nature and it is important to remember that they also have a spatial dimension, (Table 10.1). The tendency for the firms located in Auckland is for any impacts, both market and technological, to be concentrated locally. Preference is for Auckland firms to do the subcontracting, to provide components and to serve as the major customers. This is probably a reflection of the fact that much of New Zealand's industrial activity is concentrated in the Auckland region. By contrast, firms in Wellington often develop technological and capital goods linkages with Christchurch firms. The Wellington firms claim that Auckland firms are able to charge a higher price for their services because of the inconveniences involved in using firms located in other centres. Wellington firms, being at a different geographical location, operate under a different set of conditions and any delays that may arise in terms

Table 10.1: Spatial Pattern of Linkage Development.

Firm Location	Market Impacts		Technological Impacts		Capital Goods Impact	
	Regional	National	Regional	National	Yes	No
AUCKLAND	15	5	13	7	12	8
WELLINGTON	8	5	5	8	7	6
CHRISTCHURCH	8	3	8	3	5	6
DUNEDIN	4	-	4	-	2	2
OTHERS	12	2	11	7	10	4

Source: Field Survey, 1975.

of transport are more than compensated for by the lower costs of the Christchurch firms.

Christchurch firms have strong linkages with the immediate geographical area and also place a lot of importance on the use of Dunedin based engineering firms. This applies equally to both marketing and technological linkages. Firms in the secondary areas appear to have a concentrated linkage pattern also although the technological impacts are somewhat broader. For example, there is a company in Marton that is actively involved in research and development work. Wherever possible their policy is to use local manufacturers and subcontractors. A Marton panelbeater bought a new piece of equipment and he now provides all the sheetmetal requirements. Firms in Feilding and Palmerston North also provide a range of components so that any growth impacts wouldtend to be localised. This is also the case in the Tokoroa-Kinleith area where many satellite industries are directly dependent for their existence and survival upon the technological developments associated with pulp and paper manufacturing.

From this discussion it is seen that a complex of intraindustry and interindustry linkages do result from research and development activity. Impacts are generated for those firms supplying inputs, for those consuming outputs and for those of the capital goods industry. It must be realised that the linkages can be responsible for both positive and negative effects, for if the expansion of the original firm is constrained so too is that of linked firms. In the words of one Christchurch manufacturer, 'Foundries, and other sub-contractors are deeply affected by our sales rise and fall'. It has also been shown that, except for the Wellington firms, most of the growth inducing impacts associated with research and development activity tend to have localised benefits.

Chapter Four :

THE ORGANISATION OF RESEARCH AND DEVELOPMENT IN NEW ZEALAND'S RESEARCH ASSOCIATION

> The primary aim of all research associations is to benefit, by the application of research results, New Zealand manufacturing and processing industries, by maintaining their trading competitiveness on the domestic and overseas market.
>
> Dr. R.W. Willett, former Assistant Director General, Department of Scientific and Industrial Research.

Industrial competition has become increasingly dependent upon technological change and advance in the twentieth centry, with even the most traditional of industries being involved in this process. This has led to a reassessment of attitudes towards industrial research and development, not only in New Zealand but throughout the world. The previous chapter gave a description of individual firm involvement in research and development along with some discussion of its impacts and its importance. This new interest in research and development in New Zealand is also reflected in a second way, by the establishment of the research associations. New Zealand's ten research associations represent a joint effort by industry and government to improve the overall efficiency of industry. This applies not just to agriculture, on which past attention has been concentrated, but also to manufacturing activities. Investigations are carried out by the research associations into the products and processes typical of the industry group, and any assimilation of the association's results and suggestions will almost certainly cause an improvement in the competitiveness of the industry concerned.

For this thesis a questionnaire about industrial research and development activity in research associations was formulated and responses were received from seven out of the ten associations. Because the numbers are so few in comparison with the number of firms surveyed it is difficult to differentiate patterns or trends of a widely varying nature. However, general comments about the industrial research and development function of these research organisations are possible and, from these, some indication of their role in New Zealand's Industrial growth can be ascertained.

Research and Development Expenditure

For 1975 the research and development expenditure budget (Table 11.1) for the 7 research associations totalled $2,650,000, 45 percent of which was spent by the Dairy Research Institute and 23 percent by the second largest association. This left five research associations to share the remaining 32 percent of expenditure. Such figures give some indication of the different nature of the seven associations. Obviously there is a large size range, irrespective of whether this is measured in terms of dollars spent, people employed, or quantity of work undertaken. It is the largest association that has the highest expenditure budget, while the smallest has the least.

This differential capacity is also reflected in the rate of growth of the various associations. Three of them have no expenditure figures for 1965 as they were not formed

Table 11.1: Research and Development expenditure in Research Associations

Research Association	Total Expenditure		Percentage Increase 1965 - 1975	Percentage Government		Percentage Industry		Payroll as a percentage of expenditure	
	1965	1975		1965	1975	1965	1975	1965	1975
Number 1	-	$ 619,000	-	-	28	-	72	-	-
Coal	-	$ 262,000	-	-	47	-	53	-	67
Concrete	-	$ 130,000	-	-	50	-	50	-	50
Dairy	$230,000	$1,200,000	421	43	40	57	60	46	53
Fertiliser	$ 35,000	$ 250,000	614	45	50	55	50	74	81
Launderers' Drycleaners, Dyers	$ 30,000	$ 53,000	76	50	43	50	57	66	71
Leather and Shoe	$ 47,000	$ 136,000	189	50	50	50	50	69	61

Source: Field Survey, 1975

until 1967, 1970 and 1972. As far as the percentage increase in expenditure can provide some indication of the rate of growth and progress of the associations, it can be seen from the table that the Research Institute of Launderers' Drycleaners and Dyers has the slowest rate of expenditure increase. In fact its 1975 research and development budget is about two and a half times smaller than that of the Concrete Research Association established in 1972. Absolutely and relatively, this association appears to be of least significance. However, this is not to suggest that the contribution to its industry is any less than that of the other organisations, as its need for capital investment may be considerably lower or the particular emphasis of its research and development programme may be different.

It is interesting to note the breakdown of income sources. In three out of the seven associations in 1975 the ratio between industry and government finance was equal while in the other four cases industry provided the greater share. A similar trend is apparent from the figures available for 1965 and it seems unlikely that any major alterations will occur in the future. Industry provides its finance either from member subscriptions or by paying for specific research investigations. In the first research association the proportion contributed by industry is particularly high due possibly to a greater emphasis upon individual research projects. The fact that industry does provide a large proportion of the research associations' income reinforces its accountability to that industry for its actions.

It is interesting to note how the breakdown of income sources compares with some overseas examples. According to Table 11.2, industry provides at least half of the income in every country except the Netherlands. The income gained from contract research is important in some places and it would be interesting to learn what significance contract research plays in the activities of New Zealand's research associations. Possibly this is an activity that will increase as the degree of involvement by industry increases.

It seems reasonable to anticipate that the research and development staff payroll would represent the major item of expenditure. Some capital goods investment is always required, plus long term expenditure on buildings and facilities, but it is staff salaries that represent the major immediate cost. While absolute figures will undoubtedly have increased, in proportionate terms this share of the research and development budget has not really changed over the past ten years. For the Fertiliser Manufacturers' Research Association the figure is particularly high (81 percent) as this is an association where capital investment requirements are low. This contrasts with the Concrete Research Association where immediate expenditure on long term equipment is probably of greater relative importance, and similarly in the research associations more concerned with the processing of agricultural products, where pilot plants and process trials are significant and do involve a reasonable amount of capital expenditure. Overall then, this \$3,650,000 spent in the research associations and the \$4,290,000 spent among individual firms, as discussed in the previous chapter, represents a sizeable investment by both industry and government in industrial

Table 11.2: Sources of Income for Overseas Research Associations.

Research Associations Abroad, 1962

Country	Sources of Income (Percentage of total)		
	Government	Industry	Contract Research
Austria	10	50	40
Belgium	31	57	12
Denmark	9	77	14
France	2	90	-
Germany	30	63	7
Italy	50	50	-
Netherlands	60	7	33
Norway	10	90	-
Spain	50	50	-
Sweden	20	75	5

Source: Johnson, 1973, 195.

research and development. It is therefore quite important that a reasonable level of return be made to general industrial growth and development.

Staffing

The number of research and development staff in the seven associations (Table 12.1) totalled 238 with the range being from five to 133. The Dairy Research Institute, which accounted for 45 percent of expenditure, has 55.8 percent of the staff. Its staff numbers have increased over the past ten years by about 150 percent as part of the association's general growth and the broadening of work undertaken. By contrast the Research Institute of Launderers' Drycleaners and Dyers shows no increase in staff numbers over the ten year period, suggesting that the industry it serves is a fairly stable one and one in which major technological advances are comparatively unusual. It also is reflective of the major role that its advisory services play in the association's general functioning, rather than more 'research-intensive' activities.

The number of staff that hold recognised scientific or engineering qualifications is, for all but two groups, well over half the total. From the figures it is reasonable to expect an improvement in the level of scientific and technological capacity and ability over the past ten years as the percentage of qualified personnel has certainly increased. For two of the organisations the figures are not especially high. The Coal Research Association has the same percentage qualified as when it was formed in 1967. A reasonable proportion of this association's activities is advisory work, wherein experience in the practical situation is probably just as valuable as formal qualifications.

Table 12.1: Distribution of Research and Development Staff in Research Associations.

	Total Research and Development Staff		Percentage Qualified	
	1965	1975	1965	1975
Number 1	-	33	-	69
Coal	-	25	-	28
Concrete	-	8	-	38
Dairy	55	133	31	73
Fertiliser	11	21	27	76
Launderers' Drycleaners Dyers	5	5	100	100
Leather and Shoe	8	13	50	55

Source: Field Survey, 1975.

The figures for the Concrete Research Association are also comparatively low, due in this case to the fact that it is only newly established and, as such, has not had sufficient time to establish a scientific reputation distinguished enough to attract qualified personnel.

Tables 11.1 and 12.1 therefore provide some indication of the growth pattern of the seven research associations covered. As the demands made of them increase over time so too will expenditure and staffing figures. This obviously does not occur at the same rate for every association but, irrespective of the scale of operation, there will almost certainly be beneficial feedback to the industry groups concerned.

Membership

The system of membership application varies between associations and therefore it is not always possible to determine what proportion of industry is actually represented. For two of the organisations industry finance is received by a levy placed on the total amount of production. The Dairy Research Institute received its financial contribution from the Dairy Board, and the individual firms therefore only contribute indirectly according to the quantity of their exports. In the remaining four cases affiliation is on an individual basis. The Concrete Research Association has 100 percent support from the cement industry, while the Fertiliser Manufacturers' Research Association has 6 members which is all the firms involved in such an activity. Within the Leather and Shoe Research Association there is 100 percent support from the tanners and fellmongers with 70 percent representation from footwear manufacturers. The Research Institute of Launderers Drycleaners and Dyers serves three separate groups and includes 70 percent of Laundry and Drycleaning firms, 5-10 percent of Textile firms and 28 percent of Institutional Laundries, including hospital boards.

Thus, although the means by which industry contribute financially to their particular association does vary the overall coverage of potential firms does seem to be reasonably high. This would mean that much advantage can be gained from the research associations findings and can potentially be translated to the maximum benefit of the industry concerned. It should also be noted that the government retains some representation on the executive of each research association but, in general, tends to leave the association's operation as much as possible in the hands of the industry.

These comments on expenditure, staffing and membership represent the operational details of New Zealand's research associations, with expenditure and staffing numbers having generally increased in response to the greater demands made by industry. The interaction between industry and research association, in terms of general functioning, has also been outlined. It is now useful to look at the particular structure of the research and development programme of the seven research associations. As was the case with manufacturing firms, this can be analysed firstly by differentiating between basic research, applied research and development, and secondly by looking at product/process orientation plus the relative role of the advisory functions. Any similarities or differences in particular emphases will possibly give further clues as to the contribution that research and development work within the research associations can make to national industrialgrowth.

Research and Development Programme

The relative concentration of the associations upon basic research, applied research and development can be seen from Table 13.1. Definitions of these three research categories are the same as those that applied for the manufacturing firms. Two of the seven associations are not involved in any basic research but, in compensation, their concentration upon applied research is particularly high. This is because, in both cases, the raw materials used are standard, and attention is therefore directed to learning more about the performance of these materials in production conditions rather than gaining new knowledge about their basic qualities. At the other end of the scale association number one spends 40 percent of its research and development effort on basic research. In this instance production and process performances are being re-evaluated continuously and many raw materials need to be appraised in terms of their applicability to the New Zealand context. Much basic research is therefore required to learn more about the physical and chemical properties of such materials so that industry may take full advantage of the new technological developments.

The category of applied research assumes at least equal importance as that of development. In many cases the applied research category corresponds with the advisory service that associations provide so that, for example, in the Research Institute of Launderers', Drycleaners and Dyers

Table 13.1: Research and Development Programme Emphasis.

	Basic research	Applied research	Development
Number 1	40	30	30
Coal	20	40	40
Concrete	0	80	20
Dairy	25	40	35
Fertiliser	0	90	10
Launderers', Drycleaners and Dyers	10	80	10
Leather and Shoe	10	45	45

Source: Field Survey, 1975.

where the advisory function is of major significance the emphasis on applied research is correspondingly high. The Concrete Research Association which also has no basic research component, was only established in 1972 and has therefore probably elected to concentrate on those projects which offer more immediate returns. Also, much of the basic research that would be applicable to this research association is already being carried out in other research organisations so that duplication of such effort is best avoided.

The development phase of research and development activity makes up the final component and, while all the associations engage in this work to some extent, at no stage is it of greatest importance. Its highest representation is in the Leather and Shoe Research Association. In this particular organisation there have been some recent major process advances which have potential growth impacts for the industry concerned. This potential has only been realised because equal emphasis has been given to the applied research and development phases; that is, a conscious attempt has been made to apply the results to the various processing stages.

While British industry has more research associations than New Zealand, it is possible from the following table (Table 13.2) to appreciate the relative emphasis on basic research, applied research and development within their system. Generally, basic and applied research are more important than the development category, which is similar to the New Zealand situation. Most of the British research associations give significant emphasis to basic research,

Table 13.2: Breakdown of the Research Association's Current Expenditure by Product Group into Basic Research, Applied Research and Development, 1968/69.

	Percentage of total Expenditure		
	Basic Research	Applied Research	Development
Food, Drink and Tobacco	49.9	44.1	6.0
Pharmaceutical Products and Plastics	35.9	50.7	13.4
Chemicals and Coal Products	25.1	55.7	19.2
Iron and Steel	30.2	40.5	29.3
Non-Ferrous Metals	24.4	45.7	29.9
Mechanical Engineering	29.7	46.3	24.0
Metal Products not elsewhere specified	29.5	39.6	30.9
Ships and Marine Engineering	10.0	77.9	12.1
Scientific Instruments	20.3	57.2	22.5
Electrical Engineering	30.6	59.3	10.1
Motor Vehicles	29.0	71.0	-
Railway Equipment	-	-	-
Textiles and Man-made Fibres	15.3	71.3	13.4
Clothing, Footwear and Leather	19.7	45.3	35.0
Stone and Clay products	9.8	71.7	18.5
Timber, Furniture, Paper, Printing and Publishing	18.3	54.4	27.3
Rubber and Rubber Products	-	74.9	25.1
Other Manufactures	20.0	53.3	26.7
All Product Groups	23.5	57.4	19.2

Source: Johnson, 1973, 217.

a trend which can be expected to consolidate in New Zealand as the research associations become more closely integrated into the industrial system.

The average relative distribution of research and development effort in the New Zealand research association is for 15 percent of expenditure to be allocated to basic research, 57.8 percent to applied research and 27.2 percent to development. This compares with the respective figures of 3.4 percent, 28.2 percent and 68.4 percent for research and development activity in individual firms. Probably the most obvious difference in emphasis is the concentration in the research associations upon the more fundamental phases of research and development. Basic research is by definition speculative and long term, with results inevitably being uncertain. Because of the degree of risk involved individual firms are unwilling to engage in such work, whereas the research associations are not operating under such immediate profit compulsions. This is therefore one way in which the research and development programme of the research association can readily supplement that of individual firms.

It is for similar reasons that the research associations are more concerned with applied research work. Applied research tends to concentrate on problems common to the majority of industry members. By preventing duplication of such effort on the part of individual members, this represents important savings in resources to the industry as a whole. Development work is comparatively less important to the research programme of the associations because this is closely linked to the commercialisation phase of innovation introduction. This is where the member firms become more important in their efforts to assimilate the association's research results. The successfulness of this assimilation process is reflective of the degree of integration and interaction that occurs between research association and industry.

As far as future changes in emphasis are concerned, the response was quite predictable. The Concrete Research association anticipates an increase in the role of development for the reasons previously outlined. The Coal and Leather and Shoe Research associations expected a relative increase in basic research; the Fertiliser Research Association and the Research Institute of Launderers', Drycleaners and Dyers expected an increase in applied research while two anticipated no real proportionate changes. It would appear that the research associations are going to become more concerned with the basic end of the research and development continuum, particularly as research and development activity within member firms increases in significance and becomes a more integral part of the firm's general functioning. This is a predictable trend, for New Zealand's small scale manufacturing enterprises are becoming more aware of the fact that a programme of basic research is best sustained by co-operative effort rather than on an individual basis.

Thus the research and development programme of the research association must be constructed with close reference to the needs of industry. Generally it will have a broader frame of reference than the work of individual firms because the associations are not subject to daily production pressures. However, the work must at all times serve the best interests of industry members and take into account the feedback that comes in from the field.

Product/Process Orientation

A further dimension to the programme's integration into industry's requirements is given by the particular product/process orientation of research and development activity. As far as the work programmes for the associations are concerned, five categories of activity can be delineated and their relative significance is portrayed in Table 14.1. The first variation of this table from that for the firms is the inclusion of the category advisory services. This service represents an important part of a research association's functioning with all but one of the organisations being involved. Advisory services account for a large amount of the applied research that is carried out. Firms approach the research association with problems and advice is given once the investigations have been conducted. The association most involved with this type of work is the Research Institute for Launderers', Drycleaners and Dyers which, as was previously shown, was the one to grow at the slowest rate and had the greatest emphasis on applied research. This association chooses to provide a scientific advisory service to the industry group it serves rather than being concerned with developing new technological advances. The advisory services also perform an important role in bridging the communication gap between research association and industry. Discussion about particular problems provide a useful means for industry feedback and a method by which the association can determine

Table 14.1: Programme Distribution between Products, Processes and Advisory Services.

	Develop new products	Modify existing products	Develop new processes	Modify existing processes	Advisory Services
Number 1	20	20	15	15	30
Coal	10	0	30	30	30
Concrete	20	40	40	0	0
Dairy	15	30	15	30	10
Fertiliser	10	10	10	60	10
Launderers', Drycleaners and Dyers.	0	5	10	20	65
Leather and Shoe	15	15	15	15	40

Source: Field Survey, 1975.

priorities for its research programme.

In five out of the seven associations the attention given to process development is at least equal to or greater than that given to product development. Only two associations give greater emphasis to product work. This is in strong contrast to the research and development work that was analysed in the individual firms, where concern for products was greater than that for processes in 77 percent of the cases. Further, the emphasis is on modification of existing products rather than the development of new ones. Process research is more important to the associations because its long term and more basic nature cannot be readily assimilated into the research and development programme of many firms. For example, in the Fertiliser Manufacturers' Research Association, modification of processes, in this case investigating the uses of the common raw material, needs to be conducted on such a large scale that the maximum advantages accrue when the work is supported cooperatively and is carried out by the association. Similarly, there is the reduced emphasis on product development which is the type of work that is easily conducted by separate companies with reference to their individual growth strategies. This illustrates further the complementary nature of research and development activity carried out by research associations and by industry.

Sources of Project Ideas

This association-industry integration is evident too when looking at the source of ideas for research and development projects. Figures averaged out for the seven associations show that association personnel provide 42.8 percent of the ideas, the industry served provides 48.5 percent and other research organisations 8.5 percent. This almost equal importance of association and industry ideas suggests that the research associations are well aware of their accountability to industry and the need to dovetail their projects to fit closely into industry's needs and interests. The association personnel perform the function of technological gatekeepers, keeping abreast of the latest technological developments, while the industry people provide the problems that arise out of the practical production situation. Other research organisations are able to contribute also, particularly where there is some overlap in terms of materials used. For example, if the dairy industry needs specialised materials for the construction of a particular plant it would be to its advantage to consult with the findings of the association serving the building industry. This type of interaction is well summarised by the director of the Concrete Research Association when describing his own research programme: "There are two types of research: (1) research projects of wide interest to industry, selected by the Association; (2) specific research arising from problems and needs to which the industry draws attention".

Criteria for Project Selection

All of the research associations seem to be aware of the fact that the primary reason for their establishment is to improve the state of competitiveness of their industry. This comes from looking at the criteria associations consider when evaluating a particular research and development project (Table 15.1). Either directly or indirectly the goal of industrial growth is apparent. For the first asso-

Table 15.1: Ranking of Criteria for Selection of Research and Development projects.

	1	Coal	Concrete	Dairy	Fertiliser	Launderers' Drycleaners, and Dyers.	Leather and Shoe
Improved firm productivity	1	4	5	4	2	1	3
Greater efficiency for industry	2	3	4	2	1	2	2
Development of domestic markets	-	1	2	5	5	-	-
Development of export markets	-	-	-	1	-	-	1
Use of new natural resources	-	5	3	-	4	-	4
Better use available resources	-	2	1	3	3	-	-

Source: Field Survey, 1975.

ciation improved productivity for firms is the prime consideration. This is because most of the problems in this industry are the result of the lack of application of existing principles and techniques. It has been estimated that if the efficiency of the industry can be increased 5 percent by the application of existing knowledge, costs for New Zealand could be reduced by $20million a year. Thus, by improving firm productivity industrial growth will result. Firm productivity is also the prime consideration for the Research Institute for Launderers' Drycleaners and Dyers, and this is largely achieved by the emphasis given to its advisory services.

The Dairy Research Institute and the Leather and Shoe Research Association are concerned firstly with the development of new and enlarged export markets. Both associations are involved in the processing of agricultural products and therefore any expansion in export markets will have growth impacts for the industry as a whole. Similarly, the Coal Research Association is concentrating upon expanding the domestic market for its raw materials. This is done by improving the processing and distribution techneques of the industry and any advances made will hopefully encourage more widespread domestic use of this raw material. The Concrete Research Association emphasises better use of available natural resources which, if achieved, must lead to improved efficiencies and productivities to both firm and and industry. The Fertiliser Manufacturers Research Association sees greater efficiency for industry as the factor receiving greatest consideration in the selection of projects. In this association all firms of the industry are members and all are involved in processing the same basic raw material. There is little diversity of interests among the members, so industry efficiency readily becomes the central concern.

The ranking of factors in project selection varies somewhat among the research associations because of the different resource bases and different market orientations of the industries concerned. However, the principle objective behind all projects is the enhancement of the industry's efficiency and trading competitiveness. From such considerations it is therefore reasonable to anticipate that the research and development work carried out in the research associations certainly will have beneficial growth impacts for the industries concerned.

External Technology

An attempt to determine what role the research associations play in controlling the inflow of external sources of technology and in developing new forms of technology was largely unsuccessful. For the vast majority of firms analysed overseas sources represented the major supply of technology. This technology supply can flow directly to the individual firm or be channelled through the research associations. For example, in the Leather and Shoe Research Association, it is regarded as one of its major functions to introduce overseas technology. Investigations into external technologies are carried out to determine whether or not they can be used to advantage in New Zealand. The introduction of one piece of overseas technology can have multiple effects upon the total production process, so its characteristics must be carefully examined in both the short and long term context.

A similar principle applies for research association one. This association acts as a channel for overseas technology, carrying out investigations into applicability for the New Zealand context. The small size of the New Zealand market and the differences in physical conditions restricts the feasibility of many overseas developments. The Fertiliser Manufacturers' Research Association is at present conducting one investigation which, on completion, will represent a 'new' form of technology. But because of the long term nature and large scale of this project it receives low priority in terms of overall research and development work, and probably will not be completed for quite some time. The Dairy Research Institute because of its greater scale of activity, has been involved in the introduction of both types of technology but there were no real differences that arose during the marketing and production application of the two types of technological developments. Probably the problems associated with marketing and production will, to a large extent, be borne by the individual firms adopting the new technology, because this is essentially a part of the commercialisation phase of innovation adoption.

The role of research associations in the international process of technological transfer seems a little unclear. Each association must to some extent be involved in appraising and evaluating technological developments that originate from overseas, while some are also concerned with developing new forms of technology themselves. Any advances that are made will, at some stage, have an impact upon the industry's income generation, whether just through an increase in sales or through the introduction of more plant or the establishment of a new firm. Such impacts are difficult to quantify, at least in terms of the questionnaire used in this study. Possibly this is an area in which closer analysis and investigation would be advantageous, not just for industry but for gaining a greater understanding of the process of technological transfer internationally and intranationally.

Influence of Firm Characteristics

It is very seldom that the member firms of a research association show any uniformity in terms of structural or organisational characteristics. Because of such differences and diversities of interests it is reasonable to hypothesise that firms have different demands of their research association. This was certainly found to be the case when differentiating on the basis of firm size. Small firms require on the spot advice to deal with a variety of trouble-shooting problems. Proportionately they make the greatest number of demands of the research associations but the inquiries are less innovative in nature. They seek advice on productivity methods, want tests carried out on particular materials and need information about standards specifications.

The larger firm, often with its own research and development facilities, does not require this service to the same extent and may prefer the research association to be involved in more basic work, providing background material for its own research. In comparison with the smaller firms, the larger firms often have the technical capacity required to deal with short term or immediate problems.

Hence the concern with research and development rather than just advice. This trend is not without exception of course, for the research and development activities of the small research-intensive firms described in the previous chapter must be acknowledged.

Differences in requirements between science - and non sciencebased firms were apparent in the Leather and Shoe Research Association. The tanning industry is scientifically based and its demands are technologically more complex than the footwear industry which is not as scientifically concerned. Publicly owned firms in the Fertiliser Manufacturers' Research Association had a more restricted production range than those that are privately owned and therefore its research and development requirements were somewhat narrower. Further, in one association overseas ownership was to some extent a disadvantage with respect to the speed of getting technological change accepted by the parent company, as they were often out of touch with the local situation and had little appreciation of the need for change. Variations in the differences of scientific base and ownership patterns were found in one or two of the associations but could not really be regarded as typical of all seven. The only general differentiation of function was caused by firm size.

The firm size variable is also important when determining whether the research and development activities of the associations are complementary to or a substitute for private research. In four of the research associations (Coal; Concrete; Dairy; Launderers, Drycleaners and Dyers) there is no private research carried on within the industrial groups represented. In the other three organisations research and development work is complementary, more particularly with respect to the larger firms in the industrial groups. The work done in these firms is normally confidential to the firm concerned so that any benefits are internalised. Co-operation also exists between research associations and work done in universities and other government departments, always with the intention of avoiding duplication and of maximising the use of the facilities available. The relationship between research and development in associations and in industry is a dynamic one and it is expected by all associations that the future amount of private research will increase. This will largely be a byproduct of the associations' attempts to improve the research and development facilities in individual firms which will, in time, promote general industrial growth.

The analysis of research associations thus far has dealt with the general functioning of industrial research and development activities. The general principles of expenditure, staffing and membership have been outlined. The nature of the research and development programme and the criteria regarded as important in deciding the programme balance have also been considered. Further, the role of the research associations in the international technological process was briefly outlined. The overriding principle behind the analysis is that the industry's efficiency and competitiveness. Embodied technological changes that occur within the research association are readily diffused to member firms. The diffusion of an innovation developed within a noncompetitive organisation such as New Zealand's research associations will take place more quickly and on a broader scale than an innovation developed in an individual firm. Possibly there will also be some differences in the resulting growth impacts, either in terms of direction or degree, caused by this different diffusion pattern. This is something which is not examined within this thesis but would certainly be of interest when examining the general process of technological change for any country.

Locational and Linkage Impacts

Overseas illustrations can be found of instances where a research association, often in conjunction with other research organisations, has acted as a locational attraction with respect to the siting of individual firms. (Clarke, 1971; Buswell and Lewis, 1970). Either a new firm is founded in close proximity to such a science complex or an established firm relocates to take advantage of reduced costs in the acquiring of the latest technology. Two scientific complexes of a reasonable scale exist in New Zealand, one being at Gracefield, Lower Hutt where three research associations are housed in the same building and near to two of the Department of Scientific and Industrial Research industrial divisions. The second example is at Palmerston North where two research associations are located adjacent to some Department of Scientific and Industrial Research divisions and Massey University.

However these two science complexes have had no locational impacts with respect to individual firms. No company has relocated to take advantage of these pools of scientific and technological capacity. Perhaps the costs of acquiring new technology in New Zealand are not significantly spatially differentiated, and this may be a result of the successful functioning of the advisory services of the research associations. Possibly too, the scientific infrastructure of New Zealand is not developed to the extent that such locational impacts would occur. In terms of their influence as a locational attraction, it must be concluded that research associations have no real impact in the New Zealand industrial scene.

Another possible impact is for the association to promote the establishment of a new firm or new plant. Isolated examples of this were found in the various industrial groups of the firms analysed in the previous chapter and this is also the case with the research associations. For example, the Coal Research Association developed an improved means of processing its basic raw material which was embodied in a new domestic heating unit. This development was adopted by a firm in Winton who set up a new factory and now supply the product to a national market. All of this firm's expansion over the past four years can be directly attributed to the adoption of the process modification developed by its industry's research association.

Similar developments have occurred within the Dairy Research Institute. With evolutionary improvements in processing techniques there has been a widespread amalgamation process within the dairy industry. A number of small firms combine to form one large firm which locates centrally with respect to its particular supply area. As well as this relocation effect, product and process advances have stimulated the need for new plant and equipment to be introduced. Such expansions occur throughout the whole industry with some specific examples being at Warkworth where a change was made from butter to mechanised cheese production; at Longburn with the introduction of a milk biscuit plant; at Featherston with a change from casein to milk-powder; and at Eltham where fancy cheeses were introduced into the product range. The amalgamation phenomenon has meant significant improvements in the efficiencies and productivity of the industry as a whole, while the introduction of new plant has enabled general expansion and growth. This is directly a result of the research and development work carried out within this particular association.

The Leather and Shoe Research Association has also been able to generate such impacts as a result of its research and development investigations. From their work, a greater degree of processing of the tanning industry's raw materials can now be carried out before the product is exported. Unprocessed exports are replaced by semiprocessed exports. This represents a considerable increase in earnings with the value of leather exports rising from \$¼ million to \$5 million. This processing improvement has also made possible the establishment of six new tanneries to take advantage of this particular advance. These firms are located at Napier, Hastings, Wanganui, Washdyke, Oamaru and Invercargill. Once again the work of a research association has had positive growth impacts for the industry concerned.

As far as the capital goods industry is concerned, any impacts are very weak. The majority of equipment used, both for research and development work and any general production requirements, comes from overseas. The highly specialised nature of the requirements does not make it feasible for New Zealand firms to be involved in such manufacturing. Probably the only association that is able to provide regular custom for the capital goods industry is the Dairy Research Institute. This association is very much involved with continual improvements in processing technology. Sometimes this necessitates the introduction of new machinery or the modification of present equipment. This can be carried out by New Zealand firms, with the ones in the immediate geographical area having first advantage if they are able to do the work required.

From this analysis it is possible to see that research and development activities undertaken in the research associations do have significant industrial impacts. Minor technological advances can be important in improving the way in which production is carried out and the general trading competitiveness of the industry while the more innovative technological advances could cause the establishment of new firms and effect deeper changes in the industrial structure. It is the case in every research association that the distribution or concentration of these impacts follows closely the industrial distribution pattern. The benefits generated by the Coal Research Association will obviously be distributed in close relation to the location of the coal fields and the firms that are working there. The activities associated with the first research association are ubiquitous in location, so any growth impacts tend to follow the general pattern of population distribution. Similarly, the footwear and tanning industries are concentrated in Auckland and Christchurch, so the direction of any growth inducing impacts emanating from the Leather and Shoe Research Association will tend to be concentrated accordingly. The general conclusion from this analysis is that New Zealand's research associations are very conscious of their accountability to the industry they serve and are constantly endeavouring to effect improvements in their overall trading competitiveness.

Chapter Five :

CONCLUSION

This thesis has examined the nature and role of industrial research and development in New Zealand. Analysis has proceeded by investigation of two groups of organisations involved in research and development; manufacturing firms and research associations. In the first case it was suggested that manufacturing firms are primarily concerned with the adoption and adaption of overseas technology. Their research and development activities were examined generally, sectorally, organisationally and in terms of their linkage impacts.

The surveyed manufacturing firms employed 490 people fulltime on research and development, with overrepresentation evident in those firms having the largest research and development units. Research and development expenditure for 49 firms totalled $4,290,000 with 33 percent of the largest firms accounting for 71 percent of the expenditure. In absolute terms research and development appeared to be more significant in the largest firms. However, when research and development expenditure was related to total sales no such concentrations were evident. Large size was not a prerequisite for involvement in research and development and small firms were just as innovative as larger firms. This shows that any evaluation of research and development activity in a number of firms needs to consider factors such as research intensity and the technological base of a firm as explanatory variables in addition to firm size.

Firms gave greater emphasis to product development than process development and, within this, to development of new products rather than the modification of existing ones. Because process technology tends to be more complex and long term than product technology, overseas technological sources become important, a consideration which supports the basic premise put forward for manufacturing firms.

On average, firms spend 68.4 percent of research and development effort on development, as compared with 28.2 percent on applied research and only 3.4 percent on basic research. The major emphasis on development suggests the importance to the firms of external and overseas sources of technology. Development was more important than applied research in all firm size categories. Interestingly, basic research received its greatest emphasis in the non-metropolitan areas. The type of manufacturing activities carried out there are, in some cases, quite different from those of the metropolitan centres which suggests the possibility of another research and development diffusion pattern following industrial communication channels rather than the urban information networks. Basic research is generally of such minor importance because, as Hamberg (1963) suggests, most firms are profit motivated and necessarily concentrate upon those projects that give relatively immediate payoffs. Basic research is too speculative and long term for many firms to be able to support individually.

Overseas technology represented the major source of technology for 70 percent of the firms. Only for 6 percent of firms was New Zealand technology of greatest importance. Overseas technology not only provided the basis for firm product and process techniques, but also stimulates further local modifications and improvements. Such figures suggest that manufacturing firms are indeed involved in the adoption and adaption of overseas technology. The overseas sources of technology were least important in the nonmetropolitan areas which reflects firstly the uniqueness of raw materials involved in some of the manufacturing activities and, secondly, the fact that the nonmetropolitan areas are probably less integrated into the national innovation diffusion-adoption process. This innovation process does involve regional imbalances and it seems that New Zealand's nonmetropolitan areas may be at a comparative disadvantage.

A classification of organisational structure for the manufacturing firms was proposed and it was found that basic research is most emphasised in the small New Zealand-owned firms. These are firms of high research intensity, often involved in technologically complex activities, and which develop highly sophisticated products. Contrary to Galbraith's assertions, innovativeness does not require bigness. Applied research is most important in the larger New Zealand firms which suggests that they are involved in scaling down and adapting overseas technology to suit New Zealand conditions. In the subsidiaries of overseas companies, basic research is of negligible importance and development is quite significant, again reflective of the dependence on overseas technology sources. The commercialisation rate of projects was fairly constant for the firms, while market success rates were greatest in Classes 3 and 4. The coupling process between research and development and marketing staff is critical. This is one aspect where further investigation is necessary for coupling breakdown is responsible for a large number of marketing failures.

Research and development expenditure appears to be initially influenced by the general economic climate. The direction of expenditure is influenced more by market considerations and these are subject to different interpretations by the various firm organisational classes. A consideration of firm growth strategy becomes important with decisions being made on which product lines to concentrate upon and in what directions new ventures should be made. The criteria for individual project selection is explained best by industrial classification rather than organisational structure. What is wanted from a research and development project varies, with a firm manufacturing food products looking for immediacy of returns, while an electronics firm is concerned with the technologically more complex projects and a textile firm is looking for the project most conservative of the labour input. Such environmental and behavioural features of the firm as an organisation need to be considered more carefully if a better understanding of research and development and the more general process of technological change is to be gained with respect to the New Zealand manufacturing sector.

Research and development activity in the manufacturing firms does show some growthinducing linkage impacts of the types suggested by, for instance, Hirschman, Lasuen, Pred and Thomas. The degree of any market impacts generated by a research and development project, and measured by variables such as increase in sales and/or employment, seemed to be dependent upon the degree of technical advance of the project and the extent to which the product varied from the established product range. The beneficial effects of the research and development project were therefore reliant upon the position of that project on an evolutionary-innovative continuum of technological change. The linkages to the capital goods industry appeared to be fairly weak with many impacts going directly overseas or being internalised within the firm itself.

Many growth-inducing technological linkages, both backward and forward in direction, were developed. The phenomenon of subcontracting was important in causing either an increase in production for an existing firm or the establishment of a new firm. The benefits of these linkages tended to be concentrated spatially. This was particularly the case in Auckland where reliance upon local manufacturers and subcontractors was greatest. Auckland does not appear to be significant in promoting growth opportunities in other centres as a result of its research and development activities. This is in contrast to Wellington where many technological linkages were established with South Island firms and a broader diffusion of research and development growth impacts was evident.

The diffusion patterns of these growth impacts generated as a result of research and development activity is an area requiring more explicit investigation. It would be invaluable to learn about the frequency and intensity of linkage connections between different industrial groups and the different spatial areas. Just how important is the Auckland metropolitan centre in promoting growth in other areas and diffusing external benefits? Or, are the majority of growth impacts concentrated internally within Auckland, serving to cumulatively reinforce the growth of that area.

New Zealand's research associations were established with the objectives of improving the efficiency and trading competitiveness of the industry they serve. If these objectives are met to any extent some industrial impacts must arise from research and development activities. Some $2,650,000 was spent on industrial research and development in the seven associations surveyed, with a total of 238 fulltime staff being involved. The Dairy Research Institute accounted for 45 percent of the total expenditure and 55.8 percent of the staff, indicating a wide range of size and scale among the research associations. This is not to suggest that the smaller associations are less beneficial in terms of their contribution to industry. All of the associations have a reasonable proportion of potential firms as members so that any growth benefits transmitted from the research associations can have fairly broad impacts.

The research and development programme of five out of the seven research associations gives at least equal emphasis to process as compared with product developments. Furthermore, concern is for modification of existing products rather than new developments. Process technology is more important than in the individual firms because research associations are able to operate reasonably independently of profit compulsions and financial constraints and are therefore able to support the more complex, longer term work implicit in processing technology. Similarly, the research associations, on average, give greater attention to basic research and applied research (72.8 percent of total effort) than do individual firms. It is easier to sustain this more speculative, more fundamental research on a co-operative than an individual basis. Firms are concerned with commercialisation and development while the research associations may concentrate upon the more innovative technological advances.

The different emphasis between manufacturing firms and research associations suggests the complementary nature of the research programme of the firms and the associations. Duplication of effort can be readily avoided and the findings of the associations' research and development activity can serve as inputs for the research and development activity of the manufacturing firms. Three of the associations explicitly see their work as complementary to research done within firms, particularly those firms operating on a larger scale. For four of the associations their work acts as a substitute as no private research is conducted. The complementary nature of some of the programmes points to the need for close interaction between industry and research association. The research association is accountable to industry for its actions, particularly as industry provides at least half of its income. In view of this, industry-association interaction is vital especially if the results of the association's programme are to be translated for the maximum benefit of industry.

The criteria considered in the selection of particular research and development projects illustrates how aware the research associations are that they must help to improve their industry's efficiency and competitiveness. No attempt has been made to quantitatively measure efficiency advances in this thesis, and possibly this is something that could be researched into further, but some qualitative evaluations were possible. Either directly or indirectly the goal of industrial growth was apparent from the research and development projects selected. In some cases this could best be achieved by increased sales of raw materials, either locally or through the development of enlarged export markets. In another case, improvement in individual firm productivity was the most suitable means of improving general industrial efficiency. Whatever the means, contribution to industrial growth is the foremost consideration for all the research associations when deciding upon the composition of their research and development programme.

Locationally, New Zealand's research associations have had no impacts. No firms have located or relocated alongside one or a group of research associations in order to take advantage of the pool of scientific and technological resources. However, there are examples of 'spin off' firms established to market a new product that has been developed, or established in response to new advances made in processing techniques. Expansion of existing firms, in terms of the introduction of new plant and increased production capacity, has also occurred. Forward and backward technological linkages of the type described for individual firms are not really relevant forthe research associations because of their different system of functioning.

The spatial diffusion patterns of the industrial impacts that are generated by the research associations' research and development investigations vary for the different organisations. The diffusion patterns do not appear to be closely related to the structure of the urban hierarchy. Instead, they follow the distribution pattern of the industrial group concerned, or the distribution of raw material locations. Any similarity between the diffusion of research and development growth impacts and the structure of the urban hierarchy would only occur if, say, the industry's distribution pattern resembled the distribution of population. Thus, it is not automatic that the largest metropolitan centres will be the first to benefit from any research and development work that is carried out in the research associations. Accountability is firstly to industry and it is in accordance with this that the growth impacts will be distributed.

Although the manufacturing firms surveyed are essentially technologically adaptive by nature, the research and development activity that is carried out often results in significant product and process developments. These technological changes, whether they be evolutionary or more innovative in character, can have positive growth inducing impacts for industry. Production capacity does increase, new products introduced, firms are established in response to new demands induced by research and development investigations. The principle behind the establishment of a research association is for it to make some industrial impact. Process developments make possible improved production efficiencies within member firms. New or improved products enable industry to expand its markets, both internally and overseas, thereby improving its trading competitiveness. The evidence presented in this thesis confirms the hypothesis that research and development can, and does, have an industrial impact. Research and development, and the more general phenomenon of technological change, can make important contributions to industrial and economic growth and development. An increased involvement in industrial research and development, by both individual manufacturing firms and the research associations, must almost inevitably be to the country's good.

Appendix 1:

QUESTIONNAIRE FOR FIRMS ENGAGED IN INDUSTRIAL RESEARCH AND DEVELOPMENT

1. Details of firm:

	Name	Location	Number Employed	Type of activity
Firm				
Branch Plant(s)				
Subsidiary (ies)				

2. Research and Development (R. & D.) Department:

(i) How many people work in the R. & D. Department?
1975 ________

(ii) How many of these have recognised scientific or engineering qualifications? 1975 ________%

(iii) What is the amount of expenditure on R. & D. within your firm? 1975 ________

(iv) What would be the proportion of R. & D. expenditure to total sales? 1975 ________%

3. What is the relative distribution of your present R. & D. projects?

develop new products ________%
modify existing products ________%
develop new processes ________%
modify existing processes ________%.

4. How is the firm's R. & D. Expenditure distributed among -

basic research ________%
applied research ________%
development ________%

5. What is the distribution of present R. & D. projects according to anticipated length of time before completion, both technical and commercial?

	% Distribution	
	Technical	Commercial
Within 2 years Between 2 and 5 years Longer than 5 years		

6. What would be the typical origins of your R. & D. projects?

   Suggestions from R. & D. staff ________%
   Suggestions from marketing or production staff ________%
   Suggestions from 'higher' management ________%
   Suggestions from branch plants and/or subsidiaries ________%
   Suggestions from sources external to firm organisation. ________%

7. (i) Are R. & D. activities centralised in the firm's headquarters? Yes______ No_______

   (ii) Are R. & D. activities also carried out in
   a) branch plants Yes______ No_______
   b) subsidiaries Yes______ No_______

   Comment on how the type of work varies in comparison with that at firm headquarters.

8. In determining the amount of total R. & D. expenditure, what other factors does the firm take into account?

   - present sales
   anticipated profitability of particular project
   competitive position of firm.
   current state of firm profitability
   firm's growth strategy
   other.

9. (i) What factors are considered in the selection of individual R. & D. projects?

   anticipated profitability
   immediacy of returns

complexity of technology involved
others.

(ii) What percentage of technically successful projects are commercialised ________%.
Does this always occur within your own company?
Yes______ No______

Comment on the reasons for the 'non-commercialisation' of particular projects.

(iii) Once commercialised, what percentage of projects actually become market successes?
________%

Comment on reasons for failures.

10. Is your firm more concerned with -
- adapting or adopting technology that is already being used in New Zealand.
- Adapting or adopting overseas technology into the New Zealand context.
- developing totally 'new' technology, in both a national and international context. (Examples of this).

Comment on the varying nature of the problems associated with the introduction of those different forms of technology.

11. Is it possible to trace the market impact of, say, three significant R. & D. projects? Include comments on -

Sales employment
exports productivity.

12. (i) Where were the capital goods required for the establishment of your R. & D. department purchased?
N.Z.________% Overseas______%

(ii) Has the introduction of external technology into New Zealand by your firm ever resulted in growth impacts for the capital goods industry?

13. Does the size of your firm, measured in employment

terms, represent an advantage or a disadvantage in adapting or adopting external sources of technology?

Comment on any other advantages or disadvantages relating to firm size in the carrying out of I.R. & D. activity.

14. (i) What are examples of growth impacts in linked firms or Industries that have occurred as a result of I.R. & D. carried out in your own organisation?

(ii) Have the I.R. & D. activities of other firms generated growth impacts within your own organisation?

Appendix 2:

QUESTIONNAIRE FOR RESEARCH ASSOCIATIONS

1. Details of Research organisation:

   (i) what is the total number of your Research and Development (R. & D.) staff?

   1965 ____ 1975 ____

   (ii) of these, what percentage have recognised scientific or engineering qualifications?

   1965 ____ 1975 ____

   (iii) Expenditure:

	1965	1975
Total expenditure %Government Finance % Industry Finance R. & D. Staff payroll		

   (iv) What is the total number of member firms?

   ____

   What is the percentage membership of firms within the industry? ________%

   (v) Of the approaches your organisation receives, what percentage would be from returning firms (_____%)
   and what percentage from 'new' firms(_____%).

2. What is the relative orientation of your present R. & D. projects?

   develop new products ______%
   modify existing products ______%
   develop new processes ______%
   modify existing processes______%
   advisory services ______%
   others ______%

3. How is the R. & D. expenditure of your organisation distributed among - basic research ______%
   applied research ______%
   development ______%

Have there been, or do you expect, changes in emphasis in this distribution pattern?

	1965	1975	1985
More basic research Less basic research More applied research Less applied research More development Less development Others (specify)			

4. Where do the ideas for your R. & D. projects originate from?

   From your own personnel ______%

   From suggestions made by the industry you serve ______%

   from other research organisations ______%

5. What factors are most important when considering whether to undertake a particular R. & D. project?

   RANK : Improved productivity for firms

   Greater efficiency for industry

   Development of new or enlarged domestic markets

   Development of new or enlarged export markets

   Use of new natural resources

   Better use of available natural resources

   Others (specify).

   Comment on the way in which these factors may vary depending upon the nature of the particular R. & D. project.

6. (i) Has your organisation been responsible for the first introduction of overseas technology into New Zealand? Examples.

   (ii) Has your organisation been responsible for the development of a completely 'new' form of technology, in both the national and international context? Examples.

(iii) How did the problems encountered in production and marketing application differ for these two types of technology?

7. Can you trace the impact of the introduction of two examples from both technological groups presented in question 6.
   - creation of new plants, firms, industry
   - greater employment opportunity
   - greater sales.

   Note spatial component of these impacts.

8. How do the functions provided by or demanded of your organisation vary in relation to firm characteristics?

Small firms	v	Large firms
Science-based	v	Non science-based firms
Private	v	Public ownership
Domestic	v	Overseas ownership
Others.		

9. To what extent do you regard your organisation's activities as complementary to, and how far is it a substitute for, private research?

   Is this present working relationship different to that of the past, and what you anticipate in the future?

10. What kinds of impacts has your organisation had in terms of the location and/or relocation of private firms?

11. Have the activities of your organisation, say through the development of a new product or a new process, or by the actions of a former employee, ever caused the establishment of a new firm or new plant?

Name of firm or plant	Location	Reason for establishment

12. The establishment of your R. & D. activities presumably required some investment in capital goods.

(i) Where were these goods originally bought from -
New Zealand _____% Overseas _____%

(ii) Where are present demands met?
New Zealand _____% Overseas _____%

(iii) Has the introduction of 'overseas' or 'new' technology into New Zealand by your organisation resulted in any growth impacts for the capital goods industry?

Examples.

13. How would the growth-inducing impacts associated with your R. & D. activities tend to be distributed?

Concentrated in the largest firms in your industry

Concentrated in the largest cities

Concentrated in the immediate geographical region

Spread throughout the country.

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