Research and Development in New Zealand: A Public Policy Framework

Alan Bollard & David Harper
with Margriet Theron

NZIER

NZ INSTITUTE OF ECONOMIC RESEARCH/RESEARCH MONOGRAPH 39

THE N.Z. INSTITUTE OF ECONOMIC RESEARCH (INC.)

The N.Z. Institute of Economic Research (Inc.), founded in 1958, is an independent, non-profitmaking incorporated society with a membership open to any person or corporate body. The Institute is under the direction of a Board of Trustees, partly elected by members and partly *ex officio*.

The primary objectives of the Institute are:

(a) to conduct research into economic problems affecting New Zealand, especially in connection with economic growth;
(b) to encourage economic research by other organisations;
(c) to collect and circulate information on economic subjects;
(d) to promote the study and understanding of economic matters by training economists, by holding conferences and seminars, and by publishing the results of research and study.

AUTHORS: *Alan Bollard is Director of the NZIER.*

David Harper was a Research Economist at the NZIER, and is currently a researcher at the Technical University of Munich.

Margriet Theron is a Research Scientist with the Forest Research Institute.

Research and Development in New Zealand: A Public Policy Framework

by

Alan Bollard & David Harper
with Margriet Theron

Research Monograph 39

December 1987

NZIER

NEW ZEALAND INSTITUTE OF ECONOMIC RESEARCH (INC.)
P.O. Box 3479
Wellington
New Zealand

ISSN 0113-1877

PREFACE AND ACKNOWLEDGEMENTS

In late 1986 the Treasury, Department of Trade and Industry, Ministry of Agriculture and Fisheries, New Zealand Forest Service (now Ministry of Forestry), and Department of Scientific and Industrial Research asked the N.Z. Institute of Economic Research to coordinate a research project to investigate a public policy framework for research and development in New Zealand.

The aim was to set up a framework for a public policy approach to R & D, in order to provide policymakers with a way to think about appropriate policy responses to R & D. It does this by discussing traditional and new approaches to public policy in Part I, the economics of R & D transactions in Part II, and a new classification of policy tools and interventions in Part III. The non-technical reader is advised to concentrate on Part I and Part III.

The project does **not** attempt to determine optimal levels of R & D, nor to compare New Zealand and international spending on R & D, neither does it consider administrative arrangements for R & D policy. It covers all R & D carried out in the primary, secondary and tertiary production sectors including social science R & D for production sectors. It does not cover R & D in health, education, welfare and other social sectors.

This project was done as the joint effort of many people. The three authors wrote the body of the text jointly; it was then overviewed by Alan Bollard. Professor Clem Tisdell of the University of Newcastle played a guiding role in the early stages. The team also benefited from the assistance of Veronica Jardine of the University of Waikato in other sections of the text.

We also acknowledge the help of the inter-departmental Steering Committee for the project which included John Wilson and Kate Thompson from the Treasury, John Yeabsley, Alan Davies, Andrew Wierzbicki, Peter Macdonald and Liz Mitchell from the Department of Trade and Industry, Peter Bushnell, Syd Durbin, Grant Scobie and Ron Sandrey from the Ministry of Agriculture and Fisheries; Joan Smith from the New Zealand Forest Service; and David Lambie from the Department of Scientific and Industrial Research. In addition we received valuable assistance from Liz Mitchell, Peter Macdonald and Andrew Wierzbicki in two projects which surveyed R & D in the business sector and intellectual property rights. In addition we thank Alan Wylde of the Ministry of Energy.

We have concentrated on theoretical issues and a generalised framework in this report. For more up to date detail on R & D in New Zealand, we refer readers to a number of other publications. Principal among these are Macdonald and Mitchell (1987), Department of Trade and Industry (1987), the Beattie Report (1986), and E G Bollard (1986). In addition our study generated a number of relevant background papers : Tisdell (1986a), Theron (1987), Jardine et al (1987). A brief summary of this report has been prepared by Ron Sandrey and is available as an NZIER Working Paper.

Finally the production of a report of this nature has been a major exercise. We thank Carol Clayton for editing, Geraldine Sellens and Raewyn Hodges for typing, Noeline Armstrong for distribution, and members of the Steering Committee for helpful suggestions. The views expressed in this report are those of the three principal authors, and not necessarily of the or others associated with this project.

<u>TABLE OF CONTENTS</u>

LIST OF TABLES:

LIST OF FIGURES:

SUMMARY AND CONCLUSIONS

This report constructs a framework for public policy towards R & D using a comparative institutional approach. It commences in Part I with a clarification of what we mean by R & D, and a warning about some of the traditional definitions.

We then discuss the role of government and the objectives of intervention. This leads to the theories of market failure and the way they treat R & D policy issues. We examine the traditional justifications for intervention and the types of policy approaches they encourage. There are a number of problems with the market failure approach : both practical problems in its application; and more serious theoretical objectives to its concentration on "markets" and on "failure", and the exclusion of transaction costs.

We then summarise new approaches to intervention which address these criticisms, include transaction costs, and recognise a wider range of governance forms such as the possibility of doing R & D in-house, via a private bilateral agreement, or using a third party. The public provision of R & D is a special case of an in-house transaction. This comparative institutional approach appears to offer scope for a unifying theory that includes the possibility of market failure while also allowing for the possibility of non-market transactions.

In Part II we develop a new approach to the theory of R & D. This is done by *examining in depth the nature of* R & D *transactions, the way* R & D *is organised*, incentives for carrying it out, and rights over its output. The chapter on transaction costs defines types of costs that arise with R & D, then identifies a number of critical dimensions - uncertainty, frequency, asset-specificity, appropriability, and other lesser characteristics such as divisibility and measurability of transactions. Depending on these characteristics different R & D transactions are likely to be governed in various ways : by the market, by private ordering, via third party enforcement, and by internal integration. Each is most efficient at handling certain types of R & D transaction. We can talk about international technology transfer as a particular case of R & D transaction within this same governance framework.

Chapter 3 on organisational issues involves an examination of the degree of integration of R & D organisations, the effect of its organisational structure on R & D, and conversely how R & D activity in turn affects the organisation. The main issue here is vertical integration which in turn depends on asset structures, property rights, and the efficiency of markets. Bodies which fund R & D have their own organisational traits. Public funding bodies are typically complex organisations and may use all types of governance for R & D.

The following chapter examines incentives, rewards and controls in R & D. Carrying out R & D in an organisation typically incurs agency/principal problems because the researcher's interests need not coincide with the research funder's. There are various ways of controlling these problems such as financial and other incentives, control procedures and other bonding contractural arrangements. Sometimes however the costs involved remain high and preclude certain types of governance being used. In practice the issue of incentives and rewards is a complex one; it occurs most graphically in the public service where the clash of policy and conduct roles, a traditional lack of monitoring/accountability, bureaucratic procedures, and unclear organisational aims are common.

Finally in Part II we examine the various rights that R & D funders and researchers have over their output. The strength of intellectual property rights is important because it determines the incentives to invest in R & D, but provide by no means complete protection. Other legal instruments used are copyright, design registration, trademarks and standards systems. However, probably the most important commercial techniques for protection are the strategic use of secrecy, lead-times, learning curves, market leadership and product differentiation. When private property rights are strong and enforceable there is more tendency to do R & D, and to transfer it via market mechanisms. Weaker rights imply other ways of transferring R & D, or doing less of it.

Part III discusses how to use the new framework for public policy purposes. In principle, the range of policy tools available depends on one's views of markets, other forms of organisation, private sector rationality, government efficiency, and the nature of R & D transactions. A wide range of policies are used to promote or regulate R & D. A traditional approach to these, epitomised by the science and technology literature, speaks of "demand-pull" market-led forces and technology-push forces interacting against a regulatory background. Rather than use this framework we classify policy instruments according to whether they involve intervention in market transactions, in internal, bilateral or trilateral transactions. This derives from the classification of transactions modes developed in chapter 2. One outcome is to demonstrate that there is a far wider range of potential R & D policy tools than is sometimes envisaged, going well beyond traditional measures like public funding and tax concessions.

The final chapter builds a framework for policy action. The lesson is that policy can be broadened to take into account non-market mechanisms for R & D transfer. We construct a matrix showing what type of governance is most efficient for different types of R & D. We lay down necessary and sufficient conditions for intervention, then discuss the various policy tools available and the types of costs and benefits each incurs.

Our approach does not involve trying to induce R & D investment up to some "right" level. Rather it allows market and private mechanisms to determine levels of investment; the argument for intervention relies on an assessment of costs and benefits in a case by case basis.

In brief the policymaker is advised to:

- identify the types of R & D
- observe how each is transacted
- identify its key features
- predict the most efficient mode of governance
- select from the range of policy measures
- estimate public costs and benefits of each
- compare outcomes and institute the best value

This approach is well-developed in theory, but still developing in its policy use. It involves problems of measurement, estimating responses, and second-best outcomes. These are also problems encountered by traditional market failure theories although this is often conveniently forgotten. The comparative institution approach has the advantage of subsuming market failure theories, and directing attention at a wider range of possibilities for R & D policy.

PART 1: THE GOVERNMENT AND R & D

CHAPTER 1

PUBLIC INTERVENTION IN RESEARCH AND DEVELOPMENT

1.1 What is Research and Development?

For the purposes of this study, research and development is defined as an investment intended either to yield information that increases the stock of knowledge or to adapt this information to allow it to be used in new applications.

Within this general definition there are many sub-types of research and development. Most definitions attempt to classify R & D by some characteristic. The most common one is some assessment of the degree of appropriability of R & D (ie the extent to which its benefits may be captured), or some measure of its commercial potential. Thus for example the OECD and the National Science Foundation both group R & D into basic research, applied research and development. That classification is useful in that it helps to define in details the boundaries of what constitute R & D and what does not. Appendix 1 outlines the OECD definition in detail.

We are hesitant at this stage to adopt this definition, because we need in this study to explore other dimensions of R & D as well as its appropriability. We need a framework which is wide enough to incorporate all R & D undertaken for economic reasons ranging from what the National Research Advisory Council calls basic science, big science, and the advancement of knowledge through to highly commercial applications.

R & D investment may be oriented towards new or improved processes or towards new improved products. It may involve a process of "probe-search-major discovery" (such as the breakthrough technologies like Concorde). Much more frequently it will involve incremental adaptations and minor improvements. It may be done in the confines of a specialist research organisation, in the laboratory of a producer, or on the shop-floor during production. Further, R & D may be done both by a research specialist and by a production worker.

In this study we view expenditure on R & D as a form of investment for which an organisation must allocate funds, in competition with other investments and demands on its resources. This does not mean that organisation has to carry out the R & D itself: much is organised publicly, communally or sub-contracted. There are two issues here: who conducts R & D and who funds it, and they involve different principles that need to be clarified early. This approach to R & D emphasizes the fact that it uses scarce resources, and that spending on R & D must compete with other investments.

A problem facing a study of this nature is how to measure R & D. There are two broad ways : inputs into research (expenditure, number of personnel, etc) and outputs of research. The latter are of most interest but usually very difficult to quantify, except by proxies such as patents, licences, publications, etc. The problem is that these output measures are biased against certain types of inappropriable R & D, while input measures do not indicate the efficiency of an investment, and are usually limited to formal laboratory-type spending.

Noting these limitations, the expenditure on R & D in New Zealand by funding agency and sector of activity is usually indicated by a breakdown as in table 1.1.

TABLE 1.1: Breakdown of R & D expenditure according to sectors (1983-84).

ACTIVITY AREA	GOVERNMENT R & D EXPENDITURE (Note 1)	INDUSTRY R & D EXPENDITURE Manufacturing Industries (Note 2)	Research Assoc. (Note 3)	Total	TOTAL R & D EXPENDITURE (Note 4)
Agricultural Production	67.254	-	-	-	67.254
Fisheries Production	7.252	-	-	-	7.252
Agricultural & Fisheries Processing	11.192	14.496	6.370	21.316	32.508
Forestry (Production and Processing)	17.089	3.099	0.300	3.399	20.488
Minerals (Production and Processing)	1.590	8.895	-	8.895	10.485
Manufacturing	13.700	105.026	2.220	107.246	120.946
Building and Construction	2.655	-	2.275	2.725	5.380
Transport	3.437	3.034	-	3.034	6.471
Energy	10.972	-	0.594	0.594	11.566
TOTAL	135.141	135.000	12.209	147.209	282.350

Source: DSIR "N.Z. - R & D Expenditure in Relation to GDP," 1986.

NOTES

(1) Government R & D expenditure figures include Departmental expenditure, grants and subsidies, and research contracts, as outlined in: National Research Advisory Council 1984, Appendix to the Journals of the House of Representatives, for the year ending 31 March 1984.

(2) The figures given for manufacturing industries are based on the approximate figure of $135 million for R & D investment by the manufacturing sector for 1983/84, as outlined in: Healey, W.B.; Ball, M.E.; Mara, M.K.; Tharkurdas, P.A.: Research and development in the manufacturing sector, 1983/84. New Zealand Manufacturers Federation, Wellington. This has been apportioned to the various activity areas according to the relative contribution (to R & D investment) of the major group activities outlined in the census of manufacturing.

(3) The figures for Research Associations are those contributions from private industry. Research Associations involved in manufacturing have not been included, as this was considered to be covered by the Manufacturers' Federation survey.

(4) R & D spending by Universities is not included. This figure is approximately $90 million, excluding medical and dental R & D spending (1985).

Our main concern at this stage is to define R & D widely. This is because this study incorporates a range of types of investment that present very different problems from a policy point of view. Consequently, we would wish to include investment in market research, social science research, other non-technological research and non-formal development work such as is carried out on the shop floor by machine operatives, all of which could be excluded by the National Science Foundation definition. We aim to include all technical and non-technical R & D carried out for the primary sector, construction, energy and extractive industries, manufacturing and commerce.

1.2 The Role of Government

Research and development is one of those areas where governments have chosen to intervene fundamentally in the workings of the market. There have been a number of reasons for this, not all of them clearly articulated. The rest of this chapter investigates the general reasons for government intervention and presents criticisms of some of them, in preparation for developing a new approach to R & D and establishing a logical framework for government intervention in future chapters. We work from the general premise that government does have a role to play in research and development, but that all too often in the past this role has not been clarified or has been used to justify intervention that really has other objectives, with the consequent implications for the misdirection of resources.

Government involvement in research and development has taken a wide variety of forms. Currently in New Zealand, as in most western countries, the government is involved in at least seven identifiably different types of intervention which affect investment in research and development in this country. These are: the carrying out of research and development activity directly by the sector; the direct provision of funding for private sector R & D; the establishment of a legal/regulatory framework (the patent system, licensing etc) for private sector R & D; incentives in the form of subsidies or tax breaks to encourage private sector R & D investment; government exhortation and other indirect incentives; macroeconomic policy to promote a climate inducive to investment; and a wide range of other industry assistance measures which have indirect effects on R & D.

Why should governments get involved in this manner? The most pervasive rationale for intervention in R & D is the market failure paradigm, which we examine in some detail. Popular as this has been, it nevertheless involves a number of practical problems and theoretical objections. We then look to some of the more recent transaction-cost based theories of intervention. These still involve certain problems, particularly at a practical level. But they do allow us to present a unifying theory which still allows for the possibility of market failure, while also treating issues that fall beyond market failure.

1.3 The Objectives of Public Intervention

The traditional framework for assessing socially optimum intervention is the principle of Pareto optimality. Under certain restrictive conditions such as perfect communication, instantaneous adjustment to equilibrium, costless transactions and absence of economies of scale, Pareto optimality will be achieved by perfect competition, resulting in a state of welfare maximisation.

The principle of Pareto optimality works not on the basis of welfare measurement, but on the ordinal principle that any policy making an individual worse off will be insupportable. This principle has since been refined to allow for the situation where the winners of a policy change may compensate the losers. Broadly, however, distributional consequences are ignored by Pareto optimality.

The principle of Pareto optimality directs attention towards measuring costs and benefits at different levels of intervention. This in turn, depends on assessing the social utility of various policies which is impossible to quantify in general terms. However, the compensation concept allows policy makers to assess benefits of any particular policy by determining the amount of money a person or group would pay or accept for the implementation of the policy. Arrow (1983) derives the conditions for establishing the relationship between Pareto efficiency and competitive equilibrium.

A useful way of illustrating costs and benefits of public policy intervention in the neo-classical framework is to use the Marshallian concepts of producer and consumer surplus. The market for research and development has demand and supply curves. The government intervenes to encourage the supply of research and development; by aggregating consumer surplus, producer surplus and deadweight losses, a measure of the change in welfare is estimated. Tisdell (1986a) illustrates this in graphical form. This is particularly useful for demonstrating the effects of different market structure configurations, and for showing who stands to gain from policy intervention. It is possible, for example, under certain circumstances for the benefits of R & D-inducing policies to go almost totally to consumers rather than producers, and vice versa (Tisdell, 1981). In that case, the implications for public intervention are likely to be rather different from otherwise.

1.4 Problems of Intervention

There are certain generally recognised problems with this neo-classical welfare analysis: the major one is "the theory of second best". This says that if one of the conditions for Pareto optimality cannot be fulfilled (which is almost certain to be the case), then it is not necessarily desirable to fill the other conditions. Distortions in one market may affect other markets, so that in order to reach an optimal allocation of resources, further induced distortions are required in those other markets. These distortions may be ones that are introduced by government policies and could, in fact, move a market further from an optimal state rather than closer to one.

If, for example, it is recognised that there are problems of inappropriability or indivisibility in research and development in one sector that cannot easily be solved, it may not necessarily be desirable to try and move research and development investment in other sectors towards an optimum (Tisdell, 1972). The theory of second best carries with it rather negative policy inferences, condemning piecemeal welfare intervention and the putting into effect of first best Paretian conditions on a partial basis.

Associated with this is the problem of partial versus general effects of policies. Welfare economics traditionally uses techniques of partial equilibrium analysis that ignore the cross-market effects caused by substitutes and complementary goods. So, for example, a government policy to promote research and development in one sector, no matter how carefully thought out, can still have unexpected indirect effects through other sectors. For example, a tax credit for expenditure on R & D in the electronics industry can lead to an increased demand for technicians to work there, which in turn puts their price up in the auto industry and makes R & D more difficult there.

1.5 Theories of Market Failure

The market failure paradigm has been the most pervasive rationale for government intervention in a whole range of policy areas. Arising from Pigou, the paradigm says that in order to allocate scarce resources efficiently, economic agents rely on signalling devices. In the normal course of events, these signals are provided by the market place. However, in many cases in practice, the market fails to provide efficient signals, and in such an event it is the duty of the government to step in and regulate more directly. As Noll (1977, p.170) put it:

> "public economic policy can be viewed in the context of the proposition as seeking to create institutions that perform the functions of a market and situations where markets are unworkable or more costly than substitutes. Furthermore, since market failure can have many causes, the best choice of an institution to substitute for a market in any given case is likely to depend upon the nature of the market failure".

The market failure theorists agree that there are a limited but pervasive number of conditions that can lead to markets failing. These include: inadequate knowledge about possibilities, or restrictions on consumer sovereignty e.g the regulations surrounding genetic experimentation, use of certain chemicals, and drug trials; the existence of favourable or unfavourable externalities e.g the unavoidable spillover effects of many new inventions; the existence of decreasing costs e.g the provision of expensive R & D equipment such as nuclear accelerators; and errors or uncertainties e.g investment in an R & D idea that fails.

It was Arrow (1962) more than anyone else who was responsible for applying the market failure framework to the problem of research and development policy. Having interpreted research as being the production of knowledge, he then investigated the nature of the market for knowledge, and claimed to identify three of the classic reasons for possible failure of perfect competition to achieve optimality in resource allocation: namely indivisibility, inappropriability and uncertainty. All of these occur in the production of knowledge. Indivisibility occurs when the results of research are valuable to a number of firms, but not on a scale to justify the minimum level of spending on any one them. Inappropriability occurs when a successful discovery by one firm cannot be kept secret or otherwise be appropriated by that firm, and others can make use of the knowledge (- the discovery of phosphate deficiency on the North Island volcanic plateau is an example). Jardine (1986) also points out the possibility of overappropriation of gains (where private returns may be higher than social returns), implying too much resources being devoted to R & D. Risk and uncertainty are inherent in much R & D investment, where the chances of success are not known, or even if known are not assured.

For further details of these in the R & D context, see Gannicott (1980). It is however worth stressing that these characteristics are not unique to R & D, being found in most other forms of business investment. They impose problems of degree rather than of kind. One could equally write about the risks of not undertaking R & D.

To these three central sources of market failure have since been added a number of others that are considered relevant in research and development investment. They include the lack of property rights and potential inventions (Joseph and Johnson 1985), imperfections in capital markets (Tisdell 1986a), small numbers problems in markets (Kaplan *et al* 1976), and other imperfections (Pavitt and Walker 1976). Tisdell (1972) elaborates on some of these market shortcomings and problems in the private production of knowledge, such as externalities, and exclusion difficulties. In addition he notes problems in appropriability due to risk and uncertainty, failures in the transmission of scientific and technological information, imperfections and capital markets, duplication, national security and industry-wide economies, as all presenting potential reasons for market failure.

Arrow's conclusion forms the basic rationale for much R & D policy by governments today:

> "The previous discussion leads to the conclusion that for optimal allocation to invention, it would be necessary for the government or some other agency not governed by profit and loss criteria to finance research and invention. In fact, of course, this has always happened to a certain extent." (Arrow 1962, p.623.)

However, when it comes to practical guidelines for intervention, Arrow is more circumspect than many of his followers have assumed. He speaks of the problems of compensating for misallocation of resources as being very difficult to quantify:

> "Formally, of course, resources should be devoted to invention until the expected marginal social benefit there equals the marginal social benefit in alternative uses, but in view of the presence of uncertainty, such calculations are even more difficult and tenuous than those for public works. Probably all that could be hoped for is the estimation of future rates of return from those in the past, with investment in invention being increased or decreased accordingly as some average rate of return over the past exceeded or fell short of the general rate of return. The difficulties of an even ex-post calculation of rates of return are formidable, though possibly not insuperable. (Arrow 1962, p.623.)

There are many arguments which have frequently been used to justify intervention in innovation (as opposed to R & D) policies. Jardine (1986) notes problems encountered by small firms, strategically inappropriate patterns of R & D, other barriers to innovation, capital market problems, "national security", and the long timescale of many projects. The latter is particularly important in the New Zealand context in sectors like forestry. The issue here is whether private and social rates of time preference differ: in practice few firms favour projects with payoff periods of more than about five years. Whether governments should induce them to favour these is in question.

A major weakness of the market failure arguments (and as we will see also of the competing paradigm) is the absence of empirical work describing and quantifying the existence and extent of market failure in practice. A classic exception is the study by Griliches (1958) on the rate of return to hybrid corn. This work spawned a number of studies seeking to measure the divergence between social and private rates of return to investment in R & D, although the results are not conclusive. Mansfield (1983) notes that most studies indicate that average and marginal social rates of return tend to be very high, e.g 30% per annum, but these are in no way conclusive. Eveleens and Scobie (1986) estimate the internal rate of return to agricultural research in New Zealand from 1926 to 1983 and also find it to be around this figure. Tisdell (1986b) describes other overseas work, evaluating social returns to research, in terms of consumer and producer surplus.

A particularly interesting approach was that of Caves *et al* (1983) who studied the imperfections in markets for technology licences. They noted and estimated the importance of small numbers bargaining, impacted information and opportunism questions, uncertainty, risk aversion and various forms of transactions costs.

There can also be more general difficulties within this paradigm, for example, major innovations are likely to change tastes and social patterns of use in a radical sort of way (e.g motor car, television, air travel, etc). In such cases, markets value such investments inefficiently, from an ex post viewpoint.

To summarise, it is possible to point out many static and dynamic problems in the allocation of research and development investment by the market. Most market failure theorists agree that private parties will under-invest due to problems of risk and uncertainty, inappropriability, other externalities and short term horizons. It is also possible, however, that market failure could lead to over-investment by duplication of investment or dual approaches.

1.6 Traditional Approaches to Intervention

These market failure theories underlie much of the thinking behind post-war public policies towards R & D. A typical statement is that of the United States President's Council of Economic Advisors in 1972 (reported by Ronayne, 1984, p.40):

> "Government has an appropriate role in research and development even when its results will not be incorporated in government purchases because firms would under-invest in research and development for goods normally purchased by the private sector. Though an investment in research and development may produce benefits exceeding its costs from the viewpoint of society as a whole, a firm considering the investment may not be able to translate enough of these benefits into profits on its own products to justify the investment. This is because knowledge which is the main product of research and development can usually be readily acquired by others who will compete away at least part of the benefits. This is particularly true of basic research."

The market failure arguments for R & D policy lead generally to the conclusion that private sector R & D is likely to be suboptimal in its allocation, and that governments should intervene to equate private and social costs and benefits. If the problems of indivisibility, inappropriability and uncertainty are not severe, they should consider fiscal policies such as a subsidy on research and development, or a tax credit. To induce extra spending, they should disseminate information or bear some of the uncertainty themselves (for example, by incentives to venture capital operations) and they should set up systems such at patenting to improve the appropriability of invention.

For example the US National Science Foundation in 1980 outlined four justifications for government intervention in research geared to the commercialization of technology (Ronayne, 1984). These were that technological and market uncertainties dampen private investors' enthusiasm for innovative commercial ventures; government institutions are incapable of compensating firms adequately for their inability to appropriate all the benefits of their investments in these risky areas; the benefits to society of federal investment exceed the costs imposed on society by that investment; and the net returns to society from the investment are at least as great as the net returns from other investments the government might make.

Joseph and Johnson (1985) analyse the underlying basis of Australian science and technology policy with respect to its political and bureaucratic origins. They conclude that in Australia the economic concept of market failure has been principally used to provide justification, usually post-hoc of intervention for R & D particularly between 1975 and 1983. These examples illustrate the extent to which Arrow's three conditions for market failure have penetrated official thinking about governments' role in research.

In much basic research, R & D allocation decisions are frequently taken right out of the market system. As Winter, Nelson *et al* (1984) point out almost all university research is non-profit seeking in nature and is funded largely by the government. They say this strategy has been relatively successful in the United States for two reasons. Firstly, the information needed to guide basic research decisions is available, not in productive organisations, but rather in the mind and experience of basic research scientists. Secondly, basic research decision making has been largely decentralised in nature, proposals coming mainly from research scientists. Taken to its extreme, this leads to the decentralised "Republic of Science" approach, where those carrying out basic scientific research allocate their own resources according to those areas they see fit without the hand of government or market intervening.

There have been long arguments over the effect of market structure on innovation. If one accepts the Schumpetarian type arguments that innovation is primarily to be found amongst larger monopolistically-protected firms, then there is an argument against anti-trust policies which work to increase competition. This says that these policies may in fact decrease incentives for firms to do R & D by denying them some of the organisational possibilities of appropriating the rewards from their investment. This is investigated further in chapter three.

On the question of risky R & D investment, there have been a number of approaches to government policy. As Finger and Mehrez (1985) have pointed out, the question of governments' attitudes to risky investments vis-a-vis the private sector's attitude, is a complex one. The arguments relate to the question of what social risk actually is and how much the incidence of private risk can be altered by pooling across various sectors of the economy. Government intervention cannot actually reduce risk but rather can shift its burden. The costs of doing this are to blanket the economic signals regarding the choice between different R & D investments. The private sector has options such as the patent system, certain (imperfect) insurance markets and the common stock market available for shifting or spreading risks.

The Australian Industries Commission point to another intervention argument: that *per se* the case for intervention exists, because innovation and adoption of new technology inevitably benefits some sections of the community and makes others worse off.

A more recent R & D market failure argument has been that the public sector should support private R & D in order to build up a country's international strategic competitiveness (a sort of infant R & D industry argument). This is based on studies linking economic performance with R & D investment (though without making the line of causation explicit.)) Mowey (1984) compares the development of industrial research in Great Britain and the United States between 1900 and 1950, focusing on the reasons for much lower levels of R & D investment in Britain. He concludes that the differences in government policy with regard to anti-trust, training, and research associations, were an important element in this (although in general his is not a market failure framework).

Some of the general arguments for protection or industry assistance for R & D on trade grounds have been challenged, although recent papers by Spencer and Brander (1983) present the argument for assistance to pursue a country's short-term monopoly profits from a secret or patented high technology advance. Tisdell (1986b) points out that for a country like New Zealand a government may also wish to concern itself with the role of foreign companies in the transfer of technology and the conduct of R & D. More generally, however, the arguments for R & D support as a type of international industrial policy both to capture monopoly profits and to generate externalities, are reported by Dixit (1986), who constructs a model where policy to achieve high technology dominance could remove the profit-capture motive for investment.

1.7 Public Conduct of R & D - A Special Case of Market Failure

An additional and in some ways separate sub-issue of public intervention involves the public provision of R & D. This involves different issues from the regulatory and assistance aspects of public intervention discussed above. For most of this study we consider issues relating to government funding and regulation of R & D. Yet in a country like New Zealand a major part of the government role is the direct or joint conduct of R & D. Not only does the public sector subsidise or otherwise encourage investment in R & D, but it also carries it out itself, both for the public sector and for commercial applications.

Why should the public sector carry out R & D? One possible precondition is the occurrence of natural monopoly : in many areas of R & D in a small market like New Zealand the average costs of provision continue to decline up to the limit of the market. This involves both major R & D expenditure (e.g. the DSIR research vessel) and also more minor spending where there is a small specialist niche market. However, natural monopoly in itself is not a sufficient condition for public provision, because it can be treated by other forms of public intervention such as price guidelines, competition regulation, the tendering of monopoly rights and appropriate incentive structures.

Thus, the existence of natural monopoly does not explain why, for example, R & D into energy needs to be handled in many different ways: in New Zealand research into oil exploration has been done both privately and by a Government department, research into gas location has been done by a publicly-owned corporation, research into synthetic petrol production has been done jointly by public and private interests, and research into other fuels has been done by government departments. Even the theoretically more restrictive circumstance of a public good without possibility of exclusion is not in itself a sufficient condition for public provision.

A further possibility is related to the infant industry argument : that the private sector is initially too immature to provide certain services. Just as in New Zealand the government intervenes to provide insurance, banking, communication and transport services, so too government provision of R & D is not unusual.

A third possibility (covering the first two to some extent) is that the transaction costs of contracting out R & D may be prohibitively high : it is therefore more efficient to carry out R & D in-house. We discuss this further below.

We may also turn to other (often non-economic) explanations for direct public provision. Typically there is something in the nature of the R & D being done that is felt to relate to nationally-strategic issues, or for which private investment in R & D would be felt to be inappropriate. The reasoning may be no better thought out than that. Here the arguments are generally for public control, which does not necessarily demand public ownership. In fact the issues are much the same as those surrounding the corporatisation of other state trading activities.

1.8 Criticisms of the Market Failure Approach

The market failure approach to government intervention, being the dominant justification for many years of public spending, has attracted a wide range of criticisms, both in its practice and its theoretical outlook. We address these under three headings: some practical problems with market failure, the charges of government failure, and more profound criticisms questioning the whole approach.

Practical Problems with the Market Failure Argument

These criticisms are both quantitative and methodological in nature. Noll (1977), in a major study of government policy and technical innovation, concluded by questioning the conventional wisdom that there is not enough research and development taking place. This could be because policy makers have not been able to estimate accurately the degree of intervention predicted by market failures theories, or it could be because intervention is essentially used for other ends rather than to correct the market.

Joseph and Johnston (1985) in analysing science and technology policy in Australia conclude that the use made of a market failure framework caused policy problems by the lack of a clear-cut system for identifying a market failure and its direction, the absence of guidance on the extent of intervention necessary, and its difficulty of use in practice, as the notion of measuring private and social costs of benefits is not well developed.

Even where these problems can be resolved, the appropriate policy measure to induce the optimal private sector response is almost impossible to estimate. Lack of certainty about the response of private R & D investors to public intervention is a major weakness in this framework. Does public provision of R & D funds crowd-out or draw-out private funds? How sensitive is private R & D investment to public fiscal incentives? The evidence here is fragmentary, and often specific to the economy under investigation. Levy and Terleckyj (1983) report that in the United States from 1949-81, every $1.00 of government contract R & D performed in industry appeared to induce about $0.27 of additional private R & D spending. Government-funded R & D done in government and universities affected private R & D outlays positively but weakly, whereas overhead reimbursement of government contractors for R & D apparently reduced private R & D outlays. Lichtenberg (1984) notes a number of similar studies reporting a positive correlation between public and private spending. However, they argue that a number of these misinterpret the specification of key relationships: that correcting for these leads to crowding-out: and that increases in public R & D activity are associated with significant reductions in company-financed R & D.

Considerable discussion centres around the effects of the United States 1981 tax credit for R & D spending. A study by Mansfield (1984) concluded that the credit has had only a modest effect on firms' R & D spending. In practice this may have led to governments fully funding or carrying out R & D themselves, because they are unable to estimate the private sector response to fiscal incentives.

There are other practical difficulties: Nelson (in Winter, *et al* 1984) points out that market institutions themselves can constrain public policies, it is politically difficult and probably futile to try to force a policy on an industry. In addition he says that a strong public presence in high technology industries can upset anticipated reactions from the private sector, that government agencies are typically cut off from the knowledgeable expertise that they require to invest wisely themselves because of problems of appropriability, and that for some reasons private firms may actually mislead or resist government programmes.

Winter, *et al* (1984) describe three general problems of publicly-funded research and development. One is informational constraints, as above. The second and third are problems of fairness and the problems of bureaucratic politics. These questions were first treated in a regulatory framework by Posner (1974), who criticised the public interest theory of regulation because it failed to explain the process by which public interests were translated into legislative action, and because, empirically, it could be shown that intervention did not correspond with those areas where market failures were discernibly important.

This led to the "capture theory" of regulation posed by Stigler (1974), in which individuals or private firms are considered to seek to advance their self interest in a rational way. With science and technology policy, larger, more powerful firms or industry associations will lobby government and hope to 'capture' appropriate government departments or quasi-public bodies to induce them to frame R & D policies that are in their private interests.

Noll (1977) examines the standard arguments for market failure of inappropriability, uncertainty, indivisibility and indirect failures; all of which it has been claimed lead to private R & D investment diverging from optimality. In a series of propositions he argues that while some qualified results of this nature do hold:

> "the existing literature does not establish either that too little innovative activity takes place, or that government can be particularly effective in devising cost-effective strategies to promote more R & D, or even which of the four sources of market failure listed above is the most important and, therefore, should receive the most attention from policy makers. Furthermore, existing policies do, on balance, promote R & D relative to other investments, at least in industries not subject to public utility regulation, so that even if the case is made that a private market economy generates too little R & D, it is by no means established that this is not offset by existing policy interventions. Much more solid theoretical and empirical research must be undertaken before any of these issues can be resolved sufficiently to warrant strong conclusions about the general stance of policy towards innovative activity". (Noll, 1977, p.171)

As Winter, *et al* (1984, p.394) says:

> "notions like 'market failure' cannot carry policy analysis very far, because market failure is ubiquitous".

These criticisms are lent empirical validity by Joseph and Johnsons' (1985) account of how policymakers, scientists and economists have used or misused market failure strategies in Australian science and technology policy.

Government Failure

The other major practical criticism of the market failure approach is that it does not allow for the likelihood of government failure. Government failure means that even accepting market failure conditions for suboptimality of R & D investment, there are likely to be major problems for bureaucrats in identifying cases of suboptimality, estimating its magnitude, and devising appropriate policies to remedy this. Governments have their own problems with information, they may be captured by special interest groups, and even with the best will in the world, may be plainly inefficient. They are usually somewhat remote from the market place and have difficulty interpreting market signals. Many studies of science and technology policy find more evidence for government failure than they do for market failure. For example, Burton (1983) lists a series of dangers of government trying to act as what he calls "a superior entrepreneur".

Transaction costs in government activities are themselves likely to distort intervention. Government departments may be "captured" by large investors in R & D with special interests. Government departments may have difficulty in defining R & D goals and in communicating and coordinating policies towards them. Bureaucrats may have no more superior information about the social value of inventions than private investors, and they may be less skilled than the private sector in evaluating success in potential research. As pointed out in the following chapter, technical civil servants may tend to follow their own goals and not be motivated by market considerations. Politicians may support R & D in areas most visible to voters and, they may be swayed by short-term returns in order to attain electoral success. Public choice theory teaches that because politicians respond to these pressures, the actions of government will often create or magnify market imperfections rather than overcome them.

Tisdell (1981) summarises many of these potential costs and imperfections of government intervention. There are direct costs involved in setting up government departments to finance, regulate, direct or conduct research. There may also be indirect costs to the economy in terms of government regulation of industry R & D, such as testing of new drugs, and the operation of the patent system. He points out some dangers of government support and intervention in science and technology such as : government departments may act in a synbiotic relationship with large and powerful client groups and this can distort R & D support; politicians tend to concentrate government support on big science which is more viable; the tendency of individual departments to try to maximise R & D resources distorts allocation; governments find difficulty in defining social interests and coordinating goals; bureaucrats may be more imperfect than company managers in picking winners.

Rowley (in Cheung, 1978) commenting on the possibilities for government intervention warns of four fundamental problems : the tendency for politicians to maximise their own objectives; the costly nature of most bureaucratic intervention; the lack of incentives for governments to ensure they are adequately informed for decision-making; and the implications for industrial freedom.

Economists who hold this view take a very negative attitude to government intervention. For example, Burton (in Cheung, 1978, p.90) writes:

> "The general conclusion for public policy is the classical one: given the inherent defects, complexity, cost and bias of an intervention solution, the general rule should be to let the price system deal with externalities wherever possible: by

redefining property rights and removing barriers to trade due to externalities. Government intervention - domestic or supranational - is best kept as a 'solution of the last resort': to be used only when and where high and irreducible transaction costs prevent the internalisation of externalities by private action. Even on these grounds, government intervention must be carefully scrutinised, because the costs and external side-effects may outweigh the benefits".

Of course private bodies are also subject to organisation problems in terms of incentive, performance and monitoring. These are discussed in chapters 3 and 4 within the principal-agent framework.

More Basic Objections to the Market Failure Approach

A more basic objection is made by Toumanoff (1984): that market failure is essentially the failure of the standard welfare model to consider all relevant variables. By this he means that the standard model is incomplete because it does not explicitly include costs of the exchange process (transaction costs). The paradox is that a model that does try to consider all such variables then weakens the concept of Pareto optimality. He concludes that such limited welfare models may be useful for explaining behaviour but are not satisfactory for justifying it.

This was what Coase (1964, in Williamson 1986c, p.83) was getting at when he wrote:

> "until we realise that we are choosing between social arrangements which are all more or less failures, we are not likely to make much headway".

It was Coase's work that has lead to the comparative institutional approach to public intervention: traditional views on public intervention such as the market failure approach present policy choices as deciding between an ideal norm and an existing imperfect institutional arrangement. This is what Demsetz (1969) has called the Nirvana approach. Yet, he argues, this is not really the choice we face at all. What we have is a comparative institutional approach, a choice between a set of relevant imperfect institutional arrangements. He argues that the Nirvana approach in turn leads to three logical fallacies which he describes as; 'the grass is always greener fallacy', 'the fallacy of the free lunch', and 'the people could be different fallacy'. The first of these relates to the assumption that because the unimpeded market is not optimal in its allocation, that government intervention will do better; the second confuses incomplete adjustments to risk and other characteristics of R & D investment with non-optimal adjustments; the third relates to the potential avoidance of moral hazard. With this background, he goes on to criticise Arrow's seminal work on market failure and the production of information, and concludes by rejecting each of Arrow's three arguments for the existence of market failure, namely, appropriability, indivisibility and risk aversion. Hence, he concludes that Arrow's overall conclusion that there is likely to be suboptimal private investment in inventive activity which should be corrected by public intervention is incorrect. He further argues against Arrow's claim that monopoly reduces invention and hence there is a need for anti-trust policy in the name of science and technology policy.

His criticism of the market failure framework attacks its very foundations. In his words (Demsetz 1969, p.19):

> "To say that private enterprise is inefficient because indivisibilities and imperfect knowledge are part of life, or because people are susceptible to the human

> weaknesses subsumed in the term moral hazards, or because marketing commodity options is not costless, or because people are risk averse, is to say little more than that the competitive equilibrium would be different if these were not facts from life at zero cost, then truly efficient institutions will yield different long-run equilibrium conditions than those now used to describe the ideal norm. It is one thing to suggest that wealth will increase with the removal of legal monopoly. It is quite another to suggest that indivisibilities and moral hazards should be handled through non-market arrangements. The first suggestion is based on two credible assumptions, that the monopoly can be eliminated and that the practical institutional arrangement for accomplishing this, market competition, operates in fairly predictable ways. The second assertion cannot claim to have eliminated indivisibilities, risk averse psychology, moral hazard, or costly negotiations, nor can it yet claim to predict the behaviour of the governmental institutions that are suggested as replacements for the market".

There have been some attempts to reconcile these major differences. Toumanoff suggests that the inclusion of transaction costs into the standard market failure models would considerably help the usefulness of the latter. He interprets the market failure literature as being full of examples of unexploited benefits from exchange. This should direct our attention to the costs of the exchange process, typically called transaction costs. These are dealt with in the next chapter. Traditional models that assume transaction costs are zero cannot be used as objective standards of efficiency. Typically "market failure" exchanges are unexploited because the costs of exchange exceed the benefits. Tisdell (1986a) attempts to widen the market failure model to explicitly incorporate market transaction costs and shows how traditional analysis of welfare implications still holds. Arrow (1969) makes the point that market failure is not absolute; it is better to consider a broader category, that of transaction costs, which in general impede, and in particular cases, block the formation of markets. He is here talking of transactions costs as "the costs of running the economic system".

The market failure framework highlights the importance of information, the distribution of its benefits amongst economic agents, and the difficulties of its transmission and disclosure according to Williamson (1986a). He also quotes Coase (1960) as saying that the treatment of social cost by the market failure argument does imply that market failure analysis has transaction cost origins.

In a later publication (Williamson, 1986c), he considers a range of market failures, but points out that they are failures only in the limited sense, that they involve transaction costs and they can partially be overcome by substituting internal forms of organisation and exchange in response to external market forms. To Williamson, for example, vertical integration is a natural response to external market failure. Among his specified market failures are: static markets, where there may be only a few producers with joint production and it is likely that monopoly prices will be significantly greater than cost; contractual incompleteness where there are problems of technological complexity for all contracts; strategic misrepresentation of risk where there is not only ex-post uncertainty. In each of these three "failures" of the external market place there is an incentive to internalise transactions. The possibilities of internalising are reviewed in detail in later chapters.

1.9 New Approaches to Intervention

These new theories in turn lead to the question of government intervention. Here the argument goes back to Coase's theorem. Coase concludes that where private property rights are fully defined, policed and enforced, and there are no transaction costs, then private bargaining between individuals will result in the internalisation of all spillovers. The two assumptions of this theorem, that is the definition of private property rights and the non-existence of transaction costs, are both unlikely to hold totally true in the absence of public intervention, and form the focus for the comparative institutional view of public intervention.

Baumol (1986) explains further that there are three necessary conditions that, in the absence of externalities, make it likely that there will be suboptimal investment through a marriage of market mechanisms and internal contractual relationships. These three requirements are the existence of asset specificity (sunk costs), limits on information and calculation ability (bounded rationality) and willingness to profit at the expense of others (opportunism). The latter two of these conditions are likely to be severe in the case of research and development investment. The fourth condition that can by itself be sufficient for suboptimality is the presence of externalities and in particular free-rider problems. In these cases, Baumol agrees, transaction cost analysis is most appropriate.

Transaction costs that occur in research and development expenditure are just as real as, for example, production costs. It is perhaps a failure of Marshallian analysis that they have not been explicitly considered in firm supply curves. For the government to intervene to encourage firms to ignore such transaction costs in R & D investment would not be welfare-increasing. However, to the extent to which some of these transaction costs are government-induced and serve no particular allocative purpose (for example, red tape, stamp duty and some planning controls), it would seem to be appropriate for government to focus attention on how to remove them. There may be many areas where transaction costs can be reduced by the provision of centralised information. Whether this is a case for government support depends on the costs and benefits of such intervention, and the other mechanisms through which it could potentially be provided.

The market failure approach concludes that where private property rights do not exist, then an inefficient allocation of resources will result. If private property rights are incomplete it is because there are prohibitively high transaction costs (Jardine 1986). In the presence of transaction costs, private property rights may exist but be incomplete because of the costs of enforcing these rights.

Transaction cost theorists dismiss the notion of Pareto optimality. They argue that any "sub-optimal" position must be efficient if the transaction costs of moving to a better position are greater than the gains. Deadweight welfare losses are the consequence of unavoidable transaction costs (Jardine 1986, Toumanoff 1984). It is difficult to be more specific about how public intervention should focus on the transaction cost problem at this stage other than to say that the guiding principle should be not how to correct market failure, but how to improve the workings of markets and any governance mechanisms. In the last chapter we examine the implications for intervention in more detail.

It has been argued that anti-trust policies, for example, may adversely affect internal governance mechanisms that are important for efficiency. Williamson (1976, 1986c) has written in detail on this. His concern broadly is not with addressing market failure, but how to avoid obstructing any of governance mechanisms (including markets) that may be used for efficient allocation. The other focus for government intervention under this framework is the establishment, policing and monitoring of property rights. This involves a range of contractual mechanisms such as the patent system, licensing agreements, copyrights, trademarks and general support for bilateral or trilateral contractual arrangements via the legal system.

A related area for public intervention is the encouragement of collective action in certain areas of R & D. This may involve the government in bearing certain transaction costs of collective communication, or in establishing an appropriate collective form of property rights. Collective action may not necessarily be a precondition for government intervention. Among producers, for example, private joint ventures are commonplace in R & D. However, wider industry agreements and research associations frequently involve some government role. The role may be wider in the case of collective consumer action where informational costs are likely to be higher. These policy tools are considered in detail in chapter 7.

1.10 Some Critiques of the Transaction Cost Approach

The transaction cost approach radically alters the focus of public intervention in comparison with the heavily criticised market failure approach. However, in its pure form, the transaction cost approach itself has a number of shortcomings. Williamson admits some of these. One area in which the transaction costs approach in economics is seriously incomplete, according to him, is the undeveloped state of the theory of bureaucracy:

> "as compared with the market failure literature, the study of bureaucratic failure is very primitive. What are the biases and distortions to which internal organisation is given? Why do they arise? How do they vary with organisation form? An adequate understanding of economic organisation plainly requires more attention to those issues". (Williamson 1986a, p.392)

This introduces biases and distortions into the analysis. The approach, like the market failure argument, is partial in nature rather than general.

As Baumol (1986) points out, all of Williamson's much vaunted substitute arrangements for imperfect market mechanisms are themselves inherently imperfect. In particular, internal governance mechanisms are subject to the costs and inefficiencies of bureaucratisation, with principal-agent problems arising, as they always do when management is not identical with ownership. The approach in general is highly theoretical with a disdain for empirical testing, and a consequent lack of evidence about the existence and size of transaction costs and the efficiency of various governance mechanisms.

There are a number of other criticisms of transaction cost approach. Jardine (1986) argues that transaction cost approaches ignore the effects of money and exchange; that terminology is ill-defined and inaccurately used; that the explanation of the evolution of firms and exchange mechanisms in terms of the minimisation of transaction costs is unrealistic in terms of business histories; and that while firms are viewed as transaction costs-minimising institutions, other economic organisations such as unions and cooperatives are not viewed similarly.

It is also, as an approach, susceptible to the argument of the "Panglossian dilemma", namely that what exists must be optimal since all institutions are transaction costs economisers. This in itself is an argument for the status quo and provides no useful framework for assessing alternative government interventions. The policy outcome from this framework, as described by Noll (1977), is basically a negative one, namely that the only sure outcome is that no universal policy covering firms investing in R & D is likely to lead to an efficient rate and direction of technological innovation.

1.11 Towards a Unifying Theory

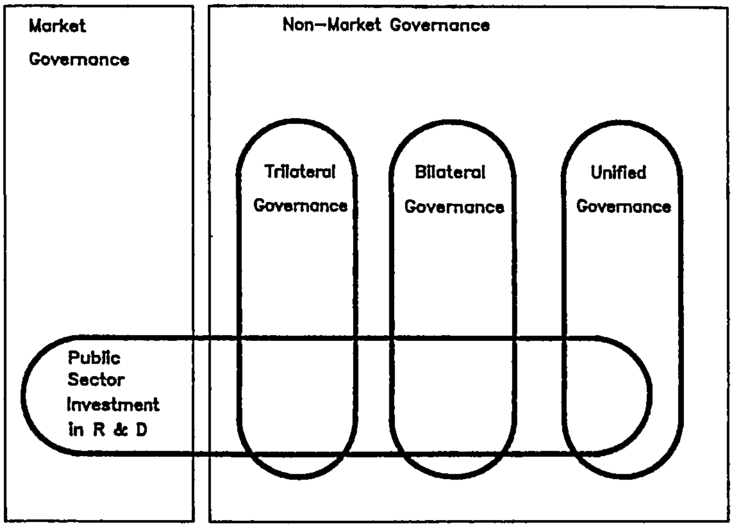
The work quoted above shows there is still considerable uncertainty about whether too little research investment actually takes place, what the results of public R & D policies are, and whether their costs are justified by the results. The market failure approach is criticised for serious procedural and practical failings. Similarly the transaction cost approach, while different in focus, is also criticised for its unrealistic assumptions and lack of attention to policy outcomes. Are we left with anything that can be used as a positive framework for intervention?

What we outline in this section and build on through Part II is a unified theory based on a Williamsonian classification of governance systems, that is ways to allocate resources. Note that under this framework market failure may still occur, but it does not take on quite the same significance because markets are not the only way of deciding investment.

When we talk about market failure we are talking about only one of a number of allocation mechanisms. Williamson (1985a) classifies others as being "trilateral", "bilateral" or "unilateral" in nature. This means that the type and volume of R & D investment may be determined not only by prices in the market, but also respectively by arbitration through a third party, by two-way negotiations between potential partners, or by vertical integration within an organisation. These terms are explained in more detail in Chapter 2.

Figure 1.1 conceptualises this framework. To simplify, there are four types of governance structures. The public sector is not limited to any particular one; in fact it is possible to find examples of governments using all types of governance in their funding and conduct of R & D, just as does the private sector.

Figure 1.1: Classification of R & D Allocation Mechanisms



The first point to come out of the above is that we should worry, not specifically about market failure but about the failure of all types of governance mechanisms. A failure in one mechanism can often be handled by another mechanism, which in allocation terms may be more or less efficient.

There is increasing agreement about this among traditional economists. Arrow (1969, p.51) says:

> "Market failure has been presented as absolute, but in fact the situation is more complex than this. A more general formulation is that of transaction costs, which are attached to any market, and indeed to any mode of resource allocation. Market failure is the particular case where transaction costs are so high that the existence of the market is no longer worthwhile".

The second point is the extent to which we can talk about allocation "failures" at all. A "failure" in this context means an allocation mechanism resulting in a welfare outcome below some theoretically "optimal" one. The existence of a transaction cost in R & D production does not necessarily imply such a failure. Many transaction costs involve true resource costs, and these should be reflected in allocation signals. We need to define the occurrence of such failures, and the conditions under which intervention will improve welfare. Arrow (1969) makes the useful distinction that transaction costs are those that can be varied by a change in the mode of resource allocation, while production costs depend only on technology and tastes, and would not vary among economic systems. Transaction costs include exclusion costs, the costs of communication and information (including information about transactions), and the costs of disequilibrium i.e. the cost of transactions which are inconsistent with a final equilibrium.

The third point is that the framework of Figure 1.1 provides a useful way of classifying instruments of R & D policy, without assuming a market failure paradigm. This is detailed in chapter 6.

Fourthly we now have a framework to build a unified theory of intervention in chapter 7. Arrow defined three conditions for market failure: indivisibility, inappropriability and uncertainty. Bearing in mind Demsetz's criticisms, and our focus on a range of governance mechanisms, we find it more useful to build on Baumol's interpretation of Williamson's conditions for governance failure : market mechanisms are likely to fail in the presence of externalities (especially spillovers) or sunk costs, bounded rationality and opportunism. However other governance mechanisms may still work satisfactorily. If they do not we have a necessary but not sufficient condition for intervention.

The sufficient condition is that for each intervention, the benefit outweighs the cost. This covers the general case of public investment in R & D. The common occurrence of public conduct of R & D is a special case which relies on a separate set of arguments. The conditions for intervention and how they apply in specific cases are developed in detail in the final chapter.

PART II : THE CONDUCT OF R & D

CHAPTER 2

TRANSACTIONS IN RESEARCH AND DEVELOPMENT

2.1 The Transaction Cost Approach

Over the next four chapters we develop a new approach to the economics of R & D. The objective here is to examine in depth, such issues as the nature of R & D transactions (this chapter), the way R & D is organised and how it affects the design of organisations themselves (chapter 3), incentives, rewards and controls in carrying out R & D (chapter 4), and rights over R & D output and intellectual property generally (chapter 5). This provides the groundwork necessary for applying our unified theory of resource allocation. It shows the likelihood of the various governance systems operating. And it allows us to build, in the last part of this report, a revised theory of public policy.

In this chapter we describe a transaction cost approach to R & D. We begin by explaining what is meant by the term "transaction costs" and then take a closer look at critical dimensions (or combinations) of R & D transactions; we next examine the different institutional arrangements (known as "governance structures") which economise on transaction costs. We find the transaction cost concept to be central in allowing us to explain the organisation of R & D - conducting and funding institutions, the design of incentive structures, and the existence and completeness of property rights in R & D.

Transaction costs refer to search and information costs in setting up a possible transaction; bargaining and decision costs in making the transaction; and policing and enforcement costs in making sure the transaction is carried out. The production and distribution of R & D results involve transaction costs.

For example, suppose that an R & D user (such as a manufacturer) requires some specific R & D to be undertaken by an outside R & D producer. Transaction costs include costs to the user of obtaining information about potential R & D producers - both domestically and internationally. These costs can be extremely high for an individual user. And even when an R & D user identifies an appropriate R & D producer, there is still likely to be a protracted process in determining the prices, timing etc of the transaction and working out the finer details of the contract between the two parties. Policing costs arise for the R & D user in monitoring the quality of output of the R & D producer.

Transaction costs in R & D also include the costs for producers in attempting to secure the benefits of their R & D investment. For example, policing and enforcement costs may also arise for the producer when it is necessary to ensure that the R & D user does not sell the R & D results to a third party. An example of enforcement costs is computer firms which invest to camouflage the technology in new models of their computers to prevent copying by rival firms (Magee 1977).

Several sources of transaction costs have been identified: costs associated with discovering prices of inputs and exchanges - which is both time consuming and expensive in rapidly changing circumstances. Four reasons have been identified for explaining why the determination of prices is costly:

> "because of the number of transactions, because consumers lack detailed information on the use of each component or contribution to a commodity, because of the difficulty of measuring varied and changing activities, and because of the need to separate contributions of input owners" (Cheung 1983, p 9).

Further, transactions costs result from 'bounded rationality': owing to computational limitations people are sometimes unable to identify easily, and hence cheaply, future contingencies and write these into contracts. Successive short term contracts may overcome this but at the expense of large transaction costs. Costs also result from opportunism: i.e. opportunism occurs if either the R & D producer or the R & D user withholds information pertinent to a mutually beneficial contract; or if either party has special skills, information or position which allow that party to bid up the price, thereby imposing costs on the other party. Lastly costs result from information impactedness : in cases in which there are asymmetries in the levels of information available to the R & D producer and user, the party with the least information may suffer costs, and contracts that turn out to be unfavourable to that party may be negotiated, even though from an ex ante viewpoint the contract was in their best interests.

Thus bounded rationality, opportunism and information impactedness may inhibit or distort the transactional process. Transaction costs are important because they impose and in particular cases can block the formation of markets (Arrow 1969). It should be noted that these sources cannot be considered in isolation. For example, the existence of bounded rationality and information impactedness provide the conditions facilitating opportunism. Opportunism would not be an issue if both parties had perfect information.

2.2 Critical Dimensions of R & D Transactions

Williamson (1979) identifies three critical dimensions for characterising transactions: uncertainty; the frequency with which the transactions recur, and the degree to which long-term transaction-specific investments are incurred. In the context of R & D, Jardine adds a fourth dimension: the degree to which returns from R & D are appropriable. We shall examine each of these dimensions in turn. These critical dimensions provide the basis for design of R & D policy in chapter 7.

Uncertainty and Risk

R & D typically involves a high degree of risk and uncertainty. (Both these concepts refer to a range of possible outcomes, including those which are unanticipated in the case of R & D; the former implies a probability distribution function may be attached to them.) The production of R & D results often involves long lead-time. Studies of R & D programmes in the United States have revealed an average probability of between 12 and 20 per cent that an R & D project would result in an economically successful product or process (Mansfield 1981). Mansfield claims that the risks in industrial R & D are mainly commercial, not technical. In fact, Mansfield reports that technical risk is often quite modest - the likelihood of a project reaching technical completion often being greater than 50 per cent. This is especially so for applied research aimed at fairly modest advances.

> "For laboratories that devote a large percentage of their resources to development rather than research, the technical risk is smaller still." (Mansfield 1981, p 100.)

In contrast, commercial risk - i.e. the probability that a new product or process will not reach commercial introduction or application or that, if it does, it will not be an economic success - is often substantial. One study quoted by Mansfield showed that 60 per cent of R & D projects reached technical completion and that 30 per cent were commercialised. However, only 12 per cent earned an economic profit. The commercial benefits of basic R & D, especially, are uncertain.

It is argued, however, that R & D is not necessarily inherently more risky than other investments undertaken by firms. The results of failed projects may be profitably redirected into other R & D projects. In addition, Noll (1977) asserts that under certain plausible conditions the failure to engage in R & D can be subject to more uncertainty than undertaking R & D projects - because of the threat of competition.

R & D transactions not only involve technical and commercial uncertainty, they also involve behavioural uncertainty arising from the tendency of R & D transactors to behave opportunistically : i.e. to deliberately and strategically withhold or distort information. Behavioural uncertainty is compounded by bounded rationality of the other parties who are unable to foresee all contingencies (Jardine 1986). Behavioural uncertainty is greatest when combined with asset-specificity (discussed below) in the context of a long term relationship which develops between R & D sellers and buyers.

Frequency

R & D transactions may be one-off, occasional or recurrent. A one-off R & D transaction means that the R & D buyer and seller only transact with each other once. For example, the buyer may purchase R & D embodied in a machine. There are no subsequent transactions involving support services, spare-parts etc. Few R & D transactions have this completely isolated nature. Occasional R & D transactions involve the periodic purchase of R & D goods or services from the seller. An example is a client firm which occasionally commissions another firm to undertake market research on its behalf. The purchase of up-dated software packages to accompany computer hardware is another example. On the other hand, recurrent R & D transactions involve the regular purchase of R & D goods and services over a period of time. An example would be a large corporate client which regularly purchases research services from a government research institute. In the next section we consider recurrent transactions which involve a long-term relationship between R & D buyers and sellers and asset specificity.

The recurrent nature of R & D transactions has been recognised by Yu (1981, p 225):

> "The market for innovation is not just a market for the end product of innovation, but rather a market for innovating services. Contracts between innovators and manufacturers can be viewed as a *continuing brokerage relationship* between providers of innovating services and consumers of those services: The significance of this relationship provides additional insights in dealing with problems relating to innovation."

Under this view, manufacturers would not contract with a 'fly-by-night' research organisation which has only a few existing patents and no prospects of future improvement.

Asset Specificity

In his subsequent work, Williamson gives greatest weighting to this characteristic of R & D transactions (i.e. he considers it to be the characteristic which is most important in choosing the most efficient institutional arrangement for organising transaction). This is not to say that Williamson does not acknowledge that uncertainty and frequency are critical attributes. Rather it is that:

> "the governance ramifications of neither, however, have been fully developed - nor can they be until they are joined with the third critical dimension : transaction-specific investments i.e. asset specificity" (Williamson 1979, p 239).

Asset specificity arises when inputs cannot be put to another use or be utilised by another user without the original owner suffering a sizeable financial loss. Specific assets do not have lease or resale markets. The production of R & D tends to involve specific assets. Williamson (1985) has identified five types of asset-specificity which we relate to R & D: site specificity; physical and human asset specificity; dedicated assets; and brand name capital.

An example of site specificity is the location of a specialised R & D department in a unique proximate relation to a downstream manufacturing stage to which it supplies vital input. The benefits of close proximity may be attributable to the need to economise on transportation and inconvenience costs or the need to have a constant interaction of R & D and manufacturing personnel.

The location of the Forest Research Institute in Rotorua is an example of site-specificity. The forestry and forest products scientists are working in the main forestry area of the country, where they are in close contact with forest managers and production staff at processing plants, and where they can grow demonstration plots near the Institute. Another example of site specificity is the DSIR's Geothermal Research Centre at Wairakei which is the Department's main base for field studies in geothermal areas. It is situated within sight of the Wairakei Geothermal Power Station.

R & D is likely to involve a great deal of physical asset specificity: specialised physical inputs (such as scientific equipment, machines) are often employed when new products and processes are being developed. These specialised inputs may not be capable of being used by other users or in other uses.

Examples in the forestry field are: computer growth models developed to study the way in which radiata pine responds to various silvicultural treatments; laboratory equipment used to evaluate the pulping characteristics of radiata pine; engineering equipment used to research the strength of glue-laminated timber beams; trees grown to research the genetics and physiology of various timber species.

Human capital will be transaction-specific when the discovery of information depends on a particular research team (Levy 1985). Researchers acquire, during the course of their employment, significant job-specific skills and related task-specific knowledge (i.e learning by doing). In extreme cases, it is plausible that scientists who have pursued a very specialised research programme for a number of years may not be able to find an alternative employer without a significant loss in salary. Conversely, the present employer may not be able to find a replacement for that scientist if the scientist chose to quit, or it may take an unreasonable time to do so.

In large research bodies, scientists have the opportunity to specialise and to develop skills particular to a very specific research job. As an example, New Zealand grown radiata pine has properties different from all other timbers. It therefore requires very specific human capital to carry out a research programme on topics ranging from the insects attacking the trees, the economically best times to prune, the most suitable adhesives to use in fibreboard production, to the most suitable temperature for timber drying. A recent study of New Zealand R & D (Department of Trade and Industry, 1986a, b) notes that in at least one company, researchers were reluctant to acquire skills which were specific to the needs of one firm. The preference of researchers was to acquire skills which were marketable, i.e. which were attractive to other employers.

Investment in dedicated assets involves the R & D seller expanding existing capacity on behalf of a particular R & D buyer. Although these assets add to an R & D firm's generalised production capability (i.e. they are not specific), the investment would not be undertaken but for the prospect of selling significant R & D results to a specific R & D buyer. Dedicated assets lose value if employed in alternative uses or used to service alternative users. Significant excess capacity would result if they are not employed for the dedicated user (Williamson 1983a). An example would be an R & D firm (or department) which buys an extra piece of equipment or hires extra staff in order to do research for a particular client (including another division of the same firm). Jardine (1986) suggests that investment in dedicate assets may explain the existence of research associations with dedicate assets to a particular group of buyers, for example the Meat Industry Research Institute of New Zealand (MIRINZ) and the Wool Research Organisation of New Zealand (WRONZ).

Another specific asset that is owned by a firm undertaking R & D is its brand name capital (i.e. trade name). Name and reputation are important ways the firm communicates with (potential) R & D buyers. Brand-name capital reduces the cost to a manufacturer of searching and comparing competitive bids offered by potential research analyst firms to undertake development work on their behalf. As an example, the high international scientific reputation of the Forest Research Institute gives local forestry companies buying FRI research, great confidence in the quality of the product for which they are paying. Its reputation and name puts the FRI in a better negotiating position than a private sector forestry consultant. If the brand-name were rented from another firm, the R & D firm renting the brand-name would be extremely hesitant to invest (in advertising, for example) to build up its goodwill, because such investment is highly specific to that brand-name.

Appropriability

Appropriability refers to the degree to which investors in R & D can secure the returns of their R & D activity. R & D appropriability depends on the nature of property rights for R & D results and other mechanisms which protect the returns to R & D. Thus, appropriability refers to the extent to which the results of R & D investment exhibit the characteristics of private property.

Private property rights have varying degrees of the following features: the right to exclude others so that the R & D producer alone may decide on its use; the right to extract exclusive income from its use; and the right to transfer the property to, or to exchange with, anyone that the R & D producer sees fit (Cheung 1983). These may be summarised as the right to control, to benefit from, and to dispose of, resources.

The degree of exclusivity and transferability in turn will depend on: the extent to which the R & D producer is able to define, police and enforce rights to the resource; the ability of the R & D producer to enter into appropriate contracts to use or transfer such rights, and the costs of such transactions. These factors are closely related to the legal and regulatory framework. The ability of a firm to appropriate its R & D output is enhanced when property rights for R & D results are well-defined.

Several institutions are used to increase the appropriability of R & D investments: namely, the patent system, copyright laws and trade secrets. These are described in chapter 5. However, numerous studies have shown that these intellectual property rights are neither the only nor the primary mechanism for appropriating returns from R & D (Levin et al 1984). Secrecy is a viable option in some industries and in several electronics industries, gaining lead-time and exploiting learning curve advantages are primary methods of appropriation. Other studies have emphasised the importance of complementary investments in marketing and service (so as to build up brand loyalty, for instance) to enhance the appropriability of R & D.

However, R & D results often display certain characteristics which complicate their treatment as private property. The problem is that there may be difficulties in securing exclusivity. Problems of exclusivity may occur in defining property rights to R & D when the skills/know-how are contained in the organisation's routines and cannot be transferred to others without on-site demonstration and involvement (Teece 1981). It may also be hard to contract, when a particular R & D result benefits a large number of small users who cannot be identified. This is especially pertinent to the agricultural sector in New Zealand. Such problems may entail prohibitive costs of specifying and enforcing contracts for R & D results. Policing problems may also occur when the organisation undertaking R & D may be unable to prevent spillovers and monopolise its use, thus creating a likely disincentive to investment.

One would expect that the more basic the research, the less appropriable it is likely to be. For example, it would be very difficult to appropriate the benefits of work undertaken to develop econometric theory (basic research) since this is often made freely available in academic literature. However, it would be much easier to establish exclusivity for new econometric models (applied research). Thus it can be seen that OECD-type definitions of R & D (appendix 1) are loosely based on the single dimension of appropriability.

The extent of appropriability differs from industry to industry, and is likely to be greater for monopolies i.e. no competitors will exploit the monopolist's ideas. Lunn (1985, p.426) comments that

> "in cases where property rights to innovating output do not exist or are weak, monopoly power may enhance a firm's ability to appropriate its innovative output"

In this sense, he considers market power of a firm to be a substitute for well-defined property rights over R & D results (and the opposite may also hold). He explains that there are two ways in which market power may enable firms to appropriate more of the benefits of their R & D investment. First, given that the firm is the sole producer of its

R & D result, it has a larger market in which to sell. Thus, a cost-reducing process innovation will increase both per unit and total profits for the firm. As for product innovations, the established marketing infrastructure of the firm (distribution, reputation etc) enables the firm to increase its return from R & D. Second, market power enhances appropriability by allowing a firm to economise on monitoring costs. The firm may have a greater willingness and capacity to initiate patent infringement suits.

Appropriability and the performance of alternative property rights depends on the characteristics of the end-product. For example, Schmid (1985) refers to the example of new varieties developed by seed companies. Were the companies to use the pure line parent rather than a hybrid, the farmer would be able to buy seeds once, save some of their harvested seeds and make their own future generations. However, the hybrid approach to breeding is popular among seed companies because a hybrid produces a harvested seed which does not breed true in the second generation. Farmers are then compelled to buy seeds each year, and the seed company is able to recover its research costs. Thus, the degree of appropriability varies according to the characteristics of the product. Schmid goes as far as saying that the character of the good and the associated degree of appropriability shape the research agenda : i.e. seed companies have not just developed hybrid seeds because they are the better in terms of yield or disease resistance; but also because it increases the appropriability of returns to the seed company.

Noll (1977, p.172) has commented that public provision of R & D need not necessarily imply inappropriability of R & D:

> "The absence of commercial R & D activities in an economic area in which nonprofit institutions are active may be due to inappropriability, but it may also be because the nonprofit institutions are so active that the rate of return to further R & D in that area is, even with full appropriability, uneconomically low."

Other Critical Dimensions

Divisibility is another critical dimension of R & D transactions. Perfect divisibility arises when a team or plant or process is capable of being increased or decreased in scale by small amounts without any change in its nature. However, in a significant number of cases, R & D activities encounter indivisibilities. In particular, some R & D activities may exhibit sufficiently large scale economies that only large organisations can support efficient R & D operations. For example, it is often claimed that it is necessary to have at least a minimum number of scientists and researchers in the same organisation so that they can benefit from mutual interaction (the "critical mass" argument). The result is that either it will be technically impossible to produce such R & D with a smaller number of research staff, or the production and transaction costs arising with a smaller research staff will be too high.

Another example of indivisibility in R & D arises with very complex R & D products such as aircraft, for which development costs may be very large compared to the total demand for the end-product. Noll (1977) claims that indivisibility is likely to be more prevalent for transactions involving R & D products at the development end of the spectrum and more instrumental technical advances. In New Zealand the indivisibility argument is frequently used to support public conduct of R & D, bearing in mind that most local private organisations have limited R & D capacity.

Yet another dimension for characterising R & D transactions is measurability (see Barzel 1982). Measurability relates to the extent to which the quality and quantity of the inputs and outputs of R & D can be assessed. Measurability imposes transaction costs both before the production or sale of R & D i.e. ex ante assessment, and after the R & D results have been produced or sold i.e. ex post assessment. In the production of R & D, it is difficult to determine the individual productivities of each researcher in a research team by measuring output. An assessment of inputs is usually required - such as hours worked. In the distribution of R & D results, it may be very difficult for the R & D buyer to assess the quality and commercial value of an R & D result. These measurement costs are likely to be greater for newer technologies; for radical technologies; for technologies with fewer and more distant substitutes; for parties which do not have a reputation in the R & D market (Davidson and McFetridge 1984).

The Beattie Report (1986) recognises the importance of measurability in publicly-conducted R & D in New Zealand, in determining accountability of the institution, evaluation of the project, and assessment of the individual researcher.

These various dimensions of R & D are used as the basis for policy assessment in Chapter 7.

2.3 Governance Structures

Each of the dimensions of R & D transactions discussed above implies different transaction costs. In this section, we examine various institutional arrangements which economise on transaction costs for each of the different types of R & D transaction. Following Williamson's analysis, we consider four types of governance structure: market governance; bilateral governance (private ordering); trilateral governance (third party enforcement), and unified governance (vertical integration).

It will become clear that different transactions have different governance (enforcement) requirements. The most efficient governance structure for any particular transaction is that which best economises on bounded rationality and which limits opportunism.

Market Governance

Market governance is the most efficient (i.e. transaction cost-minimising) governance structure for transactions that either involve non-specific assets; involve a low degree of uncertainty; or are single, occasional or recurrent (i.e. all frequencies of transactions).
Because there are many R & D buyers and sellers (the implications of non-specific assets), market governance limits opportunism because the parties to the R & D transaction can simply switch to another buyer or seller if they suspect that they have been cheated. Furthermore, the non-specific nature of the asset and the low degree of uncertainty means that bounded rationality is also less likely to be a problem. The content of R & D services provided in the markets will be well-known and established, and prices will summarise the interaction of supply and demand conditions. Kay (1984) points out that replicability, repetition and reputation all help to reduce bounded rationality to manageable proportions.

Examples of market governance of R & D transactions are routine laboratory testing and some professional services such as market research and engineering. The purchase of some non-specific assets used in the production of R & D is another example (e.g. calculators, some machinery, test tubes, offices etc). One or both parties may be public bodies provided the transaction is made through the marketplace. "User pays" is one way this may occur.

Market governance of R & D transactions is likely to be less frequent in New Zealand than larger economies because of the "thin" nature of some markets for R & D results in New Zealand. By thin, we mean that the number of buyers and sellers is small, so that R & D transactors do not have the same flexibility to switch to an alternative buyer or seller if they suspect opportunism by the other party. This applies particularly to the markets for R & D in forestry and agricultural research.

Third Party Enforcement

Trilateral governance involves explicit regulatory specification or third-party enforcement (e.g. government, courts) of R & D transactions: to determine enforcement where there has been violation, to arbitrate when a dispute arises, to assess damages, to impose penalties, to evaluate performance (e.g. quality of R & D results, appraisal of methodology etc).

Trilateral governance is the most efficient governance structure for R & D transactions which are occasional, and which involve medium to high degrees of asset specificity: for example, the importation of R & D output embodied in advanced plant, machinery or equipment. Because specific assets (which by definition have a lower value to other users) have been put in place, both parties have an incentive to see that the R & D transaction is completed.

Market governance breaks down here, because there are not many buyers or many sellers: i.e. it is not possible to simply switch to an alternative R & D buyer or supplier. On the other hand, the occasional nature of the R & D transaction means that it is not possible to recoup the cost of bilateral (transaction-specific) governance. There is no long-term relationship between the parties to the R & D transaction. Trilateral governance or third party enforcement arises as an intermediate institutional arrangement for these types of transactions.

Potential trilateral governance mechanisms include: patents, copyrights, trade secrets, quality standards. In some cases, patents improve the ability of the R & D seller to appropriate the returns to R & D. The government - through its establishment of the legal framework and the system of property rights - is the third party which governs the R & D transaction. Another example of trilateral governance is the monitoring of the R & D projects by an outside referee (such as with university theses). Monitoring can occur a several stages of an R & D project: selection of methodology, sample creation, data analysis, and the final report.

A specific example of trilateral governance was the New Zealand Energy Research and Development Committee which refereed research projects undertaken for the Liquid Fuels Trust Board.

Warranties for new products embodying R & D are also a type of trilateral governance. Jardine (1986), and Barzel (1982) maintain that warranties are an efficient governance structure when the costs of quality measurement are prohibitive for the seller but not for the buyer. Warranties enable the seller to charge a price to recoup the costs of repair and replacement, and they reduce the buyer's costs of measuring quality. They ensure that the purchaser of a new product embodying R & D obtains a high quality at the given price. Similarly, government specification of minimum quality standards (eg via the NZ Standards Association) may be another efficient means of ensuring contract performance. Such standards are agreed minima that both parties can accept without the costs of extensive testing. To be effective, trilateral governance requires that both R & D transactors adhere to the directives of the third-party. In New Zealand an organisation such as TELARC monitors the standard of the laboratory.

Galanter (1981) acknowledges that the scope of trilateral governance may be limited, pointing out that in many instances, the participants can devise more satisfactory solutions to their disputes than can professionals constrained to apply general rules. Then we look to other governance structures.

Private Ordering

Bilateral governance or private ordering is the most efficient governance structure for R & D transactions that either involve a moderate degree of asset specificity; involve a moderate degree of uncertainty; or are recurrent, involving a constant flow of R & D information between buyers and sellers.

A moderate degree of asset specificity implies that assets are not totally sunk. Assets have at least some alternative uses or potential uses. The threat of opportunism is high but not so high as to warrant common ownership (i.e. through vertical integration) of the assets involved. Outside procurement via market transactions enables each party to achieve any economies of scale from specialisation that may exist.

Outside procurement, however, is exposed to opportunism when adaptations are required during the course of the relationship, as a result of exogenous changes (such as cost increases). But because some investment is at least partially sunk, there is an incentive for both parties to maintain the relationship. R & D buyers will not search for other sellers because this would involve high set up costs; R & D sellers continue to supply because the particular assets are specialised to a particular buyer to some degree.

The merits of bilateral governance relative to trilateral governance (namely the direct enforcement of patent rights) are weighed by Yu (1981). First, the cost of evaluating research is lower for people in an industry than for outsiders, such as judges and lawyers, and the former can thus more efficiently tailor the degree of property right protection through contractual arrangements of their own. The second advantage of bilateral governance is the lower enforcement cost of contract law than of patent law, the former being based on directly observable enforcement mechanisims, with violations easier to detect.

Prior contracts are examples of bilateral contracts in R & D. A prior contract is entered into before the production of R & D and before patents have been obtained. Output of the contract is, by definition, uncertain and so is the production of that output. Prior contracts are entered into when one (or more) buyers commissions one (or more) sellers to undertake R & D. The two parties are then in a bilateral relationship in which their identity is important. In the pre-patent period, there are a large number of R & D sellers and buyers: contracting is competitive. In contrast, the post-patent period is characterised by a small numbers (non-competitive) situation in which one R & D seller who holds the patent has considerable (monopoly) bargaining power and is able to charge a high price. The threat of facing a high royalty rate prompts individual R & D buyers and sellers to enter prior contracts. These contracts alleviate the free-rider problem common in the early phases of the production of R & D results. Yu (1981) discusses three major forms of prior contracts: development contracts, employment contracts, and patent licences.

The most familiar form of prior contract is the development contract; this is used when research organisations subcontract parts of their research project. These research organisations place public advertisements inviting candidates to apply. Candidates submit their bids outlining their methodology, noting their expertise in the area, and detailing the prices that they charge. The research organisation selects the applicant on the basis of both price and expected quality.

Employment contracts i.e. the hiring of R & D personnel by an organisation is another example of a prior contract: personnel are selected before their R & D results are known. Furthermore, R & D personnel are usually remunerated on the basis of input (hours worked) rather than on output (the market value of R & D results). Employment contracts are notoriously difficult to enforce with key R & D personnel often quitting to work for rival firms or to set up their own rival company (as is common in the semiconductor industry). These problems are less severe in New Zealand because of the thin market for scientists and the lower tradition of mobility. It is also less of a problem in basic research.

Pakes and Nitzen (1983) conclude that the potential mobility of scientific personnel need not, by itself, have an adverse effect on project profitability. In fact, they claim that if the firm is able to choose between alternative (prior) labour contracts, the firm can provide an incentive structure which controls the mobility of the scientist - only inducing scientists to leave and set up a rival when it is in the firm's interest for the scientist to do so.

Another form of prior contract occurs when a research company (which owns a patent) grants a licence to a manufacturer. Patent licences typically grant the right to use future patented inventions (made by the research organisation) for the relevant area of research. Because the term of the licence is quite long, many patents may be invented under some form of prior contract.

Several mechanisms exist to enforce prior contracts. Yu describes these briefly as: the imposition of penalties for R & D buyers who break their contract e.g. non-refundable lump sum fees and royalties for the term of a licence regardless of early contract cancellation; the granting of rewards for R & D buyers who comply with their contract; the provision of "hostages" by the R & D buyer, i.e. the depositing of money which is refunded once the contract is fulfilled; the R & D seller contracting with other inventors to secure their promise that they will not compete with the original R & D seller in licensing (e.g. patent pooling and cross licences); and the investment in specific assets by R & D buyers: so that the R & D buyer will incur high costs in switching to another R & D seller e.g. computer software is specific to particular brands of computer hardware.

Vertical Integration

Unified governance or vertical integration is the most efficient governance structure for R & D transactions which either involve a high degree of asset specificity, are recurrent, or involve a high degree of uncertainty. We discuss vertical integration at some length in the next chapter on the boundaries of a firm undertaking R & D. We do not repeat that discussion here but merely summarise the argument.

Opportunism is potentially a great problem in R & D transactions involving a high degree of asset specificity and in which there is a long-term relationship between both parties. In particular, small numbers bargaining problems may arise. Monteverde and Teece's (1982) study of the development activities of new automotive parts is an example. The design of a new vehicle model is a complex, long-term (5-year) undertaking. For some components it is necessary that suppliers be involved with the assembler in preproduction development. During this process, component suppliers acquire production as well as design knowledge and gain a 'first-mover advantage' in follow-on production. This creates problems for the assembler who is "locked in", in the sense that subsequent production cannot be contracted in a fully competitive fashion. Secondly, the supplier may be able to price subsequent production above long-run costs because of the advantage it has acquired relative to its rivals. In short, the assembler's dependency on the supplier could readily translate into inefficiency (Teece 1982b).

Vertical integration into the production of such automotive components is likely to occur. Vertical integration eliminates the "lock-in" problem because it harmonises incentives between the assembler and supplier. The other advantage of vertical integration is that it facilitates sequential adaptive decision making. It is easier for separate stages of R & D (such as development and commercialisation) to be coordinated within a single firm than it is to coordinate activity amongst separate organisations. Thus, vertical integration is more efficient when R & D results require a major readjustment of other parts of the system (e.g. other components or other items of equipment) before they can be commercialised. Development and commercialisation require considerable coordination.

Vertically integrated structures also have more sophisticated information bases and are thus able to conduct superior monitoring and internal control, which further limits opportunism. Although internal organisation does have several advantages, it suffers from agency costs which were discussed in an earlier section. The boundaries of the firm need to be wide enough to economise on agency costs.

2.4 International Technology Transfer

The analysis of R & D transactions discussed above can be extended to international technology transfer. As with R & D transactions conducted within national boundaries, it is the characteristics of the R & D transaction that determine which governance structure is most efficient. The continuum of institutional arrangements for organising transactions spans from market transactions, e.g. importing R & D embodied in a good, at one end; through to hybrid forms such as joint ventures and franchise operations, and intrafirm organisation i.e. direct foreign investment, at the other end. Market governance is the most efficient governance structure for international R & D transactions which do not involve specific assets or much uncertainty. Bilateral governance is appropriate for recurrent international transactions involving a moderate degree of asset specificity. Trilateral governance is most efficient for international R & D transactions which are one-off or occasional and which involve moderate to high degrees of asset specificity. Vertical integration (e.g setting up foreign subsidiaries) is most appropriate to recurrent international R & D transactions which involve high degrees of asset specificity. Although our transaction cost analysis can be readily applied to the international transfer of R & D, one should recognise that transaction cost problems are magnified when partners to contracts are international.

In his examination of intrafirm and market R & D transactions by multinational firms, Teece (1977) points out that the technology-transfer costs can be considerable when the technology is complex and the recipient unit does not have the capabilities to absorb the technology. For the typical project surveyed, transfer costs averaged 19 per cent of total project costs. There was considerable inter-industry variation in the sample data, with transfer costs ranging from 2 per cent to 59 per cent of total project costs. Technology transfer in chemicals and petroleum refining display relatively low transfer costs, presumably because it is possible to embody sophisticated process technology in capital equipment, which facilitates the transfer process. In both industries surveyed, transfer costs are higher the larger the number of firms utilising the technology (the index of diffusion) and the less experienced in manufacturing the recipient firm is. In the chemicals and petroleum refining industry, transfer costs are also higher for technologies characterised by very few previous applications. In the machinery industry, transfer costs are higher for newer technologies.

One institutional arrangement that has arisen partly in response to the high transaction costs involved in international R & D transactions is the transmission of R & D through the internal divisions of multinational firms. Multinational firms arise in order to evade the high transaction costs of certain arm's-length markets - especially for knowledge of new products, processes, and proprietary technology.

> "Specifically, intrafirm transfer to a foreign subsidiary, which avoids the need for repeated negotiations and attenuates the hazards of opportunism, has advantages over autonomous trading (i.e. arm's-length contracting). Better disclosure, easier agreement, better governance, and more effective team organisation and reconfiguration all result. Here lies the incentive for internalising technology transfer within the multinational firm" (Teece 1981, p 87).

The incentives to internalise international R & D transactions are likely to be greater, the more such transactions are characterised by: high measurement costs; frequent transfers; uncertainty; transaction-specific investments. In turn, these characteristics are most likely to arise: for newer technologies; for technologies which represent a more significant advance on the state of the art; for technologies with fewer previous transfers; for technologies with fewer and more distant substitutes; the smaller is the amount of past transfer activity of the parties involved (Davidson and McFetridge 1984).

The advantages of internalisation will be less likely to outweigh its costs, the smaller in value the transactions contemplated. The value of the R & D result depends on the availability of substitutes: the value of an R & D result will.be smaller when there are a large number of close substitutes available (Davidson and McFetridge 1984).

The hypotheses suggested above are broadly supported by empirical investigations. In their study of US-based multinationals, Davidson and McFetridge (1984) found that the probability of internal transfer is higher the newer and more radical is a technology; and the fewer the occasions upon which it has been transferred. A negative relationship between the probability of internal transfer and the type of technology has been observed by Mansfield, Romeo and Wagner (1979) and Mansfield and Romeo (1980). In a later paper, Mansfield - employing a sample of 23 multinationals, discovered that foreign subsidiaries were the principal channel of transfer during the first five years after commercialisation. For the second five-year period after commercialisation, licensing became more important. Wilson (1977) found a negative relationship between product complexity and the propensity to engage in arm's-length arrangements. Teece (1976) found that the cost advantage of an internal over a market transaction was greater for technologies which had no prior commercial application.

Many statistical studies show a correlation between multinational activity in an industry (i.e. foreign ownership) and R & D expenditure in high technology industries (see for example, Gannicott 1984). It is clear in this context that public policy on foreign ownership infringes on science and technology policy.

Coughlin (1984) examines the technology-transfer complications of foreign ownership restrictions. He makes two hypotheses: firstly, that technology transferred to countries that deter wholly owned foreign direct investment will be disproportionately process rather than product technology; and secondly, that product technology transferred to countries that deter wholly owned foreign direct investment will tend to be obsolete.

His argument relies on the assumption that it is more difficult to determine the value of a new product than it is to determine the value of a new process, because at least one alternative method of production already exists. Consequently, the incentives to internalise the transfer (via setting up wholly owned foreign subsidiaries) are greater for product technology than for process technology.

A second hypothesis relies on a product cycle view of technology, i.e., that the most efficient mode of transfer changes as time passes. The multinational corporation is considered to have an advantage in the transfer of new technologies so that foreign-ownership restrictions inhibit adoption of new technologies.

International transfers of technology are clearly important in the small country situation of New Zealand. This is more likely to be so in manufacturing technology than in primary industry which is more geographically-specific. The N.Z. Manufacturers Federation studies (1984) calculated that in 1983/84 the manufacturing sector paid out approximately $30 million as royalties on licence agreements and in return received $6 million. This means that by this crude measure, New Zealand is a net importer of R & D. The Department of Trade and Industry study on R & D (1986, 1987b) confirm this in many cases.

In public policy terms the international transfer of technology becomes a strategic instrument of industry policy. Scobie (1985) addresses concern about the relatively free access to New Zealand technological research. His conclusion is that there are problems concerning international property rights, but that broad restrictions on the flows of R & D would be unproductive.

This chapter has reviewed a number of important dimensions to R & D, and ways investment decisions may be made. We use these to aid our classification of policy instruments in chapter 6, and our framework for policy in chapter 7. Before then however we need to investigate the transaction cost approach further by analysing the organisation of R & D, how it is carried out, and how it is protected.

CHAPTER 3

THE ORGANISATION OF RESEARCH AND DEVELOPMENT

3.1 An Introduction to Organisational Issues

In this chapter we focus on the organisational issues which pertain to R & D. In particular, we examine the boundaries of an organisation undertaking R & D i.e. the degree of integration of an organisation, the effect of its organisational structure on R & D, conversely how R & D issues affect organisational structure and the organisation of R & D in the public sector. In addition we investigate the organisational distinctions between R & D-conducting bodies and R & D-funding bodies.

A public policy framework for R & D must cover the gamut of R & D production. Traditional public policy analysis has tended to concentrate on the occurrence of market failure as a sufficient prerequisite for government involvement in R & D. The traditional approach pays little attention to private sector responses to market failure (such as vertical integration). For this reason, the principal focus of this chapter is on the organisation of R & D in the private sector rather than in the public sector.

Organisational issues are important in this argument because the characteristics of R & D (chapter 2) in turn affect the organisation of the body conducting it via the transaction cost-minimizing effect. In turn this affects the types of governance most likely to be used and thus the instruments of public policy considered most appropriate.

A traditional approach to the organisation of R & D would be based on a production function: R & D investment is viewed as resulting in technological change which shifts the function. Typically the major input is human expertise, working on unstructured or poorly-defined problems. The output may be highly uncertain, not easily identifiable, or intangible, and complicated further by the joint nature of production. Production functions are sometimes characterised by economies of scope or scale, and frequently involve learning. We do not investigate these structural relationships further. Instead we use the general transaction cost approach to show how R & D is carried out in organisations.

3.2 Extent of Organisational Integration

In this section we ask to what extent do firms (vertically and horizontally) integrate in order to capture the benefits generated by their R & D. A separate question is how the definition of a firm's boundaries and its degree of integration, in particular, affects the rate and direction of R & D. The degree of integration is seen as one strategic choice available to management. Following Teece's analysis (1986), we show that the degree of integration depends on: whether specialised inputs are required in production, and distribution of R & D results (i.e. asset specificity); the efficacy of methods to protect R & D results (i.e. the enforceability of property rights); and the efficacy of the market for R & D results. This follows on from the discussion of vertical integration and asset specificity in the previous chapter.

Specific and Complementary Assets

The production and distribution of R & D results often require inputs which are specific to the R & D result. Asset specificity arises when inputs cannot be "redeployed to alternative uses or by alternative users without sacrifice of productive value" (Williamson 1986b). A high level of asset specificity thus means that there is no market for the lease or resale of an input. For example, in the commercialisation of an R & D result it is often necessary to invest in specialised marketing, manufacturing and after-sales support services. Teece (1986b) gives the example of the commercialisation of a new drug which requires the dissemination of information to doctors through a marketing/communication channel.

The existence of specific assets in the production and distribution of R & D results has important economic implications. Incentives exist for the R & D firm to own (internalise) the assets which are specific to R & D results. Otherwise, contracting problems may arise which prevent the firm from capturing the benefits of its R & D.

The most important problem arising from asset specificity is known as small numbers bargaining. For example, suppose that one firm, by virtue of its past involvement has made specific investment into a particular area of R & D. Then future contracting may no longer be competitive because this specific firm may threaten to withhold further marketing services so as to raise the price that it receives. In other words, asset specificity may enable one or both parties to behave opportunistically at subsequent recontracting stages, even though contracting was competitive at the initial stage.

The problems arising from asset specificity can be avoided if the R & D firm internalises and owns the specific asset. Opportunism is then limited by the superior monitoring and internal control that characterises activity organised within firms.

Teece also points out that firms undertaking R & D may wish to enhance their returns by investing in complementary assets. Complementary assets can be distinguished from specific assets in that they do not necessarily involve investments specialised to the R & D result (however, many specific assets may also be complementary). A complementary asset is an asset whose price will increase once the R & D result is revealed to the market. For example, a firm may hold land which is not suitable for production of a particular crop because of a soil deficiency. Research may uncover that the deficiency can be overcome, thus increasing the price of the land. Firms undertaking R & D are able to acquire complementary assets at low prices and sell them at higher prices once the R & D is complete, thus realising capital gains. The opportunity to make these profits arises because the firm undertaking R & D has superior (inside) information on the attributes of the R & D results, information which is not available to the rest of the market (Hirschleifer 1971).

Note however that opportunities for such gains are limited in the real world. The limitation arises because firms undertaking R & D often do not have adequate information (or ability) to evaluate the effects of an R & D result on the prices of end products and inputs. In addition, although firms undertaking R & D may acquire ownership of complementary assets this does not imply that the firm necessarily takes control of these assets. Referring to our previous example, a firm may own a block of land but may not necessarily be responsible for its cultivation. In other words, the boundaries of the firm need not necessarily be extended.

The Enforceability of Property Rights

The incentive for a firm to internalise specific assets depends, other things being equal, on the enforceability of a firm's property rights over its R & D investment. The more defined are the property rights, then the less is the incentive to integrate. For example, if property rights are perfectly defined (such as an iron-clad patent that lasts in perpetuity), the firm undertaking R & D may be able to license out the manufacture, distribution and marketing of the end product. The R & D firm is able to reveal the full value of the R & D result to the market (i.e. no disclosure problems) and would receive a royalty equal to the extra benefits from selling new products which embody the R & D result.

On the other hand, if property rights are ill-defined, then incentives exist for the firm undertaking R & D to integrate into manufacturing, distribution and marketing. Other potential imitators may wish to trade with the owners of specific inputs (such as in manufacturing etc). These owners may be in a strong bargaining position (because of a near monopoly situation) and be able to appropriate some of the benefits due to the firm undertaking R & D by charging higher prices for the specific inputs: hence, the move to integrate manufacturing, distribution and marketing in cases in which R & D results do not have clearly defined property rights.

The Efficacy of the R & D Market

Integration may also result from the failure of market governance. Teece (1981) suggests that the market for R & D results suffers from severe transaction cost problems. He summarises these difficulties in terms of recognition, disclosure and team organisation. These difficulties are described below.

The problem of recognition refers to the fact that participants may have imperfect knowledge and not recognise the opportunity to gain through an exchange, in which case exchange will fail to take place. This may arise from strategic protection of the ownership of R & D results, which often means concealing information on possibilities for exchange. The reputation of the seller in having something of value to trade may lessen this problem.

Even when recognition difficulties do not exist, market exchange may break down owing to 'disclosure' problems. Disclosure must be sufficient to assure buyers that the R & D result possesses value but not undermine the basis of exchange, by divulging the R & D result. Arrow (1971) described this as the "fundamental paradox" of information. Being less informed than sellers, buyers must not be taken in by sellers' opportunistic representations.

There is yet another transactional difficulty in the market for R & D results: the problem of actually transferring the R & D results. As Nelson and Winter (1982) have emphasised, individual and organisation knowledge involve an important tacit and learning-by-doing dimension, so that very often new know-how and skills cannot be articulated. Accordingly, transfer of R & D results may require the transfer of human capital. Moreover, the transfer problem may be such that it is not sufficient just to transfer key personnel. Team support, embodying the organisation's total capabilities, may be required

The transactional difficulties of market transfer of R & D results are exacerbated if a succession of transfers of know-how is required. Parties to a contract are then joined in a small numbers trading relation. As discussed by Williamson (1975, 1979, 1986a), such contracting is exposed to hazards of opportunism for both parties. The seller is exposed to hazards, such as the possibility that the buyer will employ the R & D results in subtle ways not covered by the contract, thus becoming an unexpected competitive threat to the seller. The buyer is exposed to hazards, such as the seller asserting that the R & D result has a higher value than is actually the case. In addition it may be possible to work around the edges of a contract such as a patent. Thus, there are difficulties in writing sufficiently comprehensive contracts.

Thus, we have shown that significant (and prohibitive) transaction costs may be associated with using markets to trade the R & D results so that the information content (i.e. of demand and supply) of prices is diminished. This is a major factor which is responsible for the non-market transfer of R & D results. The non-market transfer of know-how and information - that is, the internal trading of R & D results between departments and divisions of a single firm rather than across firm boundaries - avoids the transaction cost problems of recognition, disclosure and team organisation identified by Teece, and the costs arising from repeated negotiation and opportunism identified by Williamson. Another advantage of non-market transfer of R & D results is that the transactions within the financial limits of the firm can be undertaken with considerable speed. Adaptions can be made without the need to consult, complete or revise interfirm agreements. Other transaction costs may still be present under non-market transfer but at a lower level than under market transfer.

3.3 Empirical Evidence

Armour and Teece (1980) hypothesise that when various stages of a production process bear technological similarities and complementarities, common ownership of R & D and the production facilities will enhance technological innovation. They advance a number of theoretical reasons for explaining how the linkage of vertical integration can enhance innovation through easing the sharing of technological information common to separate stages of an industry; the implementation of new products and processes when complex interdependencies are involved (as in the case of systemic innovations); and the formulation of more appropriate research objectives.

They also suggest that the potential for technological synergies between stages is greater when the research activity undertaken is general in nature (as in applied and particularly in basic research) than when it is directed at solving a very specific problem (as in development projects). This implies that vertical integration has a greater effect on basic and applied research than on development activities (Armour and Teece 1980). They were able to show a strong and statistically significant relationship between vertical integration and basic and applied research in the U.S. petroleum industry for the period 1954 - 1975. Vertical integration does not appear to affect development activities nearly as much as it influences basic and applied research. Thus, it is apparent that organisational factors internal to the firm - such as the definition of a firm's boundaries (its degree of integration) - influences the rate of direction of R & D undertaken by a business enterprise.

A more recent study by Monteverde and Teece (1982) tests a transaction cost theory of vertical integration with data from the U.S. car industry. They use the transaction cost approach to explain why automobile assemblers conduct in-house production of car parts. They hypothesise that assemblers vertically integrate when the production process (particularly development activities for new automotive parts) generates specialised, non-patentable know-how (i.e. property rights not legally enforceable). Given this situation, both the assembler and parts supplier are exposed to the possibility of opportunistic recontracting. The existence of transaction-specific know-how and skills and the difficulties of transferring skills means that it will be costly to switch to an alternative supplier. An assembler will tend to integrate backwards into component production when high switching costs would otherwise lock the assembler into dependence upon a supplier and thereby expose that assembler to opportunistic recontracting or to the loss of transaction-specific know-how. They also suggest that the likelihood of vertically integrated production of a given component will be influenced by the degree to which that component's design affects the performance of other components.

From the above analysis, they suggest the following testable hypothesis: the greater is the applications engineering effort associated with the development of any given automobile component, the higher are the expected appropriable quasi-rents and, therefore, the greater is the likelihood of vertical integration of production for that component. The results of the study confirmed their testable hypothesis. The variable used as a proxy for transaction-specific skills ("engineering") is highly significant. The development effort associated with the design of any given automotive component is shown to be positively related to the likelihood of vertically integrated production of their component. They also found mild support for backward integration into components whose design must be highly coordinated with other parts of the automobile system.

In another study, Levy (1985) adopted the transaction cost approach to test implications across industries. Sampling 69 firms over 13 years, Levy also found that research intensity has an effect on vertical integration.

3.4 Structure of R & D Organisations

The potential for internal organisation for a firm undertaking R & D does have limitations. As Kay (1984, P.52) notes:

> "If the system boundaries are throw too far, protection and isolation from competitive pressures may dampen innovative incentive. The possibility of monopoly power over the environment is created, with a bureaucratic insularity of leaders or managers from external control, whether it be stockholder or political. Inertia, apathy, risk avoidance and overemphasis on vested interests and the *status quo* are well recognised problems of an insulated bureaucracy"

Williamson too has commented that transferring a transaction out of the market and into the firm usually impairs incentives, especially where innovation is important.

Although one advantage of integration is that R & D cooperation between stages may be easier, there are at least two incentive-impairing effects of integration with respect to research and development. To borrow an example from Williamson (1984), suppose that the purchasing stage proposes that the supply stage consider a process or product innovation. If the supply stage is independent, the supplier will reap (bear) all the net benefits (costs) if the research project is successful (unsuccessful). However, if the supply stage is integrated and the project is successful, the purchasing stage is likely to request that the rewards be shared between the two stages. Ex post reward sharing between the integrated stages will be ordered. If the project fails, the integrated supply stage is likely to request that the costs be shared - after all, the supplier stage undertook the project at the purchasing stage's request. Ex post cost sharing between the integrated stages will be ordered. Thus, the high-powered incentives of markets are apt to be compromised.

The next questions that we address are: what is the effect of a firm's organisational structure on its production of R & D; and how does a firm's production of R & D affect the strategic choice of organisational structure. These two questions are obviously interrelated and it is very difficult to separate the specific effect of each. For analytical purposes, however, both of these issues are pertinent. Note that in this section we are principally interested in the organisation as a conductor of R & D rather than as a funder.

Although there is no conclusive evidence, we suggest rather tentatively that there are several structural features of an organisation that are likely to enhance research and development. The first is sufficient organisational slack: i.e.

> "that cushion of actual or potential resources which allows an organisation to adapt to internal pressures for adjustment or to external pressures for change in policy, as well as to initiate changes in strategy vis-a-vis the external environment" (Bourgeois 1981).

Tisdell (1985) adds that having some surplus resources may be vital for experimentations and spontaneity in R & D. Presumably the cost of R & D results arising out of these organisations is high.

It has also been suggested that multidivisional firms have a superior performance in R & D compared with functionally organised firms. A multidivisional (M-form) firm has an internal structure in which operating and strategic decision-making are clearly separated - the group responsible for the latter monitoring the performance of the group responsible for the former. In contrast, F-form firms are organised along functional lines with the decision-making authority for both the development of long-run strategy and for daily operating tactics being highly centralised in one executive group.

Divisionalised structures, which may involve semi-autonomous firms, have separate advantages in terms of smaller, more flexible structures and, if they are profit centres, the stimulus of internal competition, a sharper appreciation of relevant external competitors and greater sensitivity to consumer wants. Decentralisation is important because it makes R & D closer to the ultimate user. Research has identified an important linkage between a firm's success at innovation and the degree to which R & D is effectively coupled to the market place. (Lawrence and Lorsch (1967), Mansfield and Wagner (1975)).

Several authors pose the hypothesis that large organisation size enhances R & D. It has been suggested that large organisations may possess scale economics with respect to plant size and/or the marketing function, thereby rendering the results of research activity more profitable for large organisations, either because of scale economies in production and marketing, or because of faster market penetration, and hence a greater discounted present value of the expected returns (Johnson 1975). It has also been maintained that larger organisations tend to have more stable cash flow characteristics and are hence able to more easily absorb the relatively high riskiness associated with investments in R & D projects (Kamien and Schwartz 1975). Furthermore, to the extent that large organisations are more capable of simultaneously conducting a larger number of R & D projects than are smaller organisations, the total risk of the R & D program is reduced through portfolio diversification effects (Johnson 1975). Finally, it has been suggested that in the case of process innovations, the larger the organisation the larger will be the absolute cost savings resulting from the adoption of an innovation, and hence, the more incentive there is for a large organisation to engage in R & D.

There are also reasons why large functional firms which involve large-scale production and centralisation may be less conducive to R & D. Large-scale production typically relies upon economies of scale to be achieved through routinisation (i.e. the establishment of rigid rules and patterns). Since R & D requires the breaking of standard patterns, we may expect that organisational inertia, and a high degree of investment in existing arrangements (i.e. asset specificity) may work against R & D. Furthermore, large firms tend to suffer from a more severe impairment of incentives, due to their more bureaucratic character.

In large firms it may be difficult to distribute the rewards of an R & D result between those people who originated the idea, discerned its commercial importance, refined it and so on. On the other hand, in small firms, the rewards of an R & D result accrue to those who have expressly assumed monetary risks (Williamson 1975). These issues receive further attention in the next chapter.

Deriving from Schumpeter, many studies have related inventiveness to firm size. For example Gilman and Siczek (1985) tested the hypothesis that smaller US companies are more inventive than larger ones. They found that inventiveness decreases with the square root of research expenditures, and that inventiveness decreases with increases in R & D spending. The cost per patent varied between $100,000 (for one of the smaller spenders on research) and $12.5 million (for Ford Motor Company which spent an average of $1,400 million per year between 1976 and 1980 on research). Gilman and Siczek conclude that decentralising research staff in large organisations may improve inventiveness.

Ahlbrandt and Blair (1986) have tried to identify the organisational requirements that make large companies innovative. They concluded that there is not a set of well-defined principles that will ensure success and innovation. A corporate culture which welcomes and supports innovative activity, is important. A decentralised R & D function will place the researchers close to manufacturing and the market, but will focus on short-term projects. Involving managers of marketing, manufacturing, and finance in decisions on the research programme, creates the risk of too much emphasis on the research needs of existing markets and processes, thus lessening the likelihood of major breakthroughs occurring or new products being developed for which new markets would have to be created.

We would also make the point that there is no single size or form of organisation which is optimal for all stages of the R & D process. Small organisations are typically suited to the early stages of invention and early development work - which often require modest resources. However, later development often requires much greater expense which may indicate a large sized organisation. This is related to the discussion of co-specialised assets in the previous sections. Teece (1986) comments that many small entrepreneurial organisations which generate new, commercially valuable technology fail, whereas large organisations survive and prosper even though their performance in R & D is not as good. He explains that large organisations are more likely to possess the relevant co-specialised assets within their organisational boundaries and thus have fewer contracting problems at later stages of R & D.

3.5 Organisation of Funding Bodies

It should not be assumed that R & D conduct and funding will necessarily involve the same organisation. What can be said about the organisational traits of specifically-funding R & D bodies? The general principle remains the same: that in the absence of regulation or other intervention they will organise to economize on transaction costs. However, the nature of the transaction costs involved in funding are rather different from those involved in R & D conduct. Here the costs relate to the identification of agents who are capable of carrying out R & D, negotiating agreements with them, working out acceptable monitoring mechanisms, ensuring the agreements are respected, and sometimes, protecting the R & D results.

We are particularly interested here in public bodies. A public body wishing to fund R & D has the following options: it may contract out R & D to researchers, either selecting them directly or using market signals. It may carry out the R & D itself in-house, either with non-specialist policy people, or using specialist research capabilities in a separate unit. Finally it could use a third party to organise the work: this might involve a direct agent (e.g the NZERDC on energy research) or it might mean a communal industry-wide organisation such as a research association.

Typically a large R & D funding body such as DSIR may use all these forms of organisation for different types of research. Which organisational form is favoured in practice typically depends on the degree of in-house specialisation, the funder's view of the market, its thinness and its tendency to "fail", and the structure of internal incentives in the organisation (see next chapter).

What should also be taken into account (using the findings of this chapter) is the characteristics of the research being undertaken (- its appropriability, specificity, measurability, enforceability of property rights, etc); the envisaged end-use of the R & D; and other organisational characteristics. These include the ability and efficiency of the organisation in doing its own research, the degree of organisational slack, the level of bureaucracy, reporting and monitoring structures, its M-form or F-form nature, and the need for non-market transfers of information and other factors.

The main R & D funding bodies in New Zealand are government departments, particularly DSIR and MAF, so these issues are clearly of importance. Government departments account for around 45% of total (including private sector) R & D expenditure in New Zealand, and employ approximately 5000 scientific personnel. Universities account for 20% of R & D spending and employ around 3000 scientific personnel. Research associations and other public institute (e.g the Carter Observatory, the Cawthron Institute and the museums) account for about 5% of expenditure. The breakdown of spending by organisation is detailed in Appendix 2.

The degree of control and monitoring varies widely by organisation. Specialist public researchers are likely to be able to exploit economies of scale or scope, though this may be at the cost of a more bureaucratized outlook, general inflexibility, or insufficient attention to the end-use of R & D. They are more likely to contract out work that is relatively measurable, appropriable and divisible, but typically will have to invest more heavily in monitoring than if it had been done in-house. Public research bodies usually (but not always) carry out generic, inappropriable, long-term or indivisible research work in-house. Universities combine both tight monitoring (e.g use of University Grants Committee research funds) with extremely loose monitoring (e.g use of staff research time and equipment under the heading of "academic freedom"). A characteristic of much university research is that the end-user may not be identified at all.

In theoretical terms the efficiency issues surrounding the organisations, and performance of such bodies, are the same as those of state-owned enterprises in other activities. Jennings and Cameron (1987) review the issues involved: these relate to the problems of separation of ownership (i.e. the state) and control - typically the members of the organisation or their client groups. Arguments for public funding do not usually impinge on public conduct of R & D. Indeed the National Research Advisory Council (1980) while pushing for more public funding, has recommended that New Zealand Government organisations should make increased use of contract research to take advantage of research manpower available outside Government funded organisations, and so introduce a flexible component into Government Departments. These issues are discussed later in the context of public policy.

A heavy concentration on public conduct of R & D can mean that private sector firms are less likely to carry out their own R & D, and this will in turn affect their inclination to vertically integrate or not.

CHAPTER 4

INCENTIVES, REWARDS AND CONTROLS IN R & D

4.1 Introduction to the Agency Framework

The last two chapters have shown why transaction costs are important, and how they affect the design of the organisations that conduct (and fund) R & D. Now we look inside these organisations to examine the nature of incentives to carry out R & D, and to deal with the common problems that arise. In this chapter, we use Williamson's transaction cost economics to examine agency problems in the production, distribution and consumption of R & D. Although we use the terms "principal" and "agent", the framework is part of the more general theory of transaction costs rather than being limited to the special cases of agency theory.

An agency relationship arises when one or more persons (the principals) appoint other persons (the agents) to undertake stipulated duties on their behalf which involve delegating some decision-making to the agents. Because principals and agents are likely to act in their own self-interest, there is no good reason to assume that the agent will always act in the best interest of the principal. This is the heart of the agency problem: "subgoal pursuit" by the agent because of conflicting incentives.

Agency problems arise from bounded rationality or opportunism. Were the principal to have perfect information and the ability to process it, or were the agent not to act with guile, agency problems would not occur. For example, consider an R & D department in a firm that produces paints. The managing director (the principal) of such a firm may want the R & D department (the agent) to undertake R & D which has an immediate commercial pay-off. However, the R & D personnel may wish to pursue research which is of a more basic character, for which there are few (if any) conceivable commercial applications, but which will increase the researcher's credibility (and perhaps marketability) in the scientific community.

The principal can limit discretionary behaviour of the agent by introducing appropriate incentives for the agent or by incurring monitoring costs. In addition, in some situations the agent will want to guarantee that he or she will not take certain actions that would harm the principal, or to ensure that the principal will be compensated if the agent does take such actions.

An example of a principal incurring monitoring costs would be the managing director requesting monthly reports from the R & D department on progress with regard to development work. As for the introduction of appropriate incentives, the managing director may set up schemes whereby a researcher who comes up with commercially viable R & D results receives a bonus, or quicker promotion or some other (not necessarily pecuniary) forms of recognition. Another arrangement would be to expose the R & D department to market-like incentives. We consider these issues in more detail below.

In more complex R & D arrangements a party may be both a principal and an agent. For example, the head of a research department in a large company will typically act as the principal of the research team and the agent of the chief executive, who is himself the agent of the board. This complicates the possibility for subgoal pursuits.

4.2 Agency Problems In R & D

Agency problems also arise from the coupling of bounded rationality and opportunism, which leads to problems of incentive compatability, auditing, monitoring, inducing specialised investment and other practical difficulties. Agency problems also arise from informational asymmetries. The agency literature refers to two types of incentive problems: moral hazard and adverse selection. Adverse selection refers to ex ante screening difficulty, whereas moral hazard refers to ex post contract execution problems (Williamson 1985). In terms of chapter 2 they may be viewed as a subset of transaction costs.

Adverse selection arises when potential agents are of different types and the principal does not know the precise type whom he/she is facing. For example, a manufacturing firm (the principal) may arrange tenders for an R & D project on some aspects of their production. Several R & D firms (the agents) may submit applications. The manufacturing firm may have varying information about each of the R & D firms - some of which are capable of undertaking the project but are unable to convince the manufacturer that they have the ability and the incentive to fulfil the contract. In practice the potential contractors probably know more about one another's capabilities than does the manufacturer.

Moral hazard has a well-defined but rather narrow meaning in the insurance literature:

> "if an individual takes out full coverage insurance, under which he will be paid the full amount of the loss in the event that it occurs, the individual loses the initiative to take (costly) action to reduce its size or probability" (Rees 1985b, p 79).

For example, if an R & D firm takes out full coverage insurance on its equipment, it loses the incentives to spend money on maintenance, fire prevention systems or burglar alarms. This, of course, is a particular instance of opportunism.

The term moral hazard does not therefore cover cases, common to R & D, where one party takes advantage of externalities by free-riding or by shifting costs onto other members of the system of which he or she is a part; where generalised commitments to cooperate are construed narrowly, so that the letter but not the spirit of an agreement is met; where deliberate efforts are made to confuse or obfuscate transactions; and where active efforts are made to expropriate investments made by others; and in which one or more parties reneges on contract (Williamson 1985).

The terms moral hazard and adverse selection are restricted to opportunism and informational asymmetries in favour of the agent. However, transaction cost theory allows for opportunism on the part of both principals and agents. For example, the licensor of technology (the principal) may not provide the licensee (the agent) with new process innovations, even though this was stipulated in the initial technology licensing contract.

Agency problems arise if the ownership of a firm undertaking R & D is separated from the control of the organisation. If this is the case, then the owners of the firm (e.g. the shareholders) are the principals who appoint agents (i.e. the managers) to manage the organisation. This principal-agent relationship involves the separation of risk-bearing and decision-making: the rights to control resources are transferred to management, whereas the rights to benefit from ownership remain with the shareholders. In such cases, we might expect management to pursue their own rather than shareholders' objectives. The shareholders will need to monitor management's activities in order to limit discretionary management behaviour. Agency issues associated with the separation of ownership and control are particularly pertinent to public sector conduct of R & D through government departments and universities, and to venture capital firms (which often involve outside equity and partial ownership by the manager), and have particular risk and monitoring problems.

Venture capitalists attempt to solve some of these agency problems by sitting on the board and sometimes even being involved in the day to day operation of the company. Agency problems also exist at every level within an organisation (whether public or private). At each level, people are able to appropriate resources to their own ends. The managing director is not able to costlessly monitor the activities of the R & D department - which may follow its own objectives (e.g. to pursue scientific knowledge, to publish in academic journals), though these may be in conflict with the objectives of the managing director (e.g. to keep ahead of competition by the introduction of new products, to maintain the secrecy of R & D results).

Within the R & D department too, agency problems can arise between the head of the department and the research personnel. For example, when four researchers are jointly involved in a project, it is difficult (if not impossible) to identify the contribution of each individual researcher. There is an opportunity for individual researchers to increase their non-pecuniary income (e.g. low stress) by shirking (i.e. avoiding work).

4.3 Agency Problems with Public Provision of R & D

Government departments and other public bodies carrying out R & D incur particularly strong agency problems. These arise particularly because of the structure and separation of policy and execution roles, unclear organisational aims, a traditional lack of monitoring/accountability, and a clash of incentives. They can occur at the policy-allocational levels, at the technical research level, and at the marketing-dissemination level. Principal-agent relationships are involved between ministers of the Crown and their departmental heads, between heads of departments and their own research heads, between these research heads and their research staff.

At the policy level, many of the Beattie Report's recommendations are directed at resolving the agency problems in directing research priorities and in improving accountability and performance of researchers in universities and government research organisations.

Government research organisations have particular adverse selection problems. When trying to sell research results to the private sector, the research organisations are faced by a number of potential buyers. The research organisation has to decide which buyer(s) to approach and what the most appropriate form for the sale of research results would be: patenting, licensing, contract research, cooperative research, etc. The scientists know and understand the technical aspects and manufacturing staff of the potential buyers, but may know less about the buyers' finances and business ethics, making it difficult to evaluate the potential agents.

Public funding bodies face separate agency problems particularly related to the problems of monitoring and controlling research at arms length. The nature of these problems will depend on the relationship with the researcher; as discussed earlier whether publicly funded R & D is done in-house, through the market place or via a third party is discussed earlier. Each of these arrangements raises its own principal-agent problems.

The public body is the principal seeking to have its R & D handled by an agent, for reasons laid out earlier, but faced with the costs of ensuring the relevance, timeliness, cost-effectiveness, quality and confidentiality of the research. The problem arises particularly from adverse selection and opportunism on the part of agents. For example a research institute may try to maximize its own research programme, or a research consultant may aim to maximize his or her fees.

The issue is complicated by the myriad of principal-agent relationships through a body as complex as a government department starting with the Minister - Departmental Head relationship, and permeating down. The critical relationship is that of the Research Manager with his/her superior, and the constraints under which the former operates. Principal-agent problems will generally be lessened in a profit centre or a corporation where incentives exist to monitor the quality of the R & D work from the point of view of the funding body.

One example of opportunism which a Government research body (or a private firm) could encounter, is that of the buyer who agrees to produce and market a product which incorporates research results, paying a royalty to the research institute. Having come to an exclusive agreement, the buyer then does little or nothing to promote and sell the product, perhaps because the product competes with another in the buyer's product range, or because the profit margin is not high enough.

The growing emphasis on revenue earning in Government research organisations is bringing hidden principal/agent problems to the surface. The research managers (principals) want to meet revenue targets and keep research results with commercial potential confidential, while many scientists (agents) want to pursue their research publicly and publish their results.

The cost of this conflict of objectives can be reduced motivation and loss of productivity by scientists. The research manager has to introduce costly monitoring systems, to report on revenue targets, value of contracts negotiated, deadlines for sub-projects, technical progress, payments received, etc. Multi-disciplinary teams have to be formed to increase the rate at which saleable research results can be produced. This relies on research directors acting as agents in relation to their Head of Department, and as principals in relation to their scientists.

The most visible and most important reward for scientists working in Government research organisations in New Zealand, is promotion to a higher grade in the science occupation class.

According to the State Services Commission (1986) promotion is competitive, being based on merit, evaluated using criteria such as scientific knowledge, output, initiative, leadership skills etc, on a biennial rating. As a reward for particularly meritorious performance, a scientist can be given a triple, double or accelerated increment. Scientists can appeal against the promotion of their peers or seek a special review of their rating by a panel appointed by their Deparment's permanent head. There are some problems with this system. As the percentage of scientists in each grade is controlled, constant career prospects are only possible under conditions of steady growth in research organisations. The system fails in ensuring constant career prospects for scientists over time.

Some of the ways, apart from promotion, in which scientists in the New Zealand Government research organisations can be rewarded, include: fellowships and scholarships; overseas trips to attend scientific meetings and to visit research institutes and industry; and attending training courses.

The Beattie Report (1986) points out a number of problems with regard to the measurement of R & D performance, and hence evaluation and accountability. To improve accountability in universities and government research organisations they recommend that tenured positions be made more difficult to attain; that salary loadings be granted to exceptional individuals; and that those not performing be removed. These latter assume away some of the agency problems of observing and measuring performance.

4.4 Controlling Agency Problems

A variety of mechanisms exist to control agency problems which arise in the production of R & D. These can be categorised into three types: self-enforcing 'price' incentives, control procedures and bonding.

Self enforcing 'price' incentives work as follows: incentives can be limited to 'prices' in such ways as by relating payments to employees to cost savings in the case of process innovation, or associating promotions with higher earnings.

Public organisations which undertake R & D have particular problems in setting price incentives as a means to limit agency problems. This is because the pay structure in the public service is relatively inflexible, and it is difficult to reward personnel for their individual research achievements:

> "Shirking and non-performing may be costly to control and achievement may be difficult to reward where government agencies are constrained in their right to hire and fire. Government service protocols, the rules of academic tenure and the practices of scientific employment may hinder the use of employment incentives to reward staff according to performance" (Jardine 1986, p 81).

Directives and control procedures can be implemented to control an agent's behaviour (i.e. to reduce the agent's opportunities to capture non-pecuniary benefits). Such procedures include: the introduction of set working hours, job specifications, direct supervision of work, formal control systems, managerial directives, disciplining procedures, contractual guarantees to have the financial accounts of a venture capital firm audited by a public accountant, screening of R & D, budget restrictions on the R & D department, progress payments (i.e. payment for project made at pre-specified stages of the project), fixed-cost

R & D contracts (which increase the research firm's incentive to work within the budget) rather than untied funding, peer monitoring in the case of research teams, and contractual limitations on the agent's decision-making power (such as in technology licensing agreements).

It is also possible to introduce researchers working for a company to market-like incentives. Operating departments may be given research budgets which they can use to buy research either from the company's own research division, or from outside.

The last control mechanism is bonding expenditure by the agent. It is possible that specialised protective governance structures will be developed in order to limit agency problems. For example, the agent could agree to acquire transaction-specific assets, such as to invest in specialised equipment which is only useful for a particular line of research. Investment in specific assets is an incentive for the fulfilment of contracts to innovate by the R & D producer.

4.5 Agency Transactions and R & D

Agency problems differ from organisation to organisation. They depend on the inherent complexity, and geographic dispersion of the operations of the body undertaking R & D. Agency problems intensify when internal signals or information flows between different levels of the firm hierarchy (e.g. between the R & D department and upper management) become blurred or incomplete. Williamson also describes a large research-intensive firm setting up small venture capital firms in which the large firm takes a one-third interest, the scientists, managers and outside investors assuming the remaining share. The investment by the scientists and managers provides an incentive for performance that cannot be equalled within large bureaucratic organisations within subsidiary arrangements. Furthermore, the raising of outside equity subjects the venture to independent examination which further serves to control agency problems.

This chapter has pointed out some of the many agency problems that arise in the range of R & D transactions noted in chapter 2. These are closely related to the various organisational forms outlined in chapter 3. Some of them may be controlled via self-enforcing incentives, control procedures and bonding. In others the costs involved remain very high and in some cases preclude certain forms of governance. In this chapter we dealt with the problems of incentives for R & D inputs. In the next chapter we look at the related problem of protection for R & D outputs.

CHAPTER 5

PROPERTY RIGHTS IN R & D

5.1 Rights Over Intellectual Property

This chapter investigates the rights that the owner of R & D output has to control, exchange, exploit or suppress this output. The existence and robustness of such rights is important because this determines how transactions and resource allocation will take place. As Kaufer (1986) says, the main incentives to innovate, to adopt and to change stem from the system of property rights. Without any property rights to R & D, there can be no private returns to R & D and therefore no private R & D will take place. As McGee (1966, p.136) says:

> "Invention is an industry, the long-term output of which will expand as expected price rises. Rationality may require that there be property rights in invention, and that there be workable techniques for compelling users to pay. Otherwise, there may be insufficient enhancement to provide proper amounts of valuable services"

The ability of a firm to appropriate the benefits of its R & D investment are enhanced when property rights for R & D output are well defined. Private property rights enable an R & D seller to benefit from, to control, and to transfer R & D results. Property rights are basic to the economic process though they are often treated by theory as implicit "rules of the game" rather than as policy instruments. Resources and products carry with them a hierarchy of property rights concerning the degree of rights to use them and the right to exclude others from using them. The effect of these rights depends on whether they are de facto. This distinction depends, in part, on the ways in which these rights are policed and disputes are arbitrated. Typically this is done by courts or by third party systems such as tribunals with delegated powers.

Intellectual property rights have a number of distinct characteristics relating to the appropriability, measurability and specificity of R & D output. Patents are one type of property rights that can be applied to R & D results. Patents should not be considered in isolation, but as the nucleus of a whole system of property rights which reinforce incentives to undertake R & D (Kaufer 1986). They warn that restricting a view of incentives to innovate to an analysis of patents means excluding essential parts of the property rights system.

Other types of property rights include copyright, trade marks, plant variety rights, trade secrets, non-competition clauses in labour contracts, etc. It has been suggested that the institution of limited liability companies enables firms and inventors to exploit R & D results by accessing the capital market directly and further facilitating the transfer of information by the trading of shares of other firms in an industry likely to benefit from (or to be hurt by) a particular R & D result or by the takeover of firms. (Littlechild 1986).

In addition, the introduction of R & D into the competitive strategy of the firm has created innovation-specific intra-industry mobility barriers which protect the innovator against imitation, independent of any protection by patents.

In the following sections we discuss the role of patents as property rights in R & D, then other types of intellectual property rights and non-formal strategic methods of appropriation. We are able in this chapter to incorporate considerably more institutional detail than in previous chapters, because the application of property rights to the R & D question is a relatively well developed one.

5.2 The Patent System

Patent Rights

Patents provide an inventor with a temporary monopoly on the use of an invention, in return for the disclosure of the knowledge of the invention to society as a whole. (Tisdell 1981.) Patents imply legal ownership over some types of R & D output. They increase the appropriability of R & D output by giving the patentee a monopoly over the invention including exclusive use of the patented item for a limited period, and helping the patentee license the R & D result to others (Lunn 1985).

The property rights provided by patents are not absolute (i.e. they are partial property rights of varying degrees). In the interests of the possibility of enforcement, patents sharply restrict the range of appropriable information. Patents have two requirements. The first is what Cheung (1986) calls an "observability conversion". In order to protect an idea with a patent, it is necessary to convert the idea into an observable product or process and to draft a patent claim that sets boundaries for the idea. That process is not easy; even when a product/process is achieved it may not be possible to write claims that are definitive enough to protect the idea. Furthermore, the patent claim may be prevented by other existing patents or it may be too costly to draft a patent claim. The second requirement for a patent is that the invention must be novel. These problems are more severe for certain types of products and processes.

The Theoretical Impact of Patents

There is considerable debate within the law and economics literature on the advantages and disadvantages of patents. One criticism has been that if an idea is treated as a "public good", any patent which permits a positive price to be charged for the use of the idea will inefficiently inhibit its usefulness and diffusion. As Arrow (1962, p.619) says:

> "Any information obtained, say a new method of production, should, from the welfare point of view, be available free of charge (apart from the cost of transmitting information). This insures optimal utilisation of the information but of course provides no incentive for investment in research since the price (for information) is positive and not at its optimal value of zero, the demand is bound to be below the optimal"

However, once R & D became included within a firm's competitive strategy, patents began to represent the prospect of monopoly profits which could be pursued by several competing firms simultaneously. R & D resources could be expended solely in an attempt to be the first to obtain the patent. Thus, there is the potential that competition amongst patents will misallocate resources by transforming wealth transfers (i.e. patent monopoly profits) into social costs. In other words, the patent is potentially responsible for rent-dissipating R & D expenditures. Several sources of potential rent-dissipation have been identified: premature introduction of inventions, selection of inferior potential inventions, duplication of substitute inventions, excessive rates of research spending, and patenting of substitute inventions.

Because R & D is a non-exclusive resource (i.e. a public good), Barzel (1968) argues there will be an inefficiently rapid depletion of basic knowledge - as with fisheries, public roads etc - except that in this case overexploitation takes the form of premature application of discoveries. Similarly, patents may lead to the selection of suboptimal invention possibilities in order to pre-empt potential rivals so as to patent first (Kaufer 1986). Wasteful duplication of R & D effort arises because ten inventors may race to have the same invention patented, but only one can win the race, the other nine inventors having undertaken their R & D for no purpose, other than providing competition.

An excessive rate of research spending may occur if the development time for an invention is a declining function of the rate of research spending, (i.e. an increase in R & D expenditures makes an innovation available at an earlier time). Suppose that there is one rate of research spending that maximises potential rent (net social gains). The problem is that any firm spending at the socially optimal rate loses the patent to a rival firm which spends faster to achieve earlier invention.

The present patent system encourages socially unprofitable production of substitutes.

> "The prospect of siphoning off some of the monopoly rents of a preceding invention provides an economic incentive to produce and patent substitute inventions. Spending for such research is a misallocation of resources because of failure to improve existing technology" (Beck 1981, p97).

Countering this argument, patents are often obtained at a fairly early stage of the R & D process - when the R & D result is still merely a crude prototype and long before its first commercialisation. Accordingly, a patent might be conceived as a prospecting right: a right to develop a known technological possibility. Rivalry occurs at the invention stage. Thus, the argument is that patents limit duplication of R & D activity (and the associated dissipation of rent) because an inventor is able to obtain a monopoly before the costly innovation stage of the R & D process. In this vein, Yu (1981) argues that a substantial proportion of patents are developed under prior contracts between potential users of an R & D result and R & D producers.

> "In Yu's view, inventors seek to identify latent demands for inventions, they patent crude methods of a solution for the perceived demand, and compete among themselves for manufacturers who are willing to use the inventions. The manufacturers select the best innovator, whose return is just sufficient to cover the cost of the invention plus a differential rent on the (innovator's) superior skill. Yu concludes that prior contracting between potential inventors and potential users precludes rent dissipation." (Kaufer 1986, p221).

Defending the rent dissipation argument, Beck (1981) argues that patents are not really prospecting rights because they are only rights to what has been invented rather than what might be invented. Beck suggests that one solution to the rent dissipation problem is the auctioning of rights to invent in a certain field (i.e. preinvention allocation of prospecting patent rights).

According to this scheme, a firm submits a bid to the patent office for the right to invent in a certain field before undertaking research. The patent office then invites other potential inventors to submit bids and allocates the prospecting right to the highest bidder. The maximum possible bid from each potential inventor is equal to each particular bidder's forecast of potential patent rent - the difference between anticipated royalty revenues and expected costs of invention. This competitive bidding breaks down for inventions that result from chance or involve high technological or economic uncertainty, and has been subjected to some criticism (Kaufer, 1986).

Other problems abound: following Cheung, Beck also recognised that the general nature of patent definitions (prior to research) might be more ambiguous and could increase costly court resolution of patent boundary disputes. A firm which has a prospecting patent right obtains first mover advantages (e.g. learning curve advantages) relative to other firms and is more likely to win subsequent rounds of bids. Thus, although bidding for the prospecting rights may be competitive, later stages may suffer from small numbers bargaining problems. Finally it has also been argued (McGee, 1966; Priest, 1977) that patents of unimportant processes are used as a cloak for collusive practices (i.e. patents are considered to be a form of cartelisation).

Empirical Research

An important study by Levin et al (1984) examines the effectiveness and structure of the various mechanisms that enable firms to appropriate the return from R & D in a comprehensive cross-section study of manufacturing industries in the USA. In particular, the authors seek to examine circumstances in which patents are or are not important, and what other mechanisms (if any) permit effective appropriation.

Lead time and learning curve advantages were rated the most effective mechanism for appropriating the benefits of R & D; patents were rated the least effective; and secrecy was rated of intermediate effectiveness. Taking the analysis further for new products: lead time, learning curves and sales or service efforts were found substantially more effective than patents; product patents were judged much more effective than process patents; secrecy was reported less effective in protecting products than processes. Note however that there was substantial inter-industry variation in the effectiveness of each mechanism. Patents are generally ineffective for protecting process innovations for most manufacturing industries.

When patents were effective in preventing competitors from duplicating, patents also tended to be effective in securing royalty income; this applied to both processes and products. For products where patents were rated as effective, lead time was also effective; and when lead time and learning advantages were effective, sales and service were effective, but secrecy was not. The opposite held true for processes.

Thus, the results suggest that the mechanisms of appropriation can be divided into two classifications: one class associated with the use of patents and the other with lead time and learning curve advantages. For process innovation, secrecy is closely connected with exploiting lead time and learning advantages. For product innovation, sales and service efforts complement lead time and learning curve advantages. There is also a group of industries in which none of the mechanisms of appropriation was particularly effective.

Having established that patents are only one of several mechanisms available to a firm to appropriate its R & D output and that in most industries they are not even the most important mechanism, the authors went on to pursue the main reasons why patents were not effective. By far the major weakness of patents (for both products and processes) was the ability of competitors to invent around patents legally. To a lesser extent, the fact that new processes are not readily patentable was another important constraint. Limitations were more severe for process patents than product patents.

Levin et al's examination of the cost and time required for imitation found that patents tend to raise the imitation cost and time for each category of innovation. The reported effectiveness of patents was positively correlated with the increase in duplication cost and time associated with patents. However, there were anomalies. The authors surmised that the relative complexity of some products makes imitation (i.e. reverse engineering) costly even when patents are relatively ineffective. Imitation costs and time do not appear to be related to any of the other mechanisms of appropriability: the effectiveness of patents depends on raising imitation and duplication costs whereas the effectiveness of lead time and learning advantages in appropriating the benefits of R & D depends on other factors.

The New Zealand Experience with Patents

The patent system in New Zealand is broadly modelled on the British system. The New Zealand system is contained in the Patents Act 1953, stemming from the 1949 Commission to Report on New Zealand Law Relating to Patents, Designs and Trade Marks. International property rights are protected by New Zealand's membership of the World Intellectual Property Organisation and the International Convention for the Protection of Industrial Property (1883). The convention holds that each participating country grant nationals from other countries the same rights as nationals from their own country. It is not intended to harmonise patent systems in different countries.

A survey by the Department of Trade and Industry (1986a) found that most organisations in New Zealand (except pharmacuetical companies) do not use patents significantly. Patent protection is not considered to be important to R & D in such industries as electronics. In contrast, the pharmaceutical industry makes extensive use of patents.

Patent protection is used by firms which are generally involved in high volume production and/or for which product patents provide effective protection. (e.g. whiteware, cordage, eartags, pharmaceuticals and other chemical compounds especially agrochemicals). In contrast, patents are considered inappropriate in many circumstances such as when patents can be easily circumvented, especially with electronic circuitry and food ingredients. In the electronics area, for example, there are a number of different ways of arranging a circuit board to produce the same end result. To patent one of those simply gives competitors a lead on how to develop their own solution to the same problem without breaking the patent.

The biotechnology industry provides an interesting (though probably extreme) example of the kinds of problems encountered with patenting. In particular, specific problems arise in disclosing new products of biotechnology in patent applications. In return for monopoly rights to an invention, the inventor is obliged to describe the invention in such detail that an appropriately skilled person is able to reconstruct it.

"Some, but not all, inventions involving micro-organisms are very difficult, if not impossible, to disclose in writing in this way. In some overseas countries a solution has been found in allowing an applicant to deposit in a culture collection the culture of any micro-organism necessary to perform the invention. The concern of the industry is that in no other field does an inventor have to make available to competitors actual material and, in addition, it is material which only needs to be placed in the right environment to work" (Dept of Trade and Industry 1986a, p20, drawn from a UK white paper).

For this reason, organisations in the biotechnology area principally rely for protection on secrecy rather than patents.

The high cost of acquiring, maintaining and enforcing patents is considered to be another factor detering their use (by small companies, in particular). Separate applications must be made in each country for which a patent is sought. The costs of acquiring a patent include the direct application costs (including labour time) and the fees payable to patent attorneys. There are also costs involved in maintaining a patent in New Zealand, renewal fees must be paid every three years after the first year (i.e. at the end of the 4th, 7th, 10th and 13th years).

In New Zealand the term of a patent is 16 years, but this can be extended by up to 10 years if it can be proven that the return from the patent has been inadequate. The Department of Trade and Industry (1986a, 1986b) comments that this term is arbitrary both in length and its effect on different industries. The term of the patent is not considered a problem by most organisations, except pharmaceuticals and agricultural chemicals. These industries argue that the term of the patent is effectively reduced by government regulations (e.g. health regulations) which prevent exploitation of their new products.

As discussed in chapter 2, patents are a form of trilateral governance which require third-party enforcement, namely, the courts. The costs of enforcement by litigation can be considerable (both in terms of time and legal expenses) for both the patentee and the alleged infringer, and incentives exist for both parties to settle out of court. Yu (1981) recognises the lower enforcement cost of contract law than of patent law and draws attention to the fact that patent law protection relies heavily on the often elusive interpretation of patent claims. A further factor rendering patents unattractive is the administrative delay in obtaining a patent. The New Zealand Patent Office relies on a manual operation at present and has a two year backlog of applications.

This naturally has implications for the Patent Office's role as a disseminator of information to facilitate the transfer of technology. As Tisdell (1981 p 37) comments:

"the value of the (patent) system as a provider of information depends upon how well the invention is specified in the patent application, lags in processing such applications and the efficiency with which the Patent Office can retrieve specifications and make these available to others. In patent policy, and in science policy generally, priorities need to be established about how much information to store, what type of information to store, and how quickly and efficiently to make it available".

The survey by the Department of Trade and Industry finds that patents are not frequently used as a source of information in the context of technology transfer in New Zealand. The administrative problems with the Patent Office noted above contribute to this finding but are by no means the only factor.

Although not as detailed, the results of the New Zealand survey are broadly consistent with the findings of the overseas study discussed earlier in this chapter. First, we find the effectiveness of various mechanisms for appropriating the benefits of R & D investment varies by industry. Second, both surveys find that patents are not considered to be particularly effective in most industries - except in the pharmaceutical and other chemical industries. Thirdly, there is a feeling that lead time advantages are an important means of protecting intellectual property. Fourth, the importance of secrecy, market leadership and brand-names is emphasised even if patents do not exist or have expired.

5.3 Other Types of Intellectual Property Rights

In this section, we briefly discuss other legal instruments to protect R & D investment, namely copyright, trademarks and designs. For a more detailed discussion of these instruments in New Zealand, see Department of Trade and Industry (1986a); and NRAC Science and Technology Plan (1985). Many of their effects are broadly similar to the property right protection offered by patents.

Copyright

A copyright is defined as follows:

> "a legal exclusive right to do certain things (e.g. to print, reprint, copy, perform, broadcast, make an adaptation and vend) in regard to certain types of works (e.g. literary, dramatic, musical, artistic) and other subject-matter (e.g. sound recordings, cinematograph films, television and sound broadcasts, published edition of works) for a certain period, or an author, publisher, employer etc" (Puri 1983b, p 24).

Computer software, copies of dies or moulds, and fabricated engineering products made off drawings can all be protected by copyright. The central rights granted by copyright are: the right to reproduce the work or other subject matter; the right to copy it, and the right to present it to the public. Copyright prevents the unauthorised reproduction by another person of the tangible form in which a person has chosen to express ideas.

The legislation governing copyright is the New Zealand Copyright Act 1962. Unlike other forms of intellectual property (such as patents, trademarks and designs) which require registration for protection, the Copyright Act does not require any formalities to be fulfilled. The Act requires that a work must be original if it is entitled to copyright protection. Originality does not imply novelty or inventiveness. Rather, it means that the work is the result of a person's own efforts.

The 1985 Amendment to the Copyright Act 1962 relates to the industrial application of copyright. The Amendment limits copyright for industrial applications to 16 years from the time at which the industrial application is first made (which is the same term of protection as for patents). Another requirement is that the work is reduced to some material or tangible form. It is important to note that copyright only protects the particular form of expression by which the ideas are conveyed; the ideas contained in a work are freely available to anyone. So copyright is concerned only with the copying of physical material and not with the reproduction of ideas. (Puri 1985).

The general rule is that the duration of copyright protection is for the life of the author and 50 years after his or her death; copyright is not absolute. A limited range of uses of copyrighted works exist which do not infringe copyright (e.g. research or private study). However, fair dealing is required on the part of those persons who use the work in this way (Puri 1983b).

Designs

The Designs Act 1953 (N.Z.) provides for the registration of new or original designs and gives the owner the sole right to trade in the article containing the design. Design is defined to be features of shape, configuration, pattern, or ornament, applied to an article, by any industrial process or means. These features must be judged on the basis of their appearance rather than on the basis of their functionality. Thus, design registration is not granted for articles that may serve a practical purpose. The owner of a design must register it at the Patent Office. Designs are granted for a term of five years from the date of filing and may be extended, after payment of the necessary fees, for two five-year periods to a maximum of fifteen years. In New Zealand, there is a duality of protection for designs by copyright and design laws i.e. the owner of a design can invoke either or both laws simultaneously. Infringement of a registered design requires third party enforcement, through the courts.

The Department of Trade and Industry survey found little industrial application of registered designs. Copyright is preferred because it gives automatic protection over the drawings of new products, including elements of design.

Trademarks

New Zealand legislation relating to trademarks is contained in the Trademarks Act 1953. According to this statute, trademarks must be registered with the Patent Office. Protection is provided for an initial period of 7 years and must be renewed every 14 years thereafter. Trademarks which are not registered may be protected by the common law remedy of "passing off," although this is more difficult to defend than a registered trademark.

The Trade and Industry survey finds extensive use of trademarks. Problems encountered with the trade-mark system are: the time lag in completing registration; the limitation of trademarks to businesses which provide products (however, it is proposed to amend the trademarks legislation in 1987 to cover businesses which provide services); the inability of proprietors of trademarks to trade in marks; and the specification of the user of a trademark, although this may be difficult in the early stages of an international franchise arrangement.

Brand names are another form of product protection, enforceable by the courts when registered.

Plant Variety Rights

Legislation governing plant variety rights is contained in the Plant Variety Rights Act 1985. The Act provides monopoly rights for a period of 3 years after which the owner is required to make reproductive material available to the public at reasonable prices. The Act harmonises New Zealand's legislation with that of other member countries of the International Union for the Protection of New Varieties of Plants - UPOV (Department of Trade and Industry 1986a).

Standards and Quality Assurance

Further protection may be offered to intellectual property by standards systems. The Standards Association of New Zealand (SANZ) set up under the Standards Act of 1965 sets standards and supplies certification in the building industry, mechnical and electrical engineering, and other product areas. The intentions are to provide quality information and improve compatability. The Testing Laboratory Registration Council (TELARC) and the New Zealand Organisation for Quality Assurance are also involved in testing and certification.

5.4 Other Strategic Methods of Appropriation

There are many other methods of appropriation, other than the legal property rights described above. These are broadly referred to as strategic techniques. They involve deliberate use of business techniques intended to prevent or slow competitors from making use of research results, without recourse to law. Such strategic moves have only recently been accorded the importance they deserve by business economists. These non-formal mechanisms were referred to implicitly in the empirical studies discussed previously. In this section we briefly list the non-formal methods of appropriation.

Commercial secrecy is an important method of appropriation. R & D results vary widely in the extent to which they are amenable to protection by secrecy. For example, the design of an aircraft would require most of the work to be redone by an imitator (unless all the detailed drawings were turned over). On the other hand, in the pharmaceutical industry once a therapeutically effective molecular configuration has been found and clinically proven, it is easy to free-ride with identical or slightly manipulated imitative molecules (Scherer 1977).

For these reasons it is probable that most R & D results are protected to some degree by commercial secrecy. Levin et al (1984) found that secrecy is particularly important for process innovations and that it is closely connected with exploiting lead time and learning curve advantages. A recent New Zealand survey found that secrecy agreements for staff are common and that secrecy agreements for customers are also used. In research-intensive industries like financial services these understandings are normal. Non-disclosure agreements on trial results, exclusive contracts, and office and laboratory security are other mechanisms to keep R & D results secret (Trade and Industry 1986a).

Lead-time and learning-curve advantages are of great importance - especially in such industries as semiconductors and telecommunication equipment (Teece 1986). Levin et al (1984) emphasised the importance of these advantages and suggested that the mechanisms of appropriation reduce to two dimensions: one associated with the use of patents, the other with lead time and learning curve advantages. These techniques are particularly important in microelectronics manufacture where the costs in say circuit board research must be recouped in the year or two's lead that a manufacturer may have over his/her competitors.

Another non-formal method of appropriation is marketing effort. Marketing is taken to be broadly defined to include: sales, promotion, product differentiation, market niche and market leadership strategies, brand names and brand loyalty. Scherer (1977) refers to an American study of the anti-anginal and oral diuretic drug field, which shows that despite vigorous promotional efforts by imitators, the firms which pioneered those fields and established a reputation maintained significant sales and price advantages for more than a decade to follow.

The Department of Trade and Industry's survey also provides valuable insights into the importance of market leadership and product differentiation as mechanisms for appropriating R & D output. The promotion of drugs whose patents have expired is a case in point. Local generic manufacturers are then able to produce these non-patented drugs. However, multinational pharmaceutical companies which originally patented these drugs are able to promote their particular brand of a drug at considerably higher (20-40 per cent) prices than local manufacturers who use the generic name. Thus, when patents expire, the brand loyalty which was built up over the duration of the patent can provide continuing protection to their R & D investment. Furthermore, these brand names can be registered as trademarks so as to provide even stronger protection.

Monopolists and oligopolists can typically appropriate a higher degree of their R & D output as a result of entry barriers into the industry - such as economies of scale, high capital costs, or well-established distribution channels. At the very least, they are assured of capturing the benefits from a cost-saving innovation on their own production volume (Scherer 1977). The Trade and Industry study confirmed that barriers to entry into an industry are a viable method of appropriation in New Zealand.

Another method of appropriation for product R & D is to package an innovation in such a way that makes it very difficult to remove the packaging without destroying the innovation inside (known as "potting" in the microprocessing industry). The Coca Cola formula has been successfully protected from reverse engineering for many years. Potting is not likely to be very successful in the long-term industry but a firm can expect to gain a little lead time. Potting is not a successful counter strategy to protect trade secrets involving process innovations (Rogers 1982).

It can be seen from this account that intellectual property stemming from successful R & D may be protected in a wide range of ways. However, the efficacy of this protection varies widely. Consequently the resulting property rights are generally incomplete. The discussion on patents shows the different effects on transactions that total and partial property rights offer.

This chapter shows the role of property rights in R & D. When private property rights are strong and enforceable there is more tendency to do R & D, and to transfer it via market mechanisms. When rights are weaker firms look to other ways to protect their investments such as strategic protection moves or internal governance. If these still do not work less R & D will be done.

This chapter completes the discussion of the economies of R & D in Part II. We have built a theory in which agency costs and other transaction costs, together with the prevailing set of property rights, determine the organisation of research bodies, the R & D they choose to fund or conduct, and the ways in which this is governed.

Using this theory as a foundation we now set out in Part III a framework for public policy intervention.

PART III : PUBLIC POLICY FOR R & D

CHAPTER 6

INSTRUMENTS OF R & D POLICY

6.1 Traditional Views on Public Involvement

The sorts of policy instruments available for R & D public policy and the way that they are used, are closely related to the theories of public intervention discussed in Part I. In Part III we are interested in how this range of policy tools impact and what this means for appropriate government policy on R & D. Chapter 7 attempts a classification of policy instruments both from a traditional viewpoint, and using the transaction cost analysis to develop a new classification system that goes wider than (but still includes) market failure. In the next chapter we make some suggestions about how these instruments might be applied.

In principle, the range of policy tools available depends on one's views of markets, other forms of organisation, private sector rationality, government efficiency and the nature of R & D transactions. These were the subject of Part II.

In practice, public R & D policies tend to be a pot pourri of measures, arrived at through a mixture of economic, political and institutional reasons. Economic guidelines for R & D policy may conflict with political realities, with policies designed for other non-R & D ends, and with exogenous and sometimes unpredictable events.

The idea of a programme of R & D measures is itself a relatively recent one. Whereas work deriving from Schumpeter and others had long pointed to the potential role of innovation in growth it was not till the 1960s that macroeconomic studies began to confirm that technological change was an important source of productivity growth (Nelson and Langlois, 1983). This in turn persuaded policymakers to view R & D not simply as a form of private investment beyond their immediate interest, but as a sort of control variable through which the performance of the whole economy could be affected. This led to interventionist programmes to promote R & D, or in slightly different form, science and technology (E G Bollard 1986). Associated with this was the formulation of public goals for science and technology policy, rather than programmes confined to helping the private sector achieve their own goals. This sometimes meant "picking winners" though it could also be done in a more general way. There is a considerable industrial policy literature debating the wisdom of such a strategy (see e.g. Bollard, 1984).

Recently Spencer and Brander (1983) have reopened the controversy in the context of trade policy, pointing out the conditions where public intervention for international strategic competitiveness may be justified. It is such programmes that we investigate in this chapter, and suggest how they may be rationalised in the light of our unifying framework of the previous chapter. We then look at public intervention in New Zealand and analyse it in this framework.

If there has been one underlying comprehensive justification for intervention in most Western countries to date, it has been the market failure framework. This means market failure in its widest sense; market-based R & D decisions are judged sub-optimal and the government may intervene in a wide variety of ways to improve them.

The widely accepted framework here has been that of Rothwell and Zegveld (1981). Rather than speaking directly about research and development, they postulate the existence of an aggregated concept called, "innovation," implying the introduction of new products and processes. They view successful innovation as depending on a favourable combination of technology supply and market demand factors. (Economists should note that they are using the word "market" in a slightly different sense.)

On the supply side they postulate that research on the development of new products and processes depends on three main factors: scientific and technological knowledge and manpower; information about the likely market for the innovation, together with the management skills needed to ensure successful research and development; and sales and financial resources. These three inputs are shown on the left hand side of Figure 6.1.

The demand side is represented by the conditions in domestic markets and international markets for public and private services, as shown on the right hand side of Figure 6.1.

These demand and supply side forces interact against a background of social, legal and political framework, which is labelled as the environment for innovation.

Rothwell and Zegveld (1981) then list a wide range of current and potential government policy tools available to influence these forces. They see government intervention as being able to affect demand, supply or environmental factors, as shown in Figure 6.1. For example, a government wishing to influence the supply side of the innovation process can do so through direct participation in the processes itself (i); or through improving the supply of one of three factor inputs (ii, iii, iv); or it can intervene less directly by attempting to modify the wider economic, political and legal environment (v) in which the production of new goods takes place.

Alternatively a government wishing to improve the demand side of the innovation process may do so in domestic markets, either indirectly (vi) or directly (vii) or in international markets where it can alter the overall environment in which international trade takes place (viii) or intervene more directly (ix).

The underlying tenor of this approach is that it defines markets and innovation in a very wide sense; It assumes that they fail to bring the best outcome if left unregulated; and frequently it has an implicit view of government as knowledgeable, powerful, innovative and capable of efficient cost-effective intervention.

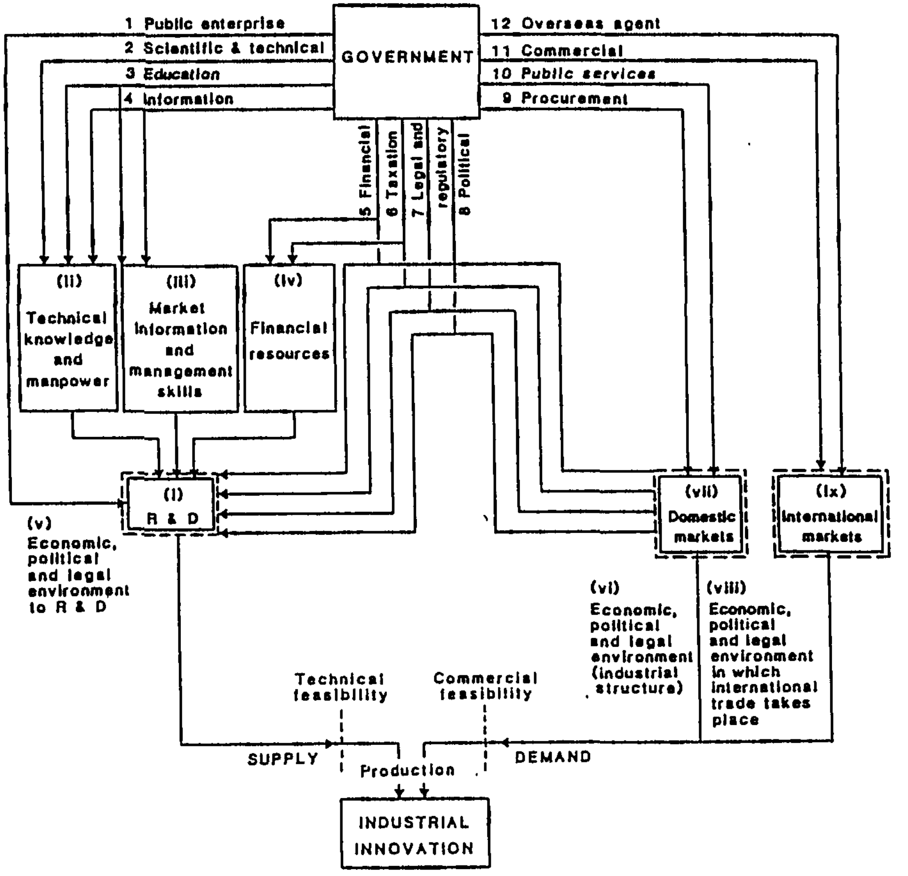
The policy instruments available for such an approach are typically conceived very widely. Rothwell and Zegveld (table 6.1) list twelve general types of instrument

TABLE 6.1: The Traditional Classification of Government Policy: Science and Technology Framework

Policy tool	Examples
1 Public enterprises	Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, participating in private enterprise
2 Scientific and technical	Research laboratories, support for research associations, learned societies, professional associations, research grants
3 Education	General education, universities, technical education, apprenticeship schemes, continuing and further education, retraining.
4 Information	Information networks and centres, libraries, advisory and consultancy services, data bases, liasion services
5 Financial	Grants, loans, subsidies, financial sharing arrangements, provision of equipment, buildings or services, loan guarantees, export credits
6 Taxation	Company, personal, indirect and payroll taxation, tax allowances
7 Legal and regulatory	Patents, environmental and health regulations, inspectorates, monopoly regulations
8 Political	Planning, regional policies, honors or awards for innovation, encouragement of mergers or joint consortia, public consultation
9 Procurement	Central or local government purchases and contracts, public corporations, R & D contracts, prototype purchases
10 Public services	Purchases, maintenance, supervision and innovation in health service, public building, construction, transport, telecommunications
11 Commercial	Trade agreements, tariffs, currency regulations
12 Overseas agent	Defence sales organisations

Source: Rothwell & Zegveld, 1981 [E.G. Bollard 1986 p 61].

FIGURE 6.1: The Mechanisms of Government Policy: Science and Technology Framework.



Source: Rothwell & Zegveld, 1981. [E.G. Bollard 1986, p 61.]

ranging from the use of public enterprise to pioneer innovations to the cheap provision of physical infrastructure for science and technology. This sort of general science/technology approach rarely provides detail on the costs and returns associated with specific interventions.

Typical arguments for this framework are given by science policy researchers who argue that economic analysis is weak in certain respects. For example Clark (1985) claims that economic arguments cannot easily : handle the long run involving major technological change; handle uncertainty due to the nature of its basic theorems; explain technological change and its determinaints; relate to the inter-disciplinary nature of socio-economic change; or incorporate the importance of technological explanations.

In a recent New Zealand exercise the Beattie Report (1986) adopted this approach, saying that both market pull and technology push factors are important to varying degrees in different circumstances, and warning against over-reliance on market pull factors (which they appear to equate with market governance).

This framework provides an explanation for the design of R & D programmes in some interventionist countries. For example, Joseph and Johnson (1985), Tisdell (1986a) and Gannicott (1980) all offer interpretations of Australian R & D policy within this general market failure framework, with varying degrees of criticism as to its effects. Ronayne (1984) interprets market failure theories in the narrow sense that the "demand" side has "failed" to draw forth sufficient R & D, and quotes many science-technology writers as pointing to the need for more "supply"-based intervention. This equating of intervention with supply and non-intervention with demand is rather a simplistic and confusing one.

More common amongst economists are the technology-push/demand-pull hypotheses in which R & D is viewed as a black box (Kamien and Schwartz, 1982). How well the box transmutes R & D inputs into R & D output depends on the use of public policy to affect the research environment. What goes on inside the box is beyond the policymaker's ambit.

The OECD approach has been to use a similar framework, and construct a subjective set of priorities for R & D as an aid to determining appropriate government intervention. These may be sectoral in nature (e.g. energy self-sufficiency, industrial innovation), or more general (e.g. the advancement of basic knowledge). The OECD (1986) takes a wider view in writing on R & D in Australia. It posits a model where government may see itself as an agent of demand creation (e.g. by government subcontracting of research, taxation incentives, purchasing and offsets policy); as an agent of technology transfer; or as a promoter of mobility and flexibility.

6.2 A New Classification of Policy Instruments

We find it more useful in this project to move away from the science and technology/innovation/market failure framework for classifying government intervention, (what Tisdell, 1986a, calls "non-economic and anti-economic views of science and technology policy"), and build up instead a taxonomy based on the framework that we set up in Part II, namely the systems of market and non-market governance. We classify public R & D policy into instruments that impact market R & D transactions, internal R & D transactions, bilateral R & D transactions and trilateral R & D transactions. In this classification we are talking of the effects of public intervention rather than its (purported) objectives. It is inherent in this framework that direct intervention on one mode of transaction will have secondary effects on other modes. The classification of public policy tools is summarised in Table 6.2.

Ten years of research and 200 R & D studies under the Experimental R & D Incentives Programme at the U.S. National Bureau of Standards indicates a number of things are important in terms of the public role in R & D. These studies lead to the general conclusion that "the interplay of government and industry is more complex and involves more factors than the two-sided equation traditionally assumed." They point to the need for a framework which includes such considerations as protection of proprietary rights, the importance of agency relationships, the importance of governmental regulatory actions, the potential for consortium techniques, as well as the more traditional fiscal incentives. The framework we use below is particularly designed to cover these and other considerations.

Intervention in Market R & D Transactions

Governments intervene in R & D market place transactions through a wide range of mechanisms. Frequently the justification is to correct what they perceive as market failures in the allocation of resources for investment in R & D.

The most direct form of intervention occurs when governments remove the transaction from the private sector and conduct the R & D directly. This is considered as a form of internal governance below.

In most economies there is considerable public funding of R & D. This funding covers the public research listed above, but also includes private research via grant programmes, procurement policies, and other schemes to induce firms to develop and implement changes. The balance of public funding between public conduct and private conduct of R & D varies significantly between Western countries depending partly on the sophistication of the private sector.

As pointed out in the case of the Australian Industrial Research and Development Incentives Scheme in Australia (Bureau of Industry Economics, 1986) the need for government funding depends considerably on the existence of private funding options. There, as in New Zealand, the deepening of the stock exchange, the creation of a second board, the development of private venture capital firms, the removal of restrictions on capital flows and investment, and the general regulatory reform of the capital market, have reduced the need for government as a public funder of last resort. In the U.S. in particular there has been a high funding of private sector R & D via government procurement programmes, especially involving military spending.

TABLE 6.2: New Classification of R & D Instruments

Market Transactions
Full public funding, e.g. grants
Fiscal incentives - subsidies, loans, tax breaks
Macroeconomic policy aimed at business climate
Market reform
Public exhortion of R & D
Internal Transactions
Direct public provision of R & D
Competition policy
Bilateral Transactions
Property rights
Prior contracts - development & employment contracts
Patent licences
Copyrights, brand names, trade marks, registered designs
Third Party Enforcement
Boards, tribunals, courts
Standards associations
Testing laboratories
Intellectual property law
Science & technology agreements
Research associations
Other provisions for collective arrangements (e.g. joint ventures)

Another (very wide) set of R & D policy instruments concern fiscal incentives that manipulate market signals to induce a more desired pattern of R & D market transactions. Under this heading come a wide range of investment incentives such as subsidies and loans for R & D spending. It also includes tax regimes that affect R & D capital spending, including specific tax breaks and general capital depreciation allowances. These have been popular amongst manufacturers who see them as a way of targetting selective assistance without picking winners. In addition fiscal instruments affect R & D inputs such as materials and skilled workers, and R & D-intensive products. Conversely sectoral assistance programmes, especially for high-technology "sunrise" industries can have significant effects on the demand for R & D.

Most industrial Western countries have a range of fiscal incentives for R & D. A National Science Foundation survey of corporation income tax treatment of R & D investment and innovation in major industrial companies reveals a wide range of ways in which corporate tax affects R & D investment, with respect to interest and dividends, capital gains, operating losses, depreciation, and changes in the value of inventory. In addition, treatment of expenditure on R & D, on purchasing or licensing new technology and on donations to non-profit scientific organisations differ.

It is frequently a cause for complaint from N.Z. proponents of R & D that fiscal incentives here are inferior to those found overseas. (See for example, Beattie, 1986; N.Z. Manufacturers Federation, 1984; N.R.A.C., 1983.) The latter listed a wide range of ways the tax regime for R & D could be changed, involving tax exemptions, tax holidays, tax credits, investment allowances, accelerated depreciation rates and tax relief. Other more innovative forms of funding are conceivable.

The theoretical issues surrounding taxes and subsidies for R & D are the same as those found in other areas of public finance: the likelihood of distortion and difficulty in achieving tax neutrality; the revenue and equity questions; and the efficiency loss problems. Gannicott (1980) comments on the frequent misuse of such incentives in R & D: for example outright subsidy is not an efficient means of correcting market failure due to risk or uncertainty. Loans with the expectation of recovery would be a more efficient option.

Bozeman and Link (1984) review the advantages and disadvantages of tax incentives for R & D. They include little interference in the market place; relatively less arbitrary decision-making; and more permanence and political acceptability than other more direct intervention. Weighed against this, they can bring about windfalls to particular classes of recipients, which may be arbitrary and unnecessary to elicit a response. Fullerton (1983) in his study of the accelerated cost recovery system for R & D expenditures under the 1981 U.S. Economic Recovery Tax Act points to considerable asset distortion as a result.

A major problem arises in predicting the degree to which any fiscal measure actually encourages extra R & D spending, and the extent of crowding out involved. U.S. work on the effects of the 1981 U.S. tax credit is reported in Brown (1984). He reports Mansfield's finding that U.S. private R & D was only slightly (around 1.1%) higher than it would have been without the credit. In contrast he quotes Eisner as finding that firms increased qualifying R & D spending more (by up to 20.1%) while decreasing spending on non-qualifying R & D. Later work by Eisner, Albert and Sullivan (1980) found that after the initial surge in R & D spending the tax credit had limited potential for stimulating spending and in some cases actually discouraged it.

Further work reported by Fischer and Black (1979) suggested there may have been more stimulation of R & D spending in low-technology industries and less in high technology. Mansfield (1983) indicates that a number of other recent studies tend to indicate that on balance government-supported R & D is mildly complementary to company-financed R & D. A comprehensive study of the Australian A.I.R.D.I.S. scheme which involved public grants for likely R & D projects concluded that the scheme had a limited stimulatory effect in leading firms to do specific R & D that they would not otherwise have done. The scheme did however induce a different character of spending (Price Waterhouse, 1985).

The most general form of R & D assistance under market governance (but also affecting other forms of governance) is macroeconomic policy designed to provide a "conducive" business climate for investment. There may be selective elements to this, but the broad intention here is to allow private investors to make their own decisions in the light of market signals (and internal signals) within a buoyant business environment.

A further public tool is to exhort the private sector to invest more in R & D. Governments are frequently keen to promulgate the general idea that R & D is more important than what the private investor already thinks, and also good for the country. The Science and Technology for Development Conference of May 1985, held in Wellington, is an example of this attitude (Conference Report 1985).

The principle of all these public policy instruments is that market governance mechanisms are not universally used, but that they are sufficiently important to allow corrective policies to use market signals. Taken in isolation from other measures, as a "market failure" approach, they still incur the general problems of second-best, non-generality and distortion, identified in the previous chapter.

A further type of policy aims at improving the efficiency of market governance, so that product and factor markets will work to handle transactions more adequately. To date this has involved regulatory reform in a number of industries, particularly removing regulations on entry, pricing and operation. Deregulation in product markets means firms operating there are more closely guided by prices in their investment decisions. Reform in the financial services industry can change the private sector finance available for funding long term uncertain R & D investments. Regulations concerning immigration, education and other aspects of the labour market can be very important for the supply of R & D.

The ways market deregulation has affected R & D in New Zealand are shown in the appendix. The evidence overseas is still fragmentary. Baumol (1986), for example, points out that increased economic competition resulting from deregulation could cut (as well as presumably increase) spending on basic research. He predicts this will happen with IBM and AT & T.

Intervention in Internal R & D Transactions

As described in chapter 2, an alternative to market governance of R & D transactions is to do research in-house, and transfer it internally from researcher to user. The major set of policy tools impinging on private decisions about how to organise transactions internally is competition policy. (See for example Williamson, 1986, chapter 5.) A tight competition policy affects the ability of an organisation to internalise transactions via vertical, horizontal or conglomerate (dis)integration. Restrictions on mergers and acquisitions, specific trade agreements, and joint ventures can act as an inducement to operate in the market place or via another governance mechanism.

This applies to R & D investment as much as with any other transactions. A looser competition policy may induce a firm to do R & D in-house, a tighter one to contract it out. The higher transaction costs involved in the latter could mean less R & D is done. The empirical effects on R & D of changes in competition policy are not well known, but are nevertheless likely to be as significant as more publicised fiscal policy.

A special case of internalizing R & D is where a public funding agency decides to carry out its research in-house. This has been a common feature of R & D in almost all mixed economies. Arguments given usually relate to a lack of capacity in the private sector to do the work, the "strategic" nature of the R & D, or to the indivisibility of the R & D, implying some sort of natural monopoly argument. Often the public provision of R & D appears to follow on automatically from the public provision of other services.

This public provision takes various forms. It usually involves the public sector carrying out research, development and dissemination using public or private funding via government departments such as D.S.I.R., research laboratories, universities and quasi-public research institutes. The intended user of this R & D, if identified, may itself be in public or private ownership. The form of dissemination may thus be via the market or other governance mechanisms. Often public dissemination is a project in itself.

Governments commit considerable funds to information collection and provision as part of R & D programmes.

Whether R & D should or should not be done in the pubic sector reduces, in efficiency terms, to the range of organisational forms available to handle such investment. It is primarily a question of ownership and control. Jennings and Cameron (1987) review the most appropriate scope and organisational form of state-owned activities and we refer the reader to arguments there. The efficiency of public provision depends on the researcher's accountability and links with the client. These need not be via the market, but user-pays policies are an obvious way of improving them.

Intervention in Bilateral R & D Transactions

Perhaps the earliest of all these public policies has been the establishment of the system of property rights : the rights to invest in, use or transfer a product or process, with a certain degree of exclusivity. These rights are protected through the fundamentals of common law, government policing and threat of legal enforcement through the courts.

The effect of a clearly defined system of property rights in R & D transactions is to give businesses the incentive to invest up to the point where incremental transactions yield lesser net returns, secure in the knowledge that they will be able to fully appropriate these returns. Bramstein and White (1985) point to the importance of technical compatability standards in competition and performance, and the way governments may influence these.

An important right is not to give out information and to prosecute industrial espionage. This prospect of commercial secrecy allows firms to carry out R & D secure in the knowledge that, as long as reverse engineering is not possible (i.e. it cannot be taken to pieces to find out the ingredients), they can enjoy an advantage over competitors, and use this to recoup R & D costs.

The most important rights are embodied in company law and in the laws on intellectual property (patents, licensing, trademarks etc). Another important area is contract law, governing prior contracts relating to the development of products/processes and the employment of R & D personnel. Typical issues concern the rights of the individual when employed on R & D contracts, the rights of the employer if negligence or breach of secrecy occurs, and the equivalent rights of foreign-owned firms. The examples in chapter 5 suggest that contract law offers wider and potentially stronger protection for rights in R & D than does patent law.

Again empirical detail as to the impact of property rights on incentives to research is not available. However the general feeling is that the stronger the definitions of rights, the more likely that optimal levels of bilaterally (or market) transacted R & D will take place.

Intervention in R & D Via Third Parties

In addition to other forms of governance, R & D transactions may also use third party enforcement systems. These include official and industry boards, institutes, tribunals, commissions, and increasingly, courts. These bodies can set standards (e.g. quality standards, design and testing standards), identify them, offer warranties, and enforce them. In this way the validity of the R & D transaction is established by appeal to the third party. These third parties are often public bodies constituted nationally or regionally. Nevertheless they may be funded from user-fees. Two other types of third party are communal bodies such as trade associations, and private bodies that arbitrate between claims with the agreement of both sides to a dispute.

Commercial secrecy is at odds with a long-established tradition of free exchange of scientific information by research scientists. It has been suggested that in the context of international commercial strategy countries should limit the transfer of R & D information. The U.S. has already tried to do this with regard to the Soviet bloc. Similar suggestions have been made with respect to the free flow of N.Z. R & D information, though Eveleens and Scobie (1986) discount the costs of this.

Other mechanisms for third party enforcement are science and technology agreements between countries which set a framework for private R & D transactions. Here the agreement itself sets out the framework for the third party. The New Zealand - West Germany Scientific and Technical Cooperation Agreement is an example. Tisdell (1986a) points to other examples of regional cooperation in R & D (malaria vaccination and giant clam farming in SE Asia and the Pacific).

Collective research associations are an important special type of third party arrangement. Typically they involve a group of firms in an industry, often with government presence or support, that identify common production questions and carry out research into them (usually in-house). The particular advantage of research associations is their ability to communally fund non-appropriable R & D. They are classified as a form of third party governance because individual firms resort to them as a go-between on common research problems.

The Bureau of Industry Economics (1986) in an evaluation of public support for collective research associations, points out that there are advantages to be had when R & D spill over, and industry is unaware of the benefits of informal cooperative activity.

In most countries research associations have not developed further over the last decade; rather more flexible arrangements have been sought for new technologies. These include research 'clubs' which pursue a particular line of research, and may easily disband as they lose their relevance. The O.E.C.D (1985) points to a number of these new industrial networks aimed at developing longer-term "generic" technologies. These include the pooling of resources of companies to fund research elsewhere as well as pooling internal research. An example in the U.S. is the Semiconductor Research Corporation, established in 1982 by thirteen chip manufacturers and computer companies.

Of the more formal research associations the B.I.E. found that they derived most support from medium and large firms, and tended to research "enabling technologies" from which individual firms could produce specific products. They increasingly do contract research for individual firms, technology transfer activities, and management work (e.g. related to productivity).

The research association is only one of a number of organisational possibilities for carrying out generic research. Another is the use of joint ventures. These have especially been used to coordinate research where cross-national cooperation is required. Examples are research agreements between Philips (Netherlands) and Siemens (Germany) on semiconductors; Hoechst (Germany) and Tate and Lyle (U.K.) on biotechnology; and ICL (U.K.), CMB (France) and Siemens (Germany) on computer systems.

This chapter commenced by reviewing the traditional science and technology approach to public policy, which it rejected for its lack of precision and confusion of interrelationships. We then listed the policy tools available to affect the various forms of R & D governance. What emerges is firstly that a very wide range of potential policy instruments are available, and secondly that these go far beyond traditional measures like public funding and tax concessions for private investment.

This policy classification is used to outline New Zealand measures to stimulate and regulate R & D in the appendix. In the following chapter we also use it in our guide to policy design for specific R & D issues.

CHAPTER 7

TOWARDS A FRAMEWORK FOR PUBLIC POLICY

7.1 Introduction to the Framework

In Part I of this report we analysed the traditional market failure approach to R & D policy. While it has some strengths, there are also severe limitations to its use as an all-embracing theory of public intervention. In Part II we laid the foundations for a more broadly applicable approach by showing how R & D may be validly transacted not just through the market but also through other mechanisms : the implication is that policy should also take account of these other mechanisms. The remainder of Part II teased out how these mechanisms worked and the interrelated roles played by the characteristics of the R & D, the organisations conducting it, the researchers doing it, and the rights held over the output.

Part III of this study builds a policy framework on this foundation. The key is broadening policy to take into account explicitly the new mechanisms for R & D transfer. The previous chapter reinterpreted policy and reclassified policy tools according to how they impact on these mechanisms. Appendix 2 shows how past N.Z. policies fitted this pattern.

In this chapter we address the general problem of how to translate the insights and analyses into a practical plan for policy action. We do not try to show a specific policy for every type of R & D. Such a mechanistic approach would not be possible. What we do aim to construct is the first step to working out an appropriate policy response to any particular type of R & D investment.

We do this by firstly constructing a matrix that classifies different types of R & D transaction by most efficient type of governance, showing what is implied for private action. We then talk briefly about choice of interventionist tool. Next, necessary and sufficient conditions for using these tools are laid down. Some advantages and disadvantages of the new approach are discussed, and comparisons made with traditional policies. Finally some individual examples are used to show how to handle the framework in practice.

The approach of many policymakers over the last few decades has been an aggregate one: they would look at overall levels of R & D investment, set targets for these commensurate with what could be achieved, and encourage spending to reach this level. This is a difficult approach: no one, least of all policymakers, can know the economically-desirable levels of R & D at an aggregate level, let alone other ways to achieve them. Our approach does not rely on trying to induce organisations to invest up to some exogenously determined "right" level of R & D. Rather it relies on market and private mechanisms to determine levels of investment, and where these are thought to be too high or low, uses policy tools which will work through these mechanisms.

> "The focus of the policy issue should shift from R & D levels to the portfolio of R & D projects an industry tends to generate. This entails turning our attention toward the incentive effects of policies and

institutional structures and towards consideration of access, secrecy, and information flow." (Nelson & Langlois, 1983 p 815)

The approach we use is to categorise individual cases of R & D into their important features. These are the set of characteristics pointed to earlier by Arrow (1969), Noll (1977) and others concerning the appropriability, uncertainty and indivisibility of R & D, widened to include the broad set of criteria outlined by Williamson (1979/1985), Baumol (1986) and others (in chapter 2). These concern the degree of specificity of inputs and outputs, the frequency of the transaction, and its measurability. They are important because they denote "awkward" things about R & D which prevent it all being neatly transacted in the market-place.

The particular set of features borne by any particular R & D investment will predispose its owners to use a particular mode of allocation which may be the market; equivalently it may also be handled internally, privately negotiated between partners, or handled through third parties. As detailed in Part II of this study, each of these forms of governance is particularly appropriate to handling certain features of an investment while other features will push a transaction into a different governance structure. Table 7.1 gives a broad-brush qualitative indication of how any feature of R & D will imply a certain governance mode.

In the past the dominant paradigm for public policy in New Zealand has been the market failure framework: if markets can be shown to fail some intervention is justified (see Appendix 2). However, as Troughton and O'Donnell (1986) note, the current interpretation of this approach is wider than was recognised a few years ago. The Beattie Report (1986) falls broadly within this market failure framework.

Note that our approach broadly subsumes this framework and it still allows that market governance may not work well, but this is no longer an automatic justification for intervention.

Some of the distinct differences in approach are related to certain key concepts:

Markets - Because R & D is not carried out through markets does not imply that a transaction is not being carried out adequately via another governance mechanism. Certain sorts of R & D by their nature are more efficiently carried out internally, and between or among organisations, rather than via the market place. A transaction need not be forced into the market place if it is not carried out there. Indeed the market may be signalling that such R & D is better carried out through other mechanisms.

Failure - This is a somewhat misleading term because it suggests the polar case where transaction costs are impossibly high, and implicitly assumes nirvana-like possibilities of an ideal outcome where transaction costs are zero. Our approach simply compares actual institutional possibilities that result in differing degrees of efficiency. Rather than failure of markets or any other type of transaction, we are comparing relative efficiencies.

Intervention - Interventions are possible not just in markets but in all governance mechanisms. Consequently there is a wider range of policy possibilities than is sometimes thought. Intervention of course also includes all the possibilities of dis-

Table 7.1: Governance Structures Implied by Different R & D Types

Characteristic of R & D		Degree of Each Characteristic: High	Medium	Low
Specificity	(How specific are assets to one R & D use?)	internal trilateral	bilateral	market
Frequency	(How frequently is R & D transacted?)	internal bilateral	-	trilateral
Uncertainty	(How uncertain are the results of R & D investment?)	internal	bilateral	market
Appropriability	(How much of the benefits of R & D can investors capture?)	market trilateral	-	internal bilateral
Divisibility	(How easily can R & D investments be done on a small scale?)	market internal	-	bilateral trilateral
Measurability	(How well can inputs and outputs be measured?)	market	bilateral trilateral	internal

Notes to Table 7.1

The table lists various features of an R & D investment (eg asset specificity, frequency of transactions, etc) that are important in influencing the governance made through which it is likely to be transacted (eg through the market place, internally, bilaterally or via a third party). Each entry indicates the governance form that would be used for R & D investment with a high or low degree of each characteristic.

Thus (reading across) R & D involving assets which are highly specific would, *ceteris paribus*, be transacted internally or via a third party, whereas moderately specific assets would make a bilateral arrangement more attractive, and very non-specific assets would make use of the market place.

It is important to note that this assumes no overriding public intervention. In addition it is a series of partial effects. In practice any R & D investment combines several of these features in which case more complex interrelationships are involved; it is not practicable to be more specific here. Other R & D features of less importance are mentioned in the text. This framework relies heavily on the approach of Williamson.

----

intervention. Intervention may be designed to reinforce a particular mode of governance, but it may also result in changing the transaction mode.

Conduct v Funding - The framework outlined here broadly applies to the issue of public funding. Public conduct of R & D is something of a special case, being an example of an internal transaction where the transaction costs of organising R & D under public ownership are judged to be low. The issue is discussed in more detail in chapters 2 and 6.

7.2 Procedure for Using The Framework

(i) To categorise the important features of an R & D investment (horizontally); i.e. whether any particular piece of research is specific to a particular use, whether it is a one-off transaction, whether the outcome is highly uncertain, whether the output is appropriable, how divisible the research is, and how measurable the productivity of inputs. Chapter two identified these as the important characteristics of R & D which determine how well any governance mode handles such a transaction.

(ii) To categorise the ways in which this R & D is transacted (vertically); i.e. whether R & D will be done through the market place, internally within an organisation, privately between two partners, or using a third party.

Note that we are dealing here with the funding of R & D by an organisation and its conduct either by the same organisation or a separate one. We are not directly interested in the ultimate application of the research output. Note also that the table is based on a given regulatory structure, that is it does not rest on assumptions about the absence of government or any other idealised environment.

The table uses the results of chapter two to classify R & D features by the form of governance that carries out transactions most efficiently. For example, the market place is relatively efficient for R & D involving non-specific assets and highly certain easily appropriable investments. If the same investment is likely to be less appropriable and more uncertain, it may be transacted internally. The same investment with moderate specificity and reasonable measurability may be done privately between two partners. If it is done only very infrequently, using a third party may be the most appropriate mechanism.

The R & D characteristics of asset specificity, frequency of transaction, uncertainty, appropriability, divisibility and measurability, are the most important but not the only things which may be considered. Others are the recognition aspect of R & D output, questions of discontinuity, transferability of output, enforceability questions of property rights, and other transaction characteristics stemming from agency problems. In practice only certain of these characteristics will be of importance in a particular case. Gilbertson (1987) for example picks on the degree of rivalry, appropriability and exclusion as being important in examining DSIR's pricing policies.

Using this table the policymaker can consider any particular R & D investment, reduce it to its essential characteristics, observe which governance form it operates within and how efficiently it is handled. Then comes the question whether allocative efficiency could be improved using this or another governance form. Only at this stage can it be said that an *a priori* case for considering intervention exists. That is the necessary condition for public intervention.

For example a particular type of R & D might be uncertain and of low appropriability, a common combination of characteristics that have led in the past to claims of market failure. The table indicates that this combination would indeed be unlikely to be handled via the market, and is more likely to result in an internal transaction.

The policymaker observes what happens in practice : assume that R & D does not appear to be done internally. Then what we observe may not be a market "failure" at all, but in fact a "failure" in internal governance. Rather than try to push a transaction into the market place, it would initially pay to investigate barriers to internal transactions : is competition policy too restrictive? Are public funders of R & D prevented from conducting their R & D in-house?

Thus for the case of the uncertain and inappropriable R & D mentioned above, if it is found that such investment is being handled inefficiently through the market sector then there may be a case for intervention. However rather than policymakers automatically assuming market failure, they should also consider other policy instruments that relate to the internal governance mechanisms we might have expected to prevail in such a case.

The sufficient condition for public intervention is that the expected benefits from such a move outweigh the costs of intervening (or disengaging). This refers to the public costs of measures. These are mainly financial and agency costs involved in funding and administering the measures.

The interventions could take the form of any of the wide range of measures outlined in chapter six. Based on the classification in table 6.2 we list some general types of measure (see table 7.2). For each we list some of the costs of implementing such measures, some of the private costs involved in taking them up, and some of the public advantages of each measure. Note that this table is only intended to be broadly indicative.

Thus the policymakers must judge the cost/benefit outcome of each intervention on a case by case basis. What we are attempting here is a comparative institutional approach. Just how they are to assess costs and benefits of a change in intervention is not an issue we can discuss in any depth. It will raise serious problems of identification, qualification and assessment.

For example, we have not tried to explain ways of qualifying the R & D characteristics in table 7.1. Hence we cannot answer what is "high" or "low" appropriability, uncertainty, etc. In practice most firms will be involved in several governance modes at the same time, and any particular type of R & D will also be transacted in several ways. Furthermore there may be economies of scope in doing several types of R & D simultaneously. This will all complicate policy choice and design. For some possible ways of addressing these problems we refer the reader to the evaluation procedures and further references in Freebairn and Gannon (1986).

7.3 The Framework Demonstrated By example

The following examples show very briefly how this framework might be used. They are meant to be no more than indicative of different types of research.

Improved wool scouring equipment - R & D to improve a piece of scouring technology is characterised by being highly specific in its output, involving infrequent transactions, and imposing moderate problems of appropriability; in addition it is reasonably certain and measurable. This would lead us to expect a non-market governance form. Indeed such R & D has often been trilaterally governed in New Zealand, being carried out through the Wool Research Association which is partially public-funded. A typical policy question here could be whether the same R & D would have been done without this injection of public funds, relying entirely on private funding, albeit still through this type of third party.

Pharmaceutical research - R & D to research and develop new drugs tends to involve highly specific inputs and output, infrequent, uncertain transactions; with a high secrecy element. For these reasons such research tends to be done by drug companies in-house, with public involvement only on regulatory issues. Typical policy questions here are the effects of competition policy and property rights over research and brand names on ways of organising research and the extent of investment.

Economic research - Much applied economic research is asset-specific and output-specific involving frequent transactions but with no major problems of

TABLE 7.2: The Impact of Policy Instruments

Policy Instruments	Body Involved	Costs to Public Body	Costs to Private Parties	Benefits
Market				
Grants	Spending depts	Possible distortion crowd-out room for abuse creates producer surplus	Usually limited to capital spending	Popular with recipients, but not taxpayers
Subsidies	" "			
Loans	" "			
Tax breaks	Spending/control depts			
Macro policy	Treasury	Technical difficulties	-	Unbiased
Market reform	Departments	Entrenched interests	-	Relatively popular
Public exhortation	Government	Shotgun approach	Relevance doubtful	Easy
Internal				
Competition policy	Commerce Commission and Courts	Admin cost	Admin cost	Transparent
Direct provision	Spending depts	Severe agency costs. Discrimination diffic.	Crowd out	Low transaction costs
Bilateral				
Development contracts	Courts	Enforcement problems	Costly proceedings	User pays
Employment contracts	Courts			
Patent licences	Patent Office	Enforcement problems	Cumbersome procedure	Relatively cheap
Copyrights, trademarks etc.	Patent Office	Admin problems		Transparent
Third Party				
Licensing, arbitration	Boards, tribunals, Courts	Cumbersome	-	User pays
Standards & Testing	Associations & Laboratories	Agency Costs	-	Partial user pays
Cooperative R & D	Research Associations	Transaction costs	Compatability problems	Potentially cheap
Science & technology agreements	Govts	-	Relevance	-
Joint Ventures	Commerce Commission	-	Opportunism and other transaction costs.	Cheap

Notes: This table is based on the list of measures in table 6.2. It is intended to be no more than a broad guide to the general nature of costs and benefits incurred by specific measures. The costs to enforcing or administering bodies are general agency costs, while those to private parties mainly involve other types of transaction cost.

divisibility, measurability or uncertainty. For these reasons it is mainly conducted via market governance or in-house. In addition there is some public funding and conduct of R & D normally for the consumption of public bodies: spillover problems can however affect the efficiency of market governance.

Flood control schemes - R & D to develop and improve methods of flood control on farm-land is often funded and conducted by central or local government. Such R & D typically displays the following characteristics: it is very specific in output, it involves high sunk costs; is infrequent in nature; is rather difficult to appropriate returns from; is indivisible in nature; and it is difficult to measure its benefits. As such, it incorporates many of the characteristics of R & D that governance mechanisms find most difficulty in handling. This accounts for the extent of direct public intervention. The interesting question here is the extent to which benefits from such schemes can be measured and apportioned successfully, in which case a partial or total user-pays system could be envisaged.

Forestry research - R & D into genetic improvement of tree types poses problems of specialist scientific input and highly uncertain (technical and commercial) returns given the long-term nature of tree growing. There could also be appropriability problems. This suggests R & D will not be organised in the marketplace but internally (e.g in one of the large integrated forestry firms) or bilaterally (e.g through the Forest Research Institute). The argument would normally be that a reasonably high proportion of this R & D be funded privately; market failure here does not imply governance failure.

Earthquake monitoring - R & D into earthquake frequency and probability raises issues under many of the headings in table 7.1. The dominant one is appropriability - it would be commercially and politically very difficult to keep results private. Indeed the results are likely to be regionally non-specific. Consequently internal and bilateral governance is likely, which may be either publically or privately funded.

Surimi research - R & D to develop this fish paste for Japanese markets involves specialist knowledge, but does not appear to be otherwise characterised by further problems that would limit who can do it and through what forms of governance except for potential appropriability problems. We could therefore expect to find this type of R & D carried out through any of the governance methods. In particular the market might well work here. Note we are talking here about who funds the research, not who conducts it. The latter depends on relative efficiencies.

7.4 Policy Conclusions

The comparative institutions approach is very wide in its applicability, providing policymakers for the first time with a general framework that has the potential to apply to any type of R & D. It shows from an allocative viewpoint, how any R & D investment may be reduced to its basic characteristics, which in turn reveals how the R & D is likely to be most efficiently transacted. This signals the likely appropriate focus of policy.

It tends to impose more stringent conditions for intervention than does the market failure approach, principally because "failure" is viewed as a relative concept, and "markets" as only one of a number of governance mechanisms available. Conversely it offers a wider range of R & D policy instruments: for example, the new classification system makes it clear that tools such as competition policy have important effects on R & D carried out through internal transactions.

This framework, while analytically powerful, is still at a developing stage in its policy uses. In particular, it involves complex concepts, some of them subjective, has been plagued with jargon, and is still undergoing refinement in its policy uses.

At a policy level there are a number of practical problems in its use. In fact what the theory gains in generality, it loses in detailed policy advice. In particular, there are problems involved in gauging the extent of appropriability, uncertainty, divisibility, etc. inherent in any R & D, in estimating the likely response to a policy tool, and in measuring costs and benefits of individual measures.

It should also however be noted that in most cases these problems also occur with the traditional market failure arguments, but tend to be overlooked in the face of pragmate necessity. The major one of these is the second best argument that no partial improvement can necessarily be assumed to be a general improvement in the face of other suboptimalities. This argument is somewhat lessened with the comparative institutional approach which does not concern itself with optimality *per se* but rather with comparable efficiencies. We make the usual applied economists' response to this issue which is that a "third-best" argument is to assume second-best problems are not major ones in practice.

While the policy implications of the comparative institutional approach are still being developed, it directs the policymaker to suspect across the board public interventions and rather to take a more cautious comparative approach. In the meantime the policymaker will find the approach, though still in an embryonic state for practical use, is full of general insights for R & D policies. In brief, nine practical steps for policymakers, following this comparative institutional approach to assessing possible R & D policy intervention are:

- i Identify the types of R & D under focus separately.
- ii Observe how each is currently transacted.
- iii Assess its key features, as in table 7.1.
- iv Identify the type of transaction mode predicted by this table.
- v Identify any policy measures currently affecting governance.
- vi Select possible policy measures, probably those working through this transaction mode.
- vii For each possible measure estimate public costs and benefits as in table 7.2.
- viii Noting all qualifications, compare those outcomes and institute best value ones.
- ix Repeat the steps for each type of R & D.

APPENDIX I: O.E.C.D. Definitions of R & D

1. INTRODUCTION

The purpose of this guide is to define and explain the terms and concepts required for the *Survey of Funds and Manpower Allocated to Scientific and Technological Activities.* The guide furthermore provides the standard lists of fields of application, research fields, and sources and recipients of funds.

2. DEFINITION AND EXPLANATION OF TERMS AND CONCEPTS

To make international comparison of the results of the survey possible, definitions, explanations, terms and concepts similar to those adopted by mutual consent by all member countries of the *Organization for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organization (UNESCO)* are used. The relevant pages of the "Frascati Manual 1980" of the OECD are indicated.

2.1 SCIENTIFIC AND TECHNOLOGICAL (S&T) ACTIVITIES

> Scientific and technological activities comprise the systematic activities concerned with the *generation, advancement, dissemination* and *application* of scientific and technological knowledge. This refers to knowledge in the human sciences, natural sciences and technology. (Frascati p. 14.)

The *human sciences* comprise the fields of the economic, social, political, philological and philosophical sciences and the humanities and arts, as well as the economic, aesthetic, cultural and social aspects of the natural sciences and technology.

The *natural sciences* include, for the purpose of this survey, the medical and agricultural sciences.

Technology refers to knowledge of techniques in the human sciences as well as the natural sciences, as described above, and includes the engineering sciences.

For further particulars regarding the above-mentioned three fields of knowledge, consult the research fields in section 3.2.

S&T activities are classified into three categories, namely *research and development (R&D), research-related S&T activities,* and *non-research-related S&T activities.*

2.1.1 Research and development (R&D)

> Research and development comprise creative work undertaken on a systematic basis to increase knowledge and the use of this knowledge to devise new applications. (Frascati, p. 25.)

Quite often it will be difficult to distinguish between R&D and non-R&D activities, especially because of the usual close institutional, personal, operational or other connections between R&D and other activities. To identify a particular activity as R&D, the following two criteria should be used:

- *Aim of the activity: If the activity has as aim the increase of scientific and technological knowledge and/or the devising of new applications thereof, the activity should be considered as R&D.*
- *Nature of the activity: R&D is characterized by the presence of an appreciable element of novelty or innovation, the use of scientific methods, and the presence of the element of creativity.*

It is especially the former criterion which should be used whenever doubt arises regarding the classification of a particular activity. *This means that an activity should be regarded as R&D if the main aim of the activity is to increase scientific and technical knowledge or to devise new applications, even when the activity itself is otherwise not regarded as R&D.*

According to these criteria, the routine activities needed for the support or purposes of R&D should, for survey purposes, be added to R&D.

R&D include basic research, applied research, and development, as elucidated below. Note that it is the activities during the particular survey year under each *project* which should be classified in accordance with these concepts and not the organization or discipline.

(a) Basic research

> Basic research is creative investigation (experimental, descriptive or theoretical) conducted primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts. (Adapted from Frascati, p. 54.)

The aim of basic research therefore is the solution or explanation of problems peculiar to science and technology, or the exposure of new fields of research. Two types of basic research can, however, be distinguished, namely pure basic and oriented basic research. In the case of *pure basic research* the research is directed exclusively towards problems peculiar to science, and is not performed within the framework of eventual applicability outside science. Also consult section L of the guide.

Sometimes, basic research projects may, however, primarily be selected with the aim of eventual applicability outside science, and is then termed *oriented basic research.*

Note: Descriptive research, commonly referred to especially in the historical and political sciences, should be classified under basic or applied research, depending on the intention or not to apply the results.

(b) Applied research

> Applied research is original investigation undertaken in order to acquire scientific and technological knowledge, directed primarily towards a specific practical aim or objective. (Frascati, p. 54.)

The aim of applied research may be to determine possible practical uses of the results of basic research, but it may also include the development of new methods of achieving specific and predetermined aims.

NB: *Criterion for distinguishing basic research from applied research: The main criterion used for distinguishing basic research from applied research is the OBJECTIVE in view. Basic research thus has no IMMEDIATE practical aim in view (although it may very well have such an eventual aim), whilst applied research does have a SPECIFIC practical objective in view.*

(c) Development

> Development is the systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed at producing new materials, products and devices, to installing new processes, systems and services, and to improving substantially those already produced or installed. (Frascati, p. 55.)

NB: *Criterion for distinguishing research from development:*
Research deals with the increase of scientific and technological knowledge, but development is directed toward bringing about new applications. Development also includes the activities involved in adapting and improving existing human and natural sciences technology, whether of local or foreign origin.

(d) Examples

NATURAL SCIENCES

Basic research	*Applied research*	*Development*
Determination of the amino-acid sequence of an antibody molecule	Determination of the amino-acid sequence of an antibody molecule in order to distinguish between antibodies of various diseases	Devising a method for synthesizing the antibody for a particular disease, based on the knowledge of its structure, and clinically testing the effectiveness of the synthesized antibody on patients who have agreed to accept experimental advancement treatment
Study of the influence of psychological factors on diseases	Study of the psychological factors (stress, etc.) causing stomach ulcers with a view to obtaining information required for the development of adequate treatment methods	Development of a new treatment method for stomach ulcers caused by psychological factors
Study of a given class of polymerization reactions under various conditions, of the yield of products, and of their chemical and physical properties	Study of a given class of polymerization reactions under various conditions, of the yield of products, and of their chemical and physical properties in order to optimize one of these reactions with respect to the production of polymers with given physical or mechanical properties	'Scaling up' of the process optimized at the laboratory level and the investigation and evaluation of potential methods of production of the polymer and perhaps of articles to be made from it
Study of the absorption of electromagnetic radiation by a crystal	Study of the absorption of electromagnetic radiation by a crystal under varying conditions (e.g. temperature, impurities, concentration, etc.) in order to obtain some given properties of radiation detection (sensitivity, rapidity, etc.)	Preparation of a device using this material in order to obtain better detectors of radiation than those already existing (in the spectral range concerned)

HUMAN SCIENCES

Basic research	*Applied research*	*Development*
Study of the factors determining regional variations in economic growth	Study of the factors determining regional variations in economic growth in order to prepare appropriate policy	The development of *operational models* based upon laws revealed through research for the modification of regional disparities
Analysis of the environmental determinants of learning ability	Analysis of the environmental determinants of learning ability in order to evaluate education programmes designed to compensate for environmental handicaps	The development of *operational means* of determining which education programme would be used for particular classes of children

2.1.2 Distinction between development and implementation

To distinguish 'development' from implementation and routine application, the practical rule is used that *development ends when it is decided to begin implementation and routine application.* Doubt may nevertheless arise concerning the dividing line between development and those technical services performed at the beginning of the implementation phase, immediately following upon the development phase (design engineering, patenting and licensing, 'scaling', market research etc.) Again the *immediate AIM* or the specific reason of the particular activity should be taken into consideration. Thus, according to the National Science Foundation (Washington):

'If the primary objective of the work is to make technical improvements on a product, service, process, system, method, procedure or approach, then the work falls within the definition of R&D. If, on the other hand, the product, etc., is substantially set and the primary objective is to develop markets, to render services, to do pre-production planning or to get a production control system working smoothly, then the work is no longer R&D.'

Applying this criterion, the following borderline cases may be identified:

(a) Prototypes

A prototype is a basic model possessing all the essential characteristics of the intended new service, process, system, material, product or device and which is usually modified and improved after testing. The design, construction and testing of prototypes are allocated to R&D, but after final testing are excluded from R&D.

(b) Pilot plant

The construction and operation of a pilot plant are a part of R&D as long as the immediate aim is not routine application, but to evaluate hypotheses; developing new product, service or system specifications; designing special equipment and structures required by a new process; and/or preparing guides for routine operation. As soon as a final decision has been reached concerning the product, service, system or process, the cost of the pilot plant no longer falls under R&D.

(c) Trial runs and trouble-shooting

After a prototype, with any necessary modifications, has been satisfactorily tested, the costs of the first trial runs should not be attributed to R&D since the primary objective is no longer to make further improvements, but to ensure smooth progress. The first units of a trial run for a mass production series should not be considered as R&D prototypes, even if they are loosely described as such.

After a new product, service, process or system has been turned over for implementation, and production, there will still be technical problems to be solved, some of which may demand further R&D. Such 'feed-back' R&D should be included under R&D.

Trouble-shooting should not be regarded asR&D, even though it occasionally may give rise to the need for further R&D.

2.1.3 Other scientific and technological activities (performed by research divisions)

Reference has already been made above to the close relationship between R&D activities and other scientific and technological activities. These 'other' activities are *mainly concerned with the collection, distribution and utilization of scientific and technological knowledge.* Two main groups are distinguished, namely research-related and non-research-related scientific and technological activities, as described below in 2.1.3.1 and 2.1.3.2.

NB: Activities such as secondary education, apprenticeship training not for the purposes of the R&D programme, production and distribution of goods, and in general the rendering of routine services to other institutions (e.g. routine medical, clerical, and administrative services), are throughout regarded as falling outside the scope of this survey.

2.1.3.1 Research-related scientific and technological activities

This group represents activities regarded for the purposes of the survey as essential for the development of R&D. It is subdivided into four categories according to the nature of the activity.

(a) Scientific and technological information and documentation

This group of activities refers to all management, administrative and operational activities aimed at the planning, support, control and improvement of the functions and tasks concerned with the recording, collection, evaluation, arrangement, storage, retrieval, processing, translation, provision and use of information in the fields of S&T. It likewise covers activities connected with the organization of, or attendance at, scientific and technical meetings (conferences, congresses, seminars, etc.), as well as museum libraries and documentation centres.

In cases where these activities are conducted for the purpose of intramural R&D of an organization, the appropriate portion of the funds should be included under the R&D of the organization. The information activities for the purpose of an advisory function, and not of R&D, should, in contrast, be included under section 2.1.3.2(d).

(b) *Training and education*

This includes all training and education of S&T manpower in universities and other tertiary institutions. In principle, the specialized advanced training courses for scientific and technical manpower conducted by bodies other than tertiary educational institutions should be included. The research training of students which is an integral part of R&D at universities should be regarded as R&D.

(c) *General purpose data collection*

This major group includes the systematic routine collection, through various established procedures and techniques, of data which can be made available as raw material for scientific work in broader context.

Activities classified in this group may be directed towards:

— the exploration and systematic survey of the earth and its natural resources, such as routine topographical mapping and geological, hydrological, oceanographic, meteorological and other technical surveying, including routine astronomical observations, and prospecting for oil and other mineral resources.

— the systematic gathering of data on human, social and economic phenomena, which in most cases will be routine statistics relating to the population and to the economy, e.g. censuses of population, censuses of production and distribution at the national level, and market studies and production and sales statistics at the enterprise level.

The compilation, processing, and initial interpretation or analysis of the collected data is also included. Normally, only established methodologies, procedures and techniques are used in general purpose data collection.

Data collection conducted solely or mainly for the purpose of a specific R&D programme, should be included in R&D.

NB: A particular problem experienced world-wide is to distinguish in the exploration of minerals between R&D and general purpose data collection. The following activities are regarded as R&D:

— the development of new survey methods and techniques,

— surveying conducted as an integral part of an R&D project on geological phenomena.

Theoretically, R&D on geological phenomena conducted as a subsidiary part of surveying and prospecting programmes, for example, to evaluate the extent of a deposit, could be added to R&D. For the purposes of this survey such activities should be included in general purpose data collection.

(d) *Museums and zoological and botanical gardens*

The activities of nature reserves, aquaria and wild-life conservation organizations are included.

All scientific activities are included here, except specialized R&D work which should be included in R&D, or *library services, which should be included in (a), viz. scientific and technological information and documentation.* Circuses and subsidiary provision of entertainment and recreation facilities on the premises of zoological and botanical gardens, other than those concerned with their scientific work, should be excluded.

2.1.3.2 *Non-research-related scientific and technological activities*

Often the R&D section of an organization is also responsible for a number of other scientific and technological activities which are, according to the above criteria, not regarded as R&D or as research-related activities.

This group consists of the following important categories:

(a) *Testing, standardization and quality control*

This refers to the application of established procedures, systems and techniques for the establishment of national standards, the calibration of secondary standards and testing and analysis (physical, biological, bacteriological, chemical and statistical) of materials, components, products, processes, soils, atmospheres, etc. Examples: testing physical properties of materials, radio-activity, qualities of soils, performance of engineering products, safety equipment, strength of fibres and other materials, masses and measures.

The routine evaluation of psychometric tests is also included.

The activities under this heading conducted exclusively or mainly on behalf of a specific R&D programme, should be included in R&D.

Routine testing and quality control that cannot be divorced from the production process must be ignored.

(b) Patenting and licensing activities

The work involved in the granting of patent and licensing rights to outside organizations.

(c) Specialized medical and para-medical care, and clinical activities

These activities refer to routine investigation and normal application of *specialized* medical and para-medical knowledge performed in hospitals and university clinics. They are closely related to R&D in so far as they usually consist of the application of recent results of R&D and/or imply the use of advanced methods, techniques and technical devices to be applied by specially trained medical and para-medical personnel.

(d) Technical and scientific advisory services

These activities include systematic work directed to advising and assisting customers, other departments of an organization, or independent users, to utilize established scientific, technical and managerial knowledge. Included are extension and advisory services for farmers and firms, expert reports for the purpose of assisting in the preparation and performance of specific non-R&D projects, and feasibility studies.

(e) Policy-related activities

Policy in this context refers not only to national policy, but also to policy at the regional, local and organization levels.

Policy-related activities cover inter alia the analysis and assessment of the existing programmes, policies and operations of government departments and other institutions; the work of units concerned with the continuing analysis and monitoring of external phenomena (e.g. defence and security analyses); and the work of legislative commissions of inquiry concerned with general government or departmental policy or operations.

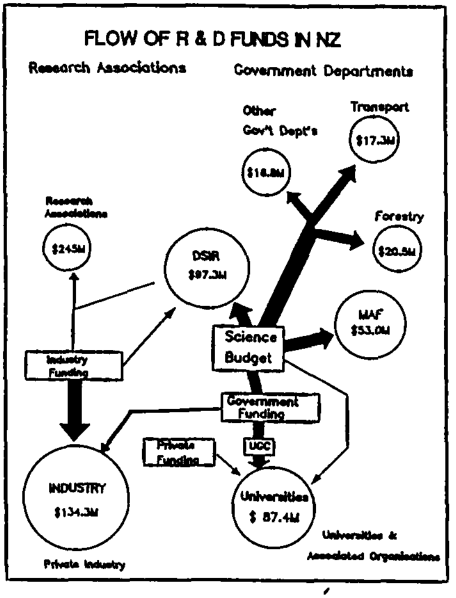
In general, but more particularly in the human sciences, where the purpose of the activities is to prepare the way for decisions, they are *excluded* from R&D. Usually, only established methodologies are employed in studies. In cases where it is necessary to modify operational models or to develop new ones which may require an appreciable amount of research, the appropriate portion should be allocated to R&D.

APPENDIX 2: RESEARCH AND DEVELOPMENT POLICY IN NEW ZEALAND

A2.1 Public Sector Involvement In R & D

There has been a long history of public sector intervention in the production and regulation of agricultural and industrial output in New Zealand. This has involved R & D, as well as many other forms, of investment. This appendix summarizes this involvement briefly, presents available data on R & D, and classifies New Zealand R & D policy in the new framework developed in this work. For further details in the history and extent of public involvement see NRAC Science and Technology Plans (1984, 85, 86).

FIGURE A.1 : Flow of R & D Funds in N.Z. (1985-6)



Source: DSIR

Notes

1. The circles represent direct expenditure by each organisation, and the areas within the circles are proportional to this expenditure.
2. The width of the arrows is roughly proportional to total funding (including funding which is subsequently distributed as grants and contracts).
3. Although not shown here, funds to Universities from the 'Science Budget' in fact pass first to Government Departments.
4. Government science was not previously been within the 'Science Budget' (eg Department of Health direct expenditure) is not shown here.

TABLE A.1 New Zealand Funding For R & D (1985-6), By Performer

	$M	$M
INDUSTRY		
Manufacturing	135.00	
Research Associations	20.50	
Electronics R&D (DTI)	1.00	
ATP	4.75	
Cawthron	0.60	
Contracts to DSIR	(3.00)	
		158.85 (35.2%)
GOVERNMENT (Science Budget, Direct Departmental Expenditure)		
MAF	53.027	
Defence	4.606	
Education	0.524	
Energy	0.140	
Forest Service	20.490	
Internal Affairs	2.681	
Justice	0.335	
Labour	0.381	
Lands & Survey	0.211	
DSIR	97.348	
Social Welfare	0.718	
SSC	0.289	
Trade & Industry	0.096	
Transport	17.338	
Works & Development	6.780	
		204.96 (45.4%)
HIGHER EDUCATION		
University Operations	78.82	
Private Grants	2.00	
Lottery Board	0.50	
ATP	0.50	
Science Budget Grants/ Subsidies	5.60	
		87.42 (19.4%)
TOTAL		$ 451.23 M

Notes:

1. The above figures include funding for science and social science research, but exclude funding for medical research.
2. For manufacturing R & D, data was taken from Man. Fed survey.
3. To avoid double-counting, industry contributions to certain RAs (i.e. those related to manufacturing) have been excluded).
4. For Universities, one third of operations expenditure has been provisionally taken as related to R&D for science and social science.
5. *The figures are for operations expenditure only, and exclude expenditure on buildings.*

Source : DSIR

Among government departments DSIR accounts for nearly half of the budget, followed by MAF with another quarter. The other government departments with major resources

Among government departments DSIR accounts for nearly half of the budget, followed by MAF with another quarter. The other government departments with major resources allocated to scientific research are the Forest Service, Ministry of Transport, and the Ministry of Works and Development. In sectoral terms this means that the largest amounts of R & D are spent on R & D in the agricultural, forestry, and fishing sectors, and on R & D in the natural environment (including soil and water conservation, meterology, geophysics, etc). It is estimated by DSIR that around 43% of government department research manpower works on agricultural R & D and another 40% on other aspects of primary production and natural science. Government departments especially DSIR, MAF and Forest Service (via FRI) have major in-house R & D organisations.

In addition a relatively small part of the public R & D budget goes to supporting R & D in a number of joint public/private and quasi-public research organisations. These are listed in table A.2. Of these, some of the industry research associations are the most significant.

Figure A.2 shows that public R & D spending has increased significantly since the 1950s both in absolute and relative terms. It is thought (e.g. see NRAC Report 1985/56) that the private sector has increased its R & D spending at a much higher rate, though this is largely conjecture. This gives New Zealand total R & D spending that is far lower than the OECD average (about half as much in relation to GDP). More interestingly the public/ private split is very different. While the New Zealand public/private proportion of R & D spending appears around 46%/36%, the OECD average is 16%/66% (bearing in mind that different definitions apply). The rest is university research. Thus, the New Zealand public sector involvement is large relative to the private sector.

It should however be pointed out that many government departments and public research bodies have had significant cuts in their research budgets (- in some cases of up to 37.5% by 1990). This will significantly change the public/private balance, whether programmes are dropped completely or supported by private funding. Further, the imposition of user-pays research policies in most government departments will increase the private sector funding ratio. In addition there are many problems relating to the conversion of public/private R & D breakdowns between countries. In particular in some countries some apparent industry spending on R & D is in fact indirectly funded by government.

A2.2 Particular Characteristics Of New Zealand R & D

Can this particular predominance of public sector R & D be explained by the special characteristics of the New Zealand economy? New Zealand commentators on science and technology have frequently made the case that New Zealand's geographical and environmental characteristics are unique and impose certain constraints on R & D transactions. For example, the Probine Report of the Review Team on Science and Technology Policy Formation (1984) listed a number of factors they felt affected R & D in New Zealand:

- the small size of New Zealand production by world standards
- the difficulty of evaluating products and markets due to isolation
- problems presented by competing diversifying land-based industries
- the small scale of most manufacturing firms
- the difficulty of appraising overseas technologies
- the problem of balancing applied and basic research work
- the limited number of scientists and the inability to specialise

TABLE A.2 Organisations Supporting S&T In Industry

	Government Grants ($000) 1984-5	Government Grants ($000) 1985-6	Industry Grants 1985-6
Research Associations:			
Building	877 *	927	2748
Concrete	384 *	564 *	424
Coal	306	454	660
Dairy	1829 *	1739	4500 **
Fertiliser Mfgers	283	777 *	422
Heavy Engineering	680 *	372	958
Textile Services	34	93	100 **
Leather and Show	274	299	312
Logging	285	271	305
Meat	1577	2099 *	2601
Wool	1102 *	1288 *	2625
Other Organisations Funded Through DSIR Programme III			
Cawthron Institute	553	624	
Testing Laboratory Registration Council	305	330	
Organisations Funded From Other Sources			
Massey University			
Agricultural Machinery Research Centre	31	31	
Fertiliser & Lime Research Centre	-	-	
Food Technology Research Centre	100	150	
NZ Nursery Research Centre	37	37	
Pig Research Centre	-	-	
Poultry Research Centre	79	89 **	
Lincoln College			
Agricultural Engineering Institute	2216	1284 **	
Other Grants Provided for Industry-Related Research ***			
LFTB	434	500 **	****
NZERDC	1489	1421 **	****
Applied Technology Programme	5250	5250 **	****
Electronics R&D	288	1000 **	****
DSIR Research Contracts with Industry	206	250	

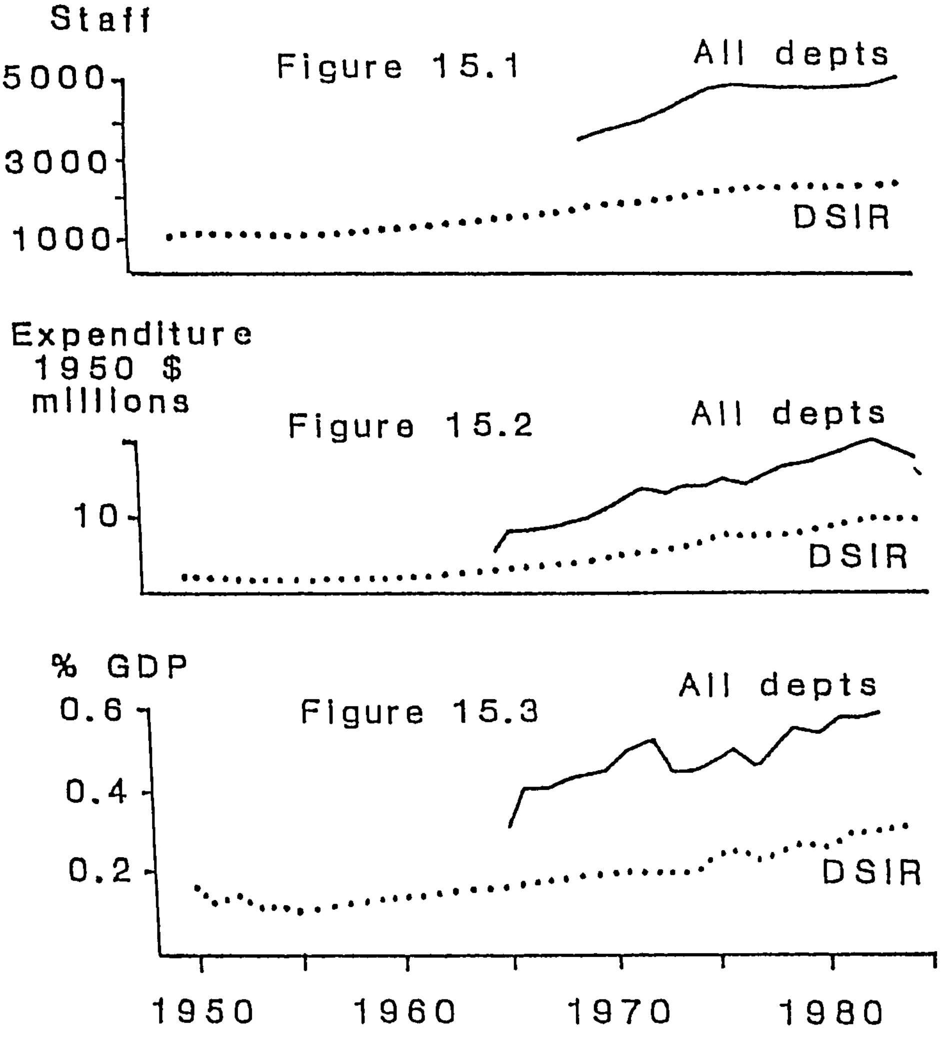
* includes grant for new buildings ** estimated expenditure

*** this list is not fully comprehensive

**** these programmes have been terminated or will be by 31.3.88

Source : DSIR

FIGURE A.2 Direct Public Spending In R & D



Source: E G Bollard (1986)

TABLE A.3 Science - Expenditure For Year Ended 31 March 1986 By Activity*

(corresponding expenditure for year ended 31 March 1985 in parentheses)

Activity	Departmental Expenditure $(000)		Grants and Subsidies $(000)		Research Contracts $(000)		Total $(000)	
Agriculture-								
Production	43,032	(65,497)	3,260	(3,955)	148	(400)	46,440	(70,267)
Processing	643	(5,747)	71	(4,837)	-	(163)	714	(10,747)
Forestry-								
Production	14,203	(14,211)	136	(266)	44	(81)	14,383	(14,518)
Processing	3,725	(3,723)	60	(143)	37	(29)	3,822	(3,895)
Fisheries-								
Production	9,137	(8,405)	-	(100)	35	(30)	9,172	(8,535)
Processing	-	(793)	-	(5)	-		-	(798)
Minerals-								
Production	-	(1,210)	-	(10)	-		-	(1,220)
Processing	-	(376)	-	(3)	-		-	(382)
Manufacturing	-	(12,075)	5,307	(847)	-	(58)	5,403	(12,980)
Building and								
Construction	544	(1,398)	-	(1,374)	-	(1)	544	(2,773)
Transport	1,674	(4,065)	92	(102)	-	(28)	1,810	(4,175)
Natural Environment								
	29,444	(42,274)	166	(609)	382	(439)	29,992	(43,322)
Social Sciences	2,388	(2,005)	4,582	(2,938)	448	(220)	7,418	(5,163)
Human Health	-	(2,679)	-	(22)	-	(5)		-(2,706)
Energy	747	(9.212)	1,500	(1,725)	406	(671)	2,653	(11,608)
Other Scientific								
Services	1,985	(5,732)	5	(352)	106	(162)	2,096	(6,246)
DSIR	97,348		10,670		614		108,632	
Total	204,870		25,849		2,360		233,079	
		(179,797)		(17,248)		(2,290)		(199,335)

Note:

The Government expenditure on buildings solely for scientific use is not included in the above tables.

The figure for 1984-85 was $17,317,000 and for 1985-86 was $25,860,000.

*DSIR expenditure not apportioned by activity

Source: NRAC Report to year ending 1986

Tisdell (1986a) adds the problems of: relative lack of specialist agents able to assist in marketing; high unit cost due to the small home market making export more difficult; and high transaction costs incurred in buying in foreign knowhow.

There is no doubt that New Zealand is distinct from most OECD countries and that our pattern of R & D will also remain distinct. However the above characteristics of New Zealand do not necessarily imply a higher public investment in R & D. They may be helpfully viewed in transactions terms. In this context they suggest that domestic market R & D transactions are likely to be limited in New Zealand, hence attention should be paid to other forms of domestic transactions, and also to the high transaction costs involved in the international transmission of R & D.

A2.3 R & D Policy Instruments In New Zealand

In this section we use the earlier classification of four types of transaction governance to classify the current R & D policy instruments in New Zealand.

The organisational responsibility for this R & D policy has in the past been held by the Minister of Science and Technology, in the Cabinet Committee on Science and Technology, serviced by an Officials Committee, with the National Research Advisory Council (NRAC) as an independent statutory body to advise the Minister. This organisational framework is currently under review, and was one of the focuses of the Beattie Report (1986) and the Probine Review Team (1984).

Market-Based R & D

The mechanisms used to reinforce market governance in New Zealand are grants, subsidies, tax incentives and tax reform. Grants and subsidies have been relatively low compared with funding for the conduct of R & D within government departments. In the 1985-86 year departmental R & D expenditure totalled $204 million in comparison with $26 million of public funds spent in grants and subsidies, and only $2 million put out in research contracts. See table A.3.

The main recipients of the grants and subsidies are the seven universities in New Zealand, 11 industry research associations, a number of research institutes and centres associated with the universities, and half a dozen other independent organisations. It is notable that only a tiny portion goes to private industry or research bodies that could be said to operate in the market place.

TABLE A.4 Science Organisations In New Zealand

GOVERNMENT DEPARTMENTS	UNIVERSITIES
DSIR	UNIVERSITY OF AUCKLAND
Antarctic Division	Science
Applied Mathematics Division	Medicine
Auckland Industrial Development Div.	Engineering
Biotechnology Division	Architecture
Botany Division	

Chemistry Division
Crop Research Division
Ecology Division
Entomology Division
NZ Geological Survey
Geophysics Division
Grasslands Division
Division of Horticulture & Processing
Division of Information Technology
Industrial Processing Division
Institute of Nuclear Sciences
Division of Marine & Freshwater Science
Physics & Engineering Laboratory
Plant Diseases Division
Plant Physiology Division
NZ Soil Bureau
Southern Industrial Development Division
Wheat Research Institute

MINISTRY OF AGRICULTURE & FISHERIES
MAFTECH
MAFFISH
MINISTRY OF DEFENCE
Defence Scientific Establishment
MINISTRTY FOR THE ENVIRONMENT
Environmental Investigations & Research
MINISTRY OF FORESTRY
Forest Research Institute

DEPARTMENT OF CONSERVATION
Science and Research Directorate

DEPARTMENT OF HEALTH
Science Services
National Environmental Chemistry and Acoustics Laboratory
National Health Institute
National Radiation Laboratory
MINISTRY OF TRANSPORT
New Zealand Meteorological Service
Road Transport Division

MINISTRY OF WORKS AND DEVELOPMENT
Water and Soil Division - Research and Survey Group
GRANT AIDED ORGANISATIONS
OTHER ORGANISATIONS

NZ Biological Resources Centre
Carter Observatory

UNIVERSITY OF CANTERBURY
Science
Engineering
Forestry

LINCOLN COLLEGE

UNIVERSITY OF WAIKATO
Science

MASSEY UNIVERSITY
Agricultural and Horticultural science
Science
Technology
Veterinary Science

VICTORIA UNIVERSITY OF WELLINGTON
Science
Architecture
UNIVERSITY OF OTAGO
Science
Medicine

Dentistry
Home Science
Physical Education

GRANT AIDED ORGANISATIONS
RESEARCH ASSOCIATIONS
Building Research Assoc of NZ
NZ Coal Research Institute
NZ Concrete Research Association
NZ Dairy Research Institute
NZ Heavy Engineering Research Assoc
NZ Leather & Shoe Research Association
NZ Logging Industry Research Association
Meat Industry Research Institute of NZ
Research Institute of Textile Services
Wool Research Organisation of New Zealand

ORGANISATIONS ASSOCIATED WITH UNIVERSITIES
NZ Agricultural Engineering Institute
Agricultural Economics Research Unit
Agricultural Machinery Research Centre
Nursery Research Centre

Cawthron Institute	Poultry Research Centre
National Museum of New Zealand	Centre for Agricultural Policy Studies
Standards Association of NZ	Fertiliser and Lime Research Centre
Testing Laboratory Registration Council of New Zealand	Food Technology Research Centre
	Pig Research Centre
	Seed Technology Centre

SOURCE: DSIR

Other public funding is available through a number of government funding schemes. These are listed in Table A.5.

TABLE A.5 Government Funding Schemes

Electronic Industry R & D Grants Scheme aims at increasing employment of qualified persons in the industry, administered by the DTI, and now marked for abolition 31.3.88.

Innovative Technologies Plan Contracts (DSIR) assists companies to prepare plans involving R & D in innovative technologies.

Research and Development Contracts (DSIR) provide funding on individual case basis for highly commercial R & D.

Applied Technology Programme (DFC) provides venture capital-type support for commercial development work. Marked for termination 31.3.88.

Energy Conservation Loans (DFC, MOE) available for capital expenditure on energy conservation and indigenous energy sources.

Regional Development Investigation Grant Scheme (DTI) offering grants towards investigations into investment in priority areas.

Industry Training Boards (VTC), 50% funded through the Vocational Training Council, they recommend training packages for industries, especially in new technologies.

Scientific and Technical Information Service (National Library), provides a first-stop information service on all technical topics.

Social Science Research Information System (National Library), SOSRIS, provides an information service similar to SATIS. In addition agricultural and other information systems are available.

Technology Management Service (DSIR & DTI) currently being established.

Historically, there has been more reluctance to use fiscal measures to signal incentives for R & D through the market-place, but in recent years this has become a preferred option by the private sector. New Zealand has not indulged widely in fiscal measures compared with some countries, preferring direct funding, fearing the costs of such measures, and distrusting the ability of the market to transmit appropriate signals.

The 1976 Income Tax Act determines assessable income for the purposes of tax. It requires that the capital revenue nature of R & D must be determined before a deduction can be allowed or denied. Under Section 113 of the 1976 Income Tax Act, the cost of plant machinery or equipment used exclusively for scientific research directly relating to the business of taxpayer can be written off over 5 years. As amended in 1986, the additional depreciation allowance, by way of a five year write-off, will not apply to plant, machinery or equipment acquired, installed or extended after 31 July 1986. Transitional measures provide that where plant, machinery or equipment is required, installed, or extended, pursuant to a binding contract entered into on or before 31 July

1986, or is leased by a taxpayer under a specified lease after 31 July 1986 pursuant to a binding agreement entered into on or before that date, it is to be treated as if it were acquired, installed, extended or leased on or before 31 July 1986. Under Section 61(24) of the Act a society or association engaged primarily in promoting or encouraging industrial research is exempt from income tax.

Section 144 of the Income Tax Act 1976 provides deductions for the cost of scientific research. It includes depreciation, allowable at ordinary rates, in respect of assets used for scientific research. It replaces the former accelerated write-off provisions of section 113 which no longer apply to assets purchased on or after 1 August 1986.

In addition to deductions for depreciation on assets, Section 114 of the Act provides for deductions for expenditure incurred by the taxpayer in that year in connection with scientific research, except so far as the expenditure relates to any asset in respect of which a deduction for depreciation is allowable under the act. In addition companies may claim deductions of up to $1000 for donations made to government departments, universities, and approved research societies that undertake research.

Under Section 156(g) of the Act any individual in business on his or her own account in New Zealand conducting research overseas, is entitled to a tax credit related to the time involved.

For some years New Zealand imposed a sales tax on selected products. For example a 40% sales tax was levied on computers, which affected the activities of retailers using computing equipment. This rate was reduced in 1983 and in 1986 was abolished, and a comprehensive goods and services tax levied on value added. This affects a far wider range of R & D spending, but is broadly neutral in its impact.

The fiscal recommendations of the Beattie Committee (1986) were that there be tax deductibility for expenditure on R & D activities on the same base as Australia amendment of Section 144 of the 1976 Income Tax Act to allow for development costs; and research costs be deductable for scientific R & D not directly related to the current business of the organisation.

A major area of recent policy reform concerns deregulation of product and factor markets in New Zealand. Certain industries (e.g. wheat and flour milling) have received radical regulatory reform that will probably result in changes in the type and extent of R & D transacted. The reform of the financial services industry has had a more significant effect. Unlike Australia the New Zealand reforms have opened up entry to traditional financing companies and venture capitalists with little restriction. The market for R & D funding has deepened and matured.

Wider interest through the stock market in innovative companies has also increased research funds available. Some idea of the likely impact may be seen in Harper (1987). Though it is too early to judge with any certainty, it may be that deregulation of the financial services industry has more effect on R & D than any other policies.

A further important change has been the reduction of trade barriers. New Zealand production is subject to more overseas competition with subsequent effects on R & D spending. On the other hand inputs for New Zealand R & D may be more freely imported, and in some cases R & D will itself be embodied in these purchases. The CER agreement and the close trans-Tasman ties has led to a number of company integrations and the concentration of R & D activities on one side of the Tasman (more usually Australia). To the extent that there is a growth in international integration and technology transfer, there is likely to be increased use of R & D results in New Zealand, even if the work was not done here.

Internally-Based R & D Transactions

As pointed out earlier the main instrument of government policy affecting internal R & D decisions is competition policy. In New Zealand's case this was revamped in the 1986 Commerce Act. This act takes a generally more liberal attitude to mergers and acquisitions but a tighter one towards restrictive trade practices. For details see Bollard (1986).

The Act does not differentiate between R & D and other forms of spending. It does however, lay down a reasonably clearly defined code relating to what is acceptable in terms of imposing restrictions on the availability of technology, taking over companies with R & D capacity, forms of research cooperation between firms, and other commercial conduct relating to internal or competitive research activities. Cases like the proposed Goodman-Fielder-Wattie merger will affect not only what R & D is done, but who does it and where it is located. Proponents of liberal competition policies argue that the need to appropriate the benefits of R & D investment is an important pressure for internal integration.

This legislation is very recent and no body of case law has yet been built up to gauge exactly how it will be interpreted. Certainly the overseas experience is that there is room for considerable confusion in complex cases.

A special case of internal governance is when the government funds R & D in-house. This is a major feature of New Zealand R & D. For example in 1985-6, of $204 million of departmental research funding, 86% was spent in-house. This is high by international standards. It seems to reflect a general feeling that in many markets there is insufficient research capacity in the private sector. The opposing view is that this public presence crowds out private researchers.

Bilaterally-Based R & D Transactions

New Zealand company law and contract law is based on British laws and there are well-established interpretations relating to research activities. Intellectual property rights are governed by the Patents Act, Designs Act, Trademarks Act (all 1953), the Copyright Act (1962), the Standards Act (1965), and the Plant Variety Rights Act (1985). Laws relating to intellectual property rights are on a par with other Western countries, and New Zealand is a signatory to the World Intellectual Property Organisation and the International Convention for the Protection of Industrial Property. Policing and enforcement is on international standards.

Third Party R & D Transactions

There are a number of important third parties which allow trilateral governance of R & D transactions in New Zealand. They are organised through government departments, statutory boards and councils, and research organisations. Some of the major mechanisms are listed below:

Offsets Policy - For all overseas tenders for government contracts worth $2 million or more, the tenderers are invited to include offset or counter purchase arrangements within their tenders. The introduction of new technologies to New Zealand is a particular criteria for these arrangements.

Building Research Association of NZ offers independent testing, appraisal and certification of new building products.

Dept of Scientific and Industrial Research offers a range of testing and certification facilities for new industrial products and equipment.

Testing Laboratory Registration Council carries out quality audits of quality assurance systems and accreditation of testing laboratories.

Standards Association of NZ offers advice on technical standards and codes of practice, and certifies products complying with standards.

The Patent Office contains information on local and foreign patents and assists investors to patent their own designs.

Scientific and Technological Cooperation Agreements have been concluded with West Germany, Singapore and China to encourage bilateral technology transfers.

All these arrangements, and others organised through research associations and private bodies encourage R & D transactions using trilateral governance. This area of public R & D policy has become increasingly important, though it may be carried more by the private sector in future years.

APPENDIX 3: GLOSSARY OF TECHNICAL TERMS

adverse selection problem of efficient transaction resulting from difficulties of screening parties beforehand

agency costs costs in an organisation stemming from incompatibility of incentives

anti-trust public policy relating to mergers and acquisitions and to restrictive trade practices.

appropriability extent to which benefits may be privately captured

asset specificity extent to which assets may be used for one purpose only

bilateral governance two-way negotiations between partners to handle as exchange

bounded rationality behaviour stemming from limits on information and calculating ability

complementary asset one whose value will rise as a result of R & D undertaken

consumer surplus benefit to consumer net of costs of purchase

copyright exclusive legal right to reproduce certain types of work (books, films, software, patterns, etc)

deadweight loss loss of consumer surplus incurred by buyers consequent on monopoly

dedicated assets assets acquired specifically to carry out research for a principal

development investment intended to adapt information to allow its use in new applications

economies of scale ability to lower unit costs by increasing level of production

economies of scope ability to lower overall unit costs by extending production to associated goods

exclusivity degree to which owner of resource can deny others its use

externalities the spillover of benefits or costs between parties

F-form firm functional firm with centralised strategic and operational decision-making authority fiscal policy government spending and taxes

franchise an authorisation to produce or sell a company's goods under an agency arrangement

free-ride party which benefits from the investment of another

frequency issue of whether a transaction is one-off, occasional or recurrent

governance structure mechanism through which transaction takes place (hence market, internal, etc)

impacted information situation where one party to an exchange is better informed than the other and will not disclose this

indivisibility situation where investment achieves positive returns but not on a scale to justify minimum level of spending

informational asymmetry situation arising when one party in a transaction has important information lacked by the other

innovation the introduction of new practices

intellectual property the output of the research and development process

invention a new practice resulting from research or development

joint venture agree between parties to pursue an investment together

licensing agreement agreement by which one party may use another's intellectual property

M-form firm multidivisional firm with separated operating and strategic decision-making authority

market failure the inability of private markets to handle certain classes of transactions

measurability degree to which quantity and quality of inputs and outputs can be assessed

moral hazard effect of certain insurance systems in causing divergence between marginal private and social costs

natural monopoly monopoly with long run decreasing average costs over the production range

nirvana approach tendency to look for ideal solutions when they are unattainable; can lead to misallocation non specific assets resources which are not dedicated to one particular use

opportunism willingness to profit at the expense of others

organisational slack cushion of resources beyond those required for current output

patent licence licence to the right to use future patented inventions for an area of research

private ordering see bilateral governance

quasi-rent return to a seller of a good over and above its opportunity cost

research investment intended to yield information increasing the stock of knowledge

Panglossion dilemma argument that what exists must be optimal since it arises from transactions cost minimization; an argument for status quo

Pareto optimality situation where no reallocation can make anyone better off without making someone worse off

patents right to monopoly use of R & D output for a limited time and under certain other conditions

principal-agent problem situation arising where interests of those appointing others to undertake duties on their behalf differ from the appointees

producer surplus surplus accruing to owners of factors of production above that necessary to induce this investment

property rights system of rights governing use of a resource, its transferability and how it may be transformed

rates of time preference degree to which current consumption is valued more highly than future consumption

risk context in which an event occurs with some probability, the distribution of which is known

second best theory of second best states if one of conditions for Pareto optimality is unattainable then it is not necessarily desirable to fill the other conditions

small numbers bargaining operation of transactions by a small number of buyers or sellers resulting in reduced efficiency of exchange; " their" markets

sunk costs costs which cannot be recovered when a firm leaves an industry tax neutrality imposition of a tax which does not distort pre-tax market signals

third party enforcement see trilateral governance

trademark registerable mark identifying design features and offering right to monopoly use

transactions costs costs other than price incurred on trading goods and services; includes information, bargaining and experiment costs in exchange

transferability extent to which owner of property rights can exchange certain of these rights with other parties

trilateral governance the use of a third party to conduct exchanges

uncertainty context in which an event occurs with some probability, the distribution of which is unknown

unilateral governance the handling of transactions in-house, eg through vertical integration

venture capital equity or debt finance to allow investment in research or development

vertical integration incorporation of successive stages of production process within one firm

BIBLIOGRAPHY

Ahlbrandt, R. and A. Blair (1986): What it Takes for Large Organisations to be Innovative, Research Management, 29 (2), pp 34-37.

Armour, H. and D. Teece (1980): Vertical Integration and Technological Innovation, Review of Economics and Statistics, 62 (3), pp 470-474.

Arrow, K.J. (1962, 1971): Economic Welfare and the Allocation of Resources for Invention, in Essays in the Theory of Risk Bearing, Chicago University Press, Chicago.

Arrow, K.J. (1983): The Organisation of Economic Activity : Issues Pertinent to the Choice of Market versus Nonmarket Allocation, in Public Expenditure and Policy Analysis, R.H. Haveman and J. Margolis (eds.), Chicago, Rand McNally, pp 47-64.

Babbie, Earl (1983): The Practice of Social Research, Belmont California, Wadsworth, pp 551p.

Barzel, Y. (1968): The Optimal Timing of Innovations, Review of Economics and Statistics, v.50(3), August 1968, pp 348-355.

Barzel, Y. (1982): Measurement Costs and the Organisation of Markets, Journal of Law and Economics, 25 (1), pp 27-48.

Baumol, W.J. (1983): Business Expenditures on Basic Research, New York Times, August 31, p D2, New York, USA.

Baumol, W.J. (1986): Williamson's The Economic Institutions of Capitalism, Rand Journal of Economics, Vol.17(2), Summer 1986.

Beattie, D. (1986): Key to Prosperity: Science & Technology, Report of the Ministerial working party, December 1986, 129p.

Beck, R. (1981): Competition for Patent Monopolies, Research in Law and Economics, 3, pp 91-110.

Bollard, A.E. (1984): Hands On, Hands Off, or Hand-Outs : Industry Policy For New Zealand, NZ Institute of Economic Research, Discussion Paper No 28.

Bollard, A.E. (1986): The Economics of Exclusion and Collusion : An Economic Interpretation of the 1986 Commerce Act, NZ Institute of Economic Research, Working Paper 86/27.

Bollard, E.G. (1986): Science and Technology in New Zealand: Opportunity for the Future, National Research Advisory Council, Wellington.

Bourgeois, L. (1981): On the Measurement of Organisational Slack, Academy of Management Review, 6 (1).

Bozeman, B. and Link, A.N. (1984): Tax Incentives for R & D: A critical evaluation, Research Policy 13, pp 21-31.

Braunstein, Y.M. and White L.J. (1985): Setting Technical Compatibility Standards: an economic analysis, Antitrust Bulletin, 30(2), Summer 1985, pp 337-355.

Brown, K.M. (1984): The R & D Tax Credit Issues in Tax Policy and Industrial Innovation, American Enterprise Institute for Public Policy Research, Washington D.C.

Bureau of Industry Economics (1986): Programme Evaluation Report 2, Public Support for Research Associations, Australian Government Publishing Service, Canberra.

Burton, J. (1983): Picking Losers? The Political Economy of Industrial Policy, The Institute of Economic Affairs, London. (Hobart Paper 99).

Bushnell, P.G. and Scobie, G.M. (1983): Conduct and Funding of Agricultural Research: Public Policy Issues. Ministry of Agriculture and Fisheries, Economic Division, Discussion Paper 8/83, April 1983, 18p.

Caves, R.E., Crookell, H. and Killing, J.P. (1983): The Imperfect Market for Technology Licenses, Oxford Bull. Econ. Stat., 45(3), August 1983, pp 249-267.

Cheung, S (1978): The Myth of Social Cost, The Institute of Economic Affairs, London, September 1978.

Cheung, S. (1982): Property Rights in Trade Secrets, Economic Inquiry, 20 January, pp 40-53.

Cheung, S. (1983): The Contractual Nature of the Firm, Journal of Law and Economics, 26 (1), pp 1-21.

Clark, I.D. (1985): The Political Economy of Science and Technology, Blackwell.

Coase, R.H. (1960): The Problem of Social Cost, Journal of Law and Economics, v.3, October 1960, pp 1-44.

Collins, E. (1981): Corporation Income Tax Treatment of Investment and Innovation Activities in Six Countries, PRA Research Report 81-1. N.S.F., Washington D.C.

Collins, E. (1982): Tax Policy and Investment in Innovation, N.S.F., Washington D.C.

Coughlin, C. (1984): The Relationship Between Foreign Ownership and Technology Transfer, Journal of Comparative Economics, 7 (4), pp 400-414.

Davidson, Q. and McFetridge, D. (1984): International Technology Transactions and the Theory of the Firm, Journal of Industrial Economics, 22 1, pp 141-162.

Demsetz, H. (1969): Information and Efficiency Another Viewpoint. Journal of Law and Economics, v.12 (1), April 1969, pp 1-22.

Department of Scientific and Industrial Research (1986): New Zealand R & D Expenditure in Relation to G.D.P.

Department of Trade and Industry (1987): Intellectual Property Protection - A Business Perspective. DTI Work Paper.

Dixit, A. (1986): The Cutting Edge of International Technological Competition, Princeton University, June 1986.

Eisner, R., Albert, S.A. and Sullivan, M.A. (1980): The New Incremental Tax Credit for R & D: Incentive or Disincentive? National Tax Journal Vol. 37.

Elger, Frank. E. (1970): The way of Science, New York, Hafner, 145p.

Eveleens, W.M. and Scobie, G.M. (1986): Efficiency and Equity in Agricultural Research, Working Paper in Economics, No. 86/2, Department of Economics, University of Waikato, Hamilton, New Zealand, August 1986.

Finger, N. and Abraham, M. (1985): The Role of Public Intervention in R & D, Managerial and Decision Economics, 6(3).

Fischer, W.A. and Black, G. (1979): Federal Funding of Industrial R & D: Stimulus or Substitute? Research Management, September 1979, pp 27-30.

Fordyce, A.M. (1986): Industrial Levies and Research Funding. Technical Report No.24, Department of Scientific and Industrial Research, Plant Physiology Divison, Palmerston North, New Zealand, February 1986, 26p.

Freebairn, J. and Gannon, C. (1986): Public Support for Industrial Research and Development: Principles of Programme Evaluation, Reversion of paper presented to Bureau of Industry Economics Seminar, Canberra.

Fullerton, D. and Lyon, A.B. (1983): Differential Effects of the Accelerated Cost Recovery System on Investment: A Survey with Implications for Understanding Effects on High Technology Investment, Princeton University, Princeton, USA, October 1983.

Galanter, M. (1981): Justice in Many Rooms: Courts, Private Ordering and Indigenous Law, Journal of Legal Pluralism, No. 19 quoted in Williamson 1983a.

Gannicott, K.G. (1980): Research and Development Incentives in Report of the Committee of Inquiry into Technological Change in Australia, Vol. 4, Canberra, Australian Government, Publishing Service, pp 291-314.

Gilbertson, D. (1987): Experience in the Pricing of Information, Paper presented to the New Zealand Association of Economists Conference, Wellington, New Zealand.

Gilman, J. and A. Siczek (1985): Optimisation of Inventivity, Research Management, 28 (4), pp 29-31.

Griliches, Z. (1958): Research Cost & Social Returns: Hybrid Corn and Related Innovations. Journal of Political Economy, 1958, pp 119-431.

Harper, D. (1987): The Financial Services Industry: Effects of Regulatory Reform, Research Paper 35, N.Z.I.E.R., 1987.

Healey, W.B., Ball, M.E., Mara, M.K. and Tharkurdas, P.A. (1984): Research and Development in the Manufacturing Sector 1983/84, New Zealand Manufacturing Federation, Wellington.

Hirschleifer, J. (1971): The Private and Social Value of Information and the Reward to Inventive Activity, American Economic Review, 61, September.

Jardine, D.V.A. (1986): Funding and Conduct of Research and Development. Theory and it's Application to New Zealand Agriculture: A Transaction Costs Approach. Hamilton, University of Waikato, Unpublished M.Soc.Sc. Thesis, 220p.

Jennings, S. and Cameron, R. (1987): State Owned Enterprise Reform in New Zealand, Ch. 7 in Economic Liberalisation in New Zealand, A. Bollard & R. Buckle (eds), Allen & Unwin, forthcoming 1987.

Johnson, P. (1975): The Economics of Invention and Innovation, Martin Robertson and Co., London.

Joseph, R.A. and Johnston, R. (1985): Market Failure and Government Support for Science and Technology, Economic Theory versus Political Practice, Prometheus, 3 (1), June 1985.

Kamien, M.I. and Schwartz, N.L. (1975): Market Structure and Innovation: A Survey, Journal of Economic Literature, 13, March, pp 1-37.

Kamien, M.I. and Schwartz, N.L. (1982): Market Structure and Innovation. Cambridge, Cambridge University Press, 251p.

Kaplan, R.S., Ijiri, T. and Visscher, M. (1976): Tax Policies for R & D and Technological Innovation, Executive Summary, Carnegie Mellan University, Graduate School of Industrial Administration, Pittsburgh.

Kaufer, E. (1986):The Incentives to Innovate under Alternative Property Rights Assignments with Special Reference to the Patent System, Journal of Institutional and Theoretical Economics, 142, pp 210-226.

Kay, N. (1984): The Nature and Function of the Patent System, Journal of Law and Economics, 20, pp 265-290.

Klein, B., Crawford, R. and Alchian, A. (1978): Vertical Integration, Appropriable Rents and the Competitive Contracting Process, Journal of Law and Economics, 21 (2), pp 297-326.

Lawrence, P. and Lorsch, J. (1967): Differentiation and Integration in Complex Organisations, Administrative Science Quarterly, 12, June, pp 1-47.

Levin, R., Klevorick, A., Wilson, R. and Winter, S. (1984): Survey on R & D Appropriability and Technological Opportunity: Part I, Working Paper, Yale University, July.

Levy, D. (1985): The Transaction Cost Approach to Vertical Integration: An Empirical Examination, Review of Economics and Statistics, 67 (3), pp 438-445.

Levy, D. and Terleckyj, N. (1983): Effects of Government R & D on Private R & D Investment and Productivity: a Macroeconomic Analysis, Bell Journal of Economics, 14(2), Autumn 1983, pp 551-561.

Lichtenberg, F.R. (1984): The Relationship Between Federal Contract R & D and Private R & D, American Economic Review, Papers and Proceedings, May 1984, pp 73-79.

Littlechild, S. (1986): The Incentives to Innovate Under Alternative Property Rights Assignments With Special Reference to the Patent System: Comment, Journal of Institutional and Theoretical Economics, 142, pp 227-229.

Lunn, J. (1985): The Role of Property Rights and Market Power in Appropriating Innovative Output, Journal of Legal Studies, 14 (2), pp 423-433.

·Macdonald, P. and Mitchell, E (1977): Attitudes and Management of Research and Development by New Zealand Business, Economics Directorate, Working Paper No 5.

Magee, S. (1977): Information and Multinational Corporation: An Appropriability Theory of Direct Foreign Investment, in The New International Economic Order: The North-South Debate, J. Bhagwati (ed), MIT Press, Cambridge, Massachusetts.

Mansfield, E. (1981): quoted in How Economists See R & D, Harvard Business Reviews, 59 (61), pp 98-106.

Mansfield, E. (1983): Technological Change and Market Structure: An Empirical Study, Amercian Economic Review, 73(2), May 1983, pp 205-209.

Mansfield, E. (1984): in The R & D Tax Credit Issues in Tax Policy and Industrial Innovation, Brown, K.M.(ed), American Enterprise Institute for Public Policy Research, Washington D.C., pp 31-38

Mansfield, E. and Wagner, S. (1975): Organisational and Strategic Factors Associated with Probabilities of Success in Industrial R & D, Journal of Business, pp 179-198.

Margolis, J. (1983): Public Expenditure and Policy Analysis, Houghton Mifflin Co., Boston, pp 42-56.

Markham, J.W. (1962): Inventive Activity: Government Controls and the Legal Environment in The Rate and Direction of Inventive Activity, N.B.E.R., Princeton University Press, Princeton, California, pp 587-609.

McGee, J (1966): Patent Exploitation: Some Economic and Legal Problems, Journal of Law and Economics, 9, pp 135-162.

Millward, R et al (1983): Public Sector Economics (Surveys in Economics), Longman, London.

Monteverde, K. and Teece, D. (1982): Supplier Switching Costs and Vertical Integration in the Automobile Industry, Bell Journal of Economics, 13 (1), pp 206-213.

Mowery, D.C. (1984): Firm Structure, Government Policy and the Organisation of Industrial Research: Great Britain and the United States, 1900-1950, Business History Review, Industrial Research, pp 505-531.

National Research Advisory Council. (1980): The Report of the Research Evaluation and Review Working Party, Wellington, 19p.

National Research Advisory Council. (1983): Research and Development Assistance to the Private Sector, Wellington, New Zealand, 14 October 1983.

National Research Advisory Council. (1984): Science and Technology Plan, 1984: The First Steps, Wellington, 165p.

National Research Advisory Council. (1985): Science and Technology Plan, 1985: The Challenge of Change, Wellington, 109p.

National Research Advisory Council. (1986a): Appendix to the Journals of the House of Representatives for the Year Ended 31 March 1984.

National Research Advisory Council. (1986b): Report for the Year Ended 31 March, 1986.

Nelson, R. and Langlois, R. (1983): Industrial Innovation Policy: Lessons from American History, Science, 219, pp 814-818.

Nelson, R. and Winter, S. (1982): An Evolutionary Theory of Economic Change, Belknap Press, Harvard University, Cambridge, Massachusetts.

New Zealand Manufacturer's Federation Incorporated (1984): Research and Development in the Manufacturing Sector, Submission to Government. May 1984.

New Zealand Manufacturer's Federation Incorporated (1986): Research and Development in the Manufacturing Sector.

New Zealand Public Service Association (1986): Circular to P.S.A. members in Science and Meteorological Occupation Classes and Regional Secretaries, 25 June 1986, pp 4.

Noll, R. (1977): Government Policy and Technological Innovation: Where Do We Stand and Where Should We Go, in Innovation, Economic Change and Technology Policies, K. Stroetmann (ed), Birkhauser Verlag, Stuttgart.

O'Donnell, D.K. and Troughton, J.H. (1986): Economic and Policy Framework for Science and Technology in New Zealand, D.S.I.R. Discussion Paper No.13, Science Information Publishing Centre, May 1986.

Organisation for Economic Co-operation and Development (O.E.C.D.) (1981): Science and Technology Policy for the 1980's, O.E.C.D., 1981.

Organisation for Economic Co-operation and Development (1985): Science and Technology Policy Outlook, O.E.C.D., 1985.

Organisation for Economic Co-operation and Development (1986): Australia - Reviews of National Science and Technology Policy, O.E.C.D., 1986.

Pakes, A. and Nitzen, S. (1983): Optimum Contracts for Research Personnel, Research Employment, and the Establishment of 'Rival' Enterprises, Journal of Labour Economics, 1 (4), pp 345-365.

Palmer, C.M. (1984): A Guide to Science and Technology in New Zealand, 2nd ed., D.S.I.R. Information Series No. 156, Wellington, New Zealand, 89p.

Pavitt, K. and Walker, W. (1976): Government Policies Towards Industrial Innovation: a Review, Research Policy. 5(1), January 1976, pp 11-97.

Posner, R.A. (1974): Theories of Economic Regulation, Bell Journal of Economics & Management Science, pp 335-358.

Price-Waterhouse (1985): Department of Industry, Technology and Commerce: The Promotion of Indigenous IR & D in Australia and the Effectiveness of the Industrial Research and Development Incentives Scheme, Main Report, Vol. 1.

Priest, G. (1977): Cartels and Patent License Arrangements, Journal of Law and Economics, 20, pp 309-377.

Probine, M.C. (1984): Report on Science and Technology Policy Formation, Cabinet Committee of the States Services: SS(84) M2, Part 1 of 1, February 1984.

Puri, K. (1983b): Fair Dealing with Copyright Material in Australia and New Zealand, Victoria University Law Review, 13, pp 277-298.

Puri, K. (1983a): Design Protection in Australia, Victoria University Law Review, 15, pp 171-191.

Puri, K. (1985): Writers and the Law of Copyright, Victoria University Law Review, 15, pp 93-99.

Rees, R. (1985a): The Theory of Principal and Agent: Part I, Bulletin of Economic Research, 37 (1), pp 3-26.

Rees, R. (1985b): The Theory of Principal and Agent: Part II, Bulleitn of Economic Research, 37 (2), pp 75-95.

Rogers, E. (1982): Information Exchange and Technological Innovation, in The Transfer and Utilisation of Technical Knowledge, D. Sahal (ed), Lexington Books, Massachusetts.

Ronayne, J. (1984): Science Government, Edward Arnold (Publishers) Limited, Australia.

Rothwell, R. and Zegveld, W. (1981): Industrial Innovation and Public Policy: Preparing for the 1980's and the 1990's, Francis Printer, London, 251p.

Scherer, F. (1966): Research and Development Resource Allocation Under Rivalry, Quarterly Journal of Economics, 81, pp 359-394.

Scherer, F. (1972): Government Research and Development Programs, in Measuring Benefits of Government Investments, Robert Dorfman, (ed), Washington D.C., Brookings Institution, pp 429.

Scherer, F. (1977): Antitrust and Patent Policies, in Innovation, Economic Change and Technology Policies, K. Stroetmann (ed), Birkhauser Verlag, Stuttgart.

Scherer, F. (1980): Industrial Market Structure and Economic Performance, 2nd ed., Rand McNally, Chicago.

Schmid, A. (1985): Intellectual Property Rights in Biotechnology and Computer Technology, Journal of Institutional and Theoretical Economics, 141, pp 127-261.

Schumpeter, J.A. (1976): Capitalism, Socialism and Democracy, 4th ed., London, George Allen and Unwin, 437p.

Science and Technology for Development (1985): Conference Report of Development, Conference held in Wellington, 7-9 May 1985.

Scobie, G.M. (1985): On Closing the Technological Frontier, Paper presented at the Annual Conference of the Australian Agricultural Economics Society (New Zealand branch), Picton, July 1985.

Shapley, William H. (1972): Comments on Scherer (1972). In Measuring Benefits of Government Investments, Robert Dorfman, (ed), Washington D.C., Brookings Institution, pp 429.

Spencer, B.J. and Brander, J.A. (1983): International R & D Rivalry and Industrial Strategy, Rev. Economic Structure, October 1983, 50(4), pp 707-722.

State Services Commission (1986): The Promotion System of Employees in the Science, Science Technician and Meteorological Occupational Classes. Circular to Government Departments, pp 12.

Stigler, G.J. (1974): Free Riders and Collective Action. An Appendix to Theories of Economic Regulation. Bell Journal of Economics and Management Science v.5(2), Autumn 1974, pp 359-365.

Teece, D. (1977): Technological Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-how, Economic Journal, 83 (346), pp 242-261.

Teece, D. (1981): The Market for Know-how and the Efficient International Transfer of Technology, Annals of the Academy of Political Science, November, pp 81-95.

Teece, D. (1982a): Towards an Economic Theory of the Multiproduct Firm, Journal of Economic Behaviour and Organisation, 3, pp 39-63.

Teece, D. (1982b): Some Efficiency Properties of the Modern Corporation: Theory and Evidence, (draft paper).

Teece, D. (1986): Firm Boundaries, Technological Innovation and Strategic Management, in The Economics of Strategic Planning, Lacy G. Thomas, (ed),

Tisdell, C. (1972): Microeconomics - the theory of economic allocation, John Wiley and Sons, Auckland, New Zealand.

Tisdell, C. (1981): Science and Technology Policy: Priorities for Governments, Chapman and Hall, London.

Tisdell, C. (1985): Conceptual Issues in the Measurement of Economic and Productive Efficiencies, South African Journal of Economics, 53 (1), pp 55-66.

Tisdell, C. (1986a): Transaction Costs/Property Rights and Market Failure in Relation to Science and Technology Policy, Working Paper 86/32, N.Z.I.E.R.

Tisdell, C. (1986b): International Scientific Co-operation Technology Transfer and Aid: Asean Countries, Australia and New Zealand, Prometheus, 4 (1), June 1986.

Toumanoff, P.G. (1984): A Positive Analysis of the Theory of Market Failure. Kyklos. 37(4), pp 529-541.

Williamson, O. (1975): Markets and Hierarchies: Analysis and Antitrust Implications, Free Press, New York.

Williamson, O. (1979): Transaction Cost Economics: The Governance of Contractual Relations, Journal of Law and Economics, 22, pp 233-261.

Williamson, O. (1983a): Credible Commitments: Using Hostages to Support Exchange," American Economic Review, 73 (4), pp 519-540.

Williamson, O. (1983b): Organisational Form, Residual Claimants, and Corporate Control, Journal of Law and Economics, 16, June, pp 351-366.

Williamson, O. (1984): The Incentive Limits of Firms: A Comparative Institutional Assessment of Bureaucracy, Weltwirtschaftliches Archiv, 120 (4), pp 736-763.

Williamson, O. (1985): Vertical Integration and Related Variations on a Transaction-Cost Economics Theme, in New Developments in the Analysis of Market Structuring, J. Stiglitz and F. Mathewson (eds), MIT Press, Cambridge, Massachusetts.

Williamson, O. (1985a): The Economic Institutions of Capitalism - Firms, Markets, Relational Contracting, The Free Press (MacMillan, Incorporated), New York, 1st ed., 1985.

Williamson, O. (1986a): The Economic Institutions of Capitalism, Free Press, New York, 2nd ed., 1986.

Williamson, O. (1986b): Vertical Integration, Working Paper Series D (Economics of Organisation), No. 19, Yale University.

Williamson, O. (1986c): Economic Organisation - Firms, Markets and Policy Control, Wheatsheaf Books Limited, Harvest Press Publishing Group, Brighton, Sussex, pp 83-163.

Winter, S., et al (1984): Survey Research on R & D Appropriability and Technological Opportunity, Part I: Appropriability, Yale University, July 1984.

Wolf, C. Jr (1983): A Theory of Non-market Failures in Public Expenditure and Policy Analysis, Haverman R.H. and Margolis, J. (eds), Houghton Mifflin Company, Boston, 3rd ed., pp 515-535.

Wolff, S.T. (1983): How Federal Actions Impact Private Sector Innovation, Research Management, May/June 1983.

Yu, B. (1981): Potential Competition and Contracting in Innovation, Journal of Law and Economics, 24 (2), pp 215-238.

NZIER