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 indus-

trial 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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C O N T E N T S

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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 mul-

tidimensional 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 facil-

itate 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, whichare 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 mul-

tiplier 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 com-

munication 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.