Knowledge spillovers, location and growth: theory and evidence*

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Melbourne Institute Working Paper No. 6/97

May 1997

ISSN 1328-4991

ISBN 0 85833 173 X

*This paper is the result of work being undertaken under the banner of the IBIS Collaborative Program in Enterprise Dynamics, a research program bringing together the resources of the Melbourne Institute and IBIS Business Information Pty Ltd and funded by the Victorian Department of State Development and the ARC Collaborative Research Grants Program. The authors are grateful for helpful advice received from Peter Dawkins, Peter Kenyon and Mark Rogers. Any errors are the responsibility of the authors.

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1. Introduction

This paper presents an overview of the issues that are being investigated as part of the Melbourne Institute's Collaborative Research Program in Enterprise Dynamics. The Program brings together the resources of the Melbourne Institute and IBIS Business Information Pty. Ltd., and is sponsored by the Victorian Department of State Development and the Australian Research Council. The Program is chartered to investigate the causes and nature of economic growth at both the industry and aggregate levels.

Issues such as how R&D, market structure, knowledge spillovers and locational clustering affect economic growth have featured prominently in the economic literature for some time. Today, the literature in these areas is growing rather than petering out. In this paper, this literature is reviewed, and some policy issues are examined.

2. Growth and Spillovers

2.a. Growth Theories Old and New

After nearly twenty years of relative neglect, the causes and consequences of long run economic growth are again featuring prominently in the economic literature. Traditional theories have sought to explain growth as a process of (physical) capital accumulation over time, where a given technology takes capital and labour and produces final outputs. By reinvesting some of the output, the stock of capital increases, leading to growth in output per capita. Observed growth over and above that attributable to observed inputs of capital and labour is then attributed to exogenous changes in the technology, ie. changes in the rate at which capital and labour transform material inputs into the final outputs. Hence the "unaccounted for" growth is termed a residual—often referred to as a "Solow residual", in tribute to the seminal figure in neoclassical growth theory, Nobel Laureate Robert Solow—and taken as a proxy for the degree of disembodied technical change in the economy over the period under study. Solow's estimation of his residual led him to conclude that most of the observed growth in the United States economy came from technical change (interpreted broadly).

This emphasis on technical change fits well the contemporary neoclassical paradigm. In standard neoclassical growth models *without* technical change, diminishing returns to capital lead eventually to per capita output converging to a steady state. This is the same as saying per capita growth tends to zero. Only with ongoing technical advance can there be ongoing growth.

Growth theory has been revitalised in the 1980s and 1990s by an emphasis on modelling that which had previously been regarded as exogenous—the technical change that explains ongoing growth. The key insight brought into a growth-theoretic context, originally by Paul Romer, is a standard one in the R&D and innovation literature: that of innovative activity as a public good. (This can alternatively be expressed as the existence of positive externalities associated with capital accumulation.)

The role of technological change in this new generation of growth models is not confined to the benefits that accrue to the developer of the idea. The concept of *knowledge spillovers*, the (involuntary and uncompensated) transfer of ideas or techniques, becomes important in these models because (i) innovation is explicitly modelled as a source of growth, and (ii) there is an under-investment in innovation due to the lack of compensation for the wider use of the idea. In these models, externalities act as a source of increasing returns, and growth can be enhanced by innovation-inducing policy actions.

An example of a knowledge spillover occurs where R&D undertaken by one firm benefits other firms in the same industry and firms in other industries. While the direct use of a particular firm's R&D is limited by patents, the indirect use of this knowledge is unlimited in other applications. According to Petit and Tolwinski (1996, page 78): “Empirical studies have shown that patents are generally ineffective in preventing knowledge spillovers and, normally, rival firms learn about technical characteristics of new products and processes within 12 months of their introduction.”

Such spillover effects can be extended to all types of capital accumulation, both human and physical, but fundamentally involve the transfer of ideas in some sense. Mankiw (1995) makes a distinction between *knowledge* (which can be regarded as the textbooks available to a society) and *human capital* (the investment in time and training needed to read and comprehend the knowledge available in the texts). In the BIE study of spillovers (BIE, 1994), the authors draw a similar distinction between spillovers of *knowledge* and of *know-how*, where knowledge is the "information that is codifiable and therefore able to be passed on to others in systematic, including written, form. Know-how, as the name suggests, refers to the *application* of knowledge and learning—the 'how to' of technology. Know-how is often very specific in nature since it represents the accumulation of 'learning-by-doing' skills" (BIE, 1994, page 9).

Paul Romer, the pioneer of the modern literature in which spillovers are used to explain growth, discusses R&D as having a two-fold effect (see Romer, 1990).[1] The first effect is a direct one, whereby the R&D leads to a "blueprint" for a new product, the benefits of which can be appropriated (as monopoly rents or quasi-rents) by the inventing firm. The second, indirect effect is the "spillover," whereby new information enters and increases the current stock of knowledge; this is information that can be freely used by others. This contribution to the stock of knowledge may take the form of (for example) scientific properties of different materials, chemical formulas, or aspects of new computer algorithms. This stock of knowledge can be drawn on without any compensation being provided to the originator of the idea.[2]

In contrast to standard endogenous growth theory, Langlois and Robertson (1996) are critical of what they argue is a mechanistic view of (a) how—and why—R&D is conducted, and (b) how spillovers occur. They argue, in line with earlier work by Nelson and Winter (1982), that the idea of knowledge as a clearly defined "free gift" is misleading: that in fact knowledge is often "sticky" due to difficulties in clearly defining what the knowledge is (what they call its tacit character), or to transactions costs of communicating it, or even to costs of either persuading others, or of being persuaded, of the worth and applicability of the knowledge. An

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[1] The papers by Arrow (1962a, b) are early examples of an economist examining the consequences of spillover effects.

[2] Surveys of issues and models in the endogenous growth literature are contained in BIE (1992); the volumes by Grossman and Helpman (1991) and Barro and Sala-i-Martin (1995); the Symposium in the *Journal of Economic Perspectives* 8(1) 1994; Mankiw, 1995; and the recent special issue of the *Journal of Economic Dynamics and Control* 1997: see for example the introductory paper by Jones and Manuelli.

extension of this view is that firms must develop (invest in) absorptive capacity with respect to knowledge. Acquiring new knowledge thus uses up resources and is not a free gift. Moreover, another limitation of the conventional literature is that as far as R&D itself goes, New Growth Theorists "explicitly model the production of technological change in terms of rational optimisation" (Langlois and Robertson, 1996, page 3).

These are not new arguments. Both the "rationality" of the R&D decisions made by companies, in the sense of being consistent with profit maximisation in some risk-adjusted sense, and the nature of spillovers, have been questioned by a number of authors in the innovation literature for some time.

For example, in his study of innovation in 45 Australian companies during the 1960s, Stubbs (1968, pages 116, 127) states: "Ideally, top management should be responsible for policy towards innovation...taken after a complete and systematic investigation of all the likely possibilities...(however) relatively few companies were really systematic in their appraisal of all possibilities open to them...Many companies are 'takers' of information rather than systematic seekers of it."

More recently, the study on "Understanding the Benefits to R&D," prepared for AusIndustry (CSES/SIRF, 1996, page 2) has argued that the conventional view of R&D, that firms "invest in projects up to the point at which the cost of the additional project, including the cost of capital, is equal to the expected benefits to them from that project" is flawed. According to this view, any government subsidy to R&D will bring forth projects which, while being socially profitable, would be privately unprofitable without the subsidy. They argue that in fact most firms are constrained in their R&D, such that "virtually no firms see themselves as able to invest in R&D projects to the point at which the expected risk adjusted return on the additional project is equal to the cost of the project." The constraints are argued to arise from some combination of finance constraints and/or "short-termism" at senior levels of the company. (See the further discussion of this report in Section 4a of this paper.)

Nelson and Phelps (1966) provide an early example of a discussion of the "absorptive capacity" issue, and this theme has been taken up by more recent authors such as Cohen and

Levinthal (1989). As explained by De Bondt (1996, page 2), "the challenge for firms may not always be to be among the first to produce the new information, but may instead be how to recognise, obtain, employ and complement the relevant innovative information. The real challenge for firms and economies may be to recognise the resources that are necessary for the appropriate organisation of innovative information activities: entrepreneurial talents, appropriate industrial and firm organisations and appropriate organisations of transfer and diffusion of technology, and of education and science activities."

2.b. Innovation and The Sources of "Market Failure"

Elsewhere (Harris and Kells, 1997, Chapter 1) the authors distinguished between "compensated" and "uncompensated" transfers of ideas, labelling the latter "knowledge spillovers" after the convention in the literature. It is an open question which of these is the most important empirically. However, the literature has focussed heavily on the idea that (uncompensated) spillovers are prevalent, and, thus, a policy issue of some importance due to the resulting market failure. "Spillovers arising from industrial R&D occur when the actions of an innovating firm affect any other party either positively (and this effect is not paid for) or negatively (and this effect is not compensated for). Spillovers are of interest to governments because their existence represents the strongest justification for subsidisation of private industrial R&D" (BIE, 1994, page vii.) In this section, we spell out the characteristics of spillovers and their market-failure implications.

The concepts of "public goods" and "externalities" in textbook economics, both of which feature in any discussion of innovation, derive from two key properties: non-rivalry and non-excludability.

A good idea is *non-rival* in use: party A's use of the idea does not diminish the amount of the good idea left for party B to use (even if it may diminish the *economic benefit* to party B from using it). Romer's argument was that investment in innovation leads to spillovers of good ideas from the source of the innovation to other potential users of the idea; that is, there are positive externalities to innovative activity which, at an economy-wide level, promote economic growth. Furthermore, this "endogenous growth" theory raises the possibility of growth-enhancing government policies which did not arise from the traditional version of growth theory.

In fact, if the non-rival nature of new ideas is combined with *non-excludability* (an inability to appropriate all the benefits of the innovation—noting the fact that it is excludability which implies the potential for commercial exploitation), writers in the literature on R&D argue that there is a serious possibility of under-investment in R&D without government intervention. In the production of agricultural commodities, for example, there is an extensive literature (surveyed in Harris and Lloyd, 1991) on the under-investment hypothesis in agricultural R&D, which includes evidence of high social rates of return on the R&D that *is* done, predominantly in the public sector.

Non-rivalry is a *technical* condition of the good in question—consumption either diminishes the quantity available or it doesn't—while non-excludability is in part technical, in part institutional. The ability to appropriate benefits from an innovation depends on the legal framework just as it does on the technical ability to exclude non-payers. In policy formulation, there is an ongoing tension between the two "market failure" implications of non-rivalry: the optimal solution being that consumption or dissemination should be allowed at zero price, but the longer run dilemma is how to provide incentives for further investment in production of the non-rival good in question. Non-excludability often then features as one of the means by which the incentive issue is dealt with: patents, trademarks and copyrights are some of the legal means by which excludability can be enhanced, although as noted above, this is at the expense of the first-best solution of zero price dissemination. A recent paper analysing the trade-off between increasing innovation as opposed to increasing *welfare* is by Horowitz and Lai (1996).[3]

The tension between theoretical ideals and practical possibilities is also reflected in a tension within the literature, as exemplified by the debate between authors concerned with departures

[3] Economists have looked at the possible implications of enhancing excludability, that is, defining and enforcing intellectual property. Not only is there a tension between first-best policy and the use of property rights with a non-rival good, but the literature on patent races etc. suggests that firms can *over*-invest resources in R&D as they try to beat others to the prize, which in this case involves the right to earn monopoly rents. See the discussion of patent races in, for example,

from theoretical first-best conditions (Arrow, 1962a, b)—viewed as a divergence between private and social rates of return, in the Pigovian tradition—and authors more interested in "comparative institutional analysis" in the Coasian tradition (Demsetz, 1969)—that is, what outcomes different feasible institutional arrangements will generate. (A not unrelated tension is evident in the growth literature itself, with the dominant tradition emphasising the technical conditions for growth, as embodied in the specification of the production function, and another body of literature focussing on the *institutional* preconditions for growth. In the latter, technological possibilities are only the beginning of the growth story. See Weder and Grubel, 1993, Pack, 1994 and Langlois and Robertson, 1996, as well as the overview in Mankiw, 1995.)

With all this in mind, the public policy aspects surrounding issues of innovation are complex, and depend on the objectives being sought and the interpretations placed upon the literature and the evidence. Before turning to a discussion of policy issues, we review the issues of market structure and industry location as they relate to innovation, and then review the evidence on returns to innovations and the extent of knowledge spillovers.

3. Location, Market Structure and Spillovers

3.a. The Importance of Market Structure

The relationship between market structure and innovation is of longstanding historical concern in the literature. In the following subsections we present arguments about how market structure may interact with firm/industry location to influence innovation and spillovers: various hypotheses about location and spillovers make different assumptions about the role of market structure, and the recent literature has thus been concerned with testing between these alternative views.

More generally, the idea that market structure (the "degree of competition" in an industry) is an important determinant of the extent of innovation in an industry goes back as far as Schumpeter (1942), who postulated that larger companies would be more active innovators. This has been the subject of rather extensive investigation (see, for example, the survey by

Tirole (1988). Also, see the discussion by Tisdell in Dowrick (1995). This and other policy issues

Kamien and Schwartz, 1982). Meanwhile, the management literature, such as the work on competitive advantage by Michael Porter (Porter 1990), has tended to endorse the counter-proposition that it is competitive pressure, rather than the luxury of profit margins and market power, that constitutes the major spur to companies to continually innovate. While very small firms are unlikely to have the resources to be especially innovative, one basic assumption of innovation theory in the management literature is that "once an organisation increases its size beyond a critical mass, it becomes more inert, less capable of meaningful organisational change, and only haltingly proficient at innovation" (Drazin and Schoonhoven, 1996, page 1066).

In a recent paper, Symeonadis (1996) surveys the theory and evidence surrounding a proposition associated with Schumpeter: that increases in firm size and/or industry concentration are positively associated with a firm's R&D. Symeonadis argues (page 3) that the main reasons for presuming such a relationship in each case are as follows:

1. Innovation & firm size:
1.1. R&D projects typically involve large fixed costs, and these can only be covered if sales are sufficiently large.
1.2. There are scale and scope economies in the production of innovations.
1.3. Large diversified firms are better placed to exploit unforeseen innovations.
1.4. Large firms can undertake many projects at a time and thus spread R&D risks.
1.5. Large firms have better access to external finance.
2. Innovation & market structure:
2.1. Firms with greater market power are better able to finance R&D from their own profits.
2.2. Firms with greater market power can more easily appropriate the returns from innovation.

will be discussed later in this paper.

The basic conclusion arising from the empirical evidence is mixed: there is no clear cut evidence of a strong correlation between size and innovative activity. There are fundamental conceptual problems in undertaking these studies: the data are usually limited and biased; and the causation is questionable in that correlations between firms size and innovation are likely to go both ways. Also, the empirical work sheds no light on what specific mechanism (if any) provides the link between firm size and innovation.

Stubbs' (1968, Chapter 5) early study on innovation in Australia examined the empirical connections between various financial measures of firm size for his sample of 45 firms, and proxy measures of their research effort (such as the proportion of research-qualified personnel), finding little or no correlation. He makes the point that in a smaller and more open economy like Australia's, there may be less emphasis on internal idea generation than in large companies in more closed economies.

The formal literature in industrial organisation has examined the question of innovation under varying market structures: the conclusions, and the welfare economics implications, are complex. Market structure may be endogenous to technological possibilities, and it is not clear whether increased market concentration is an issue of policy concern in a welfare economic sense. These issues are discussed in more detail in Tisdell (1995).[4]

3.b. Location and Innovation

The project for which this paper serves as background is particularly oriented towards the interaction between location and innovation/knowledge spillovers. In fact, much of the discussion of locational issues in the economic literature derives from issues of external effects. For example, a standard, static approach to theorising location from an economic point of view would be to view a city as being the result of residents, including industrial residents, trading off agglomeration economies (access to products, services, information) with congestion diseconomies (pollution, noise, other disamenities). The idea of knowledge spillovers leading to locational externalities goes back at least to Marshall (1890). The idea is

[4] Readers should note that many endogenous growth models tend to *assume* imperfect competition (arising for example from product diversity); see page 26, BIE (1992). These models assume imperfect competition, they do not test for it.

simple: spillovers occur more easily due to geographical proximity, in that ideas travel more quickly and easily over shorter distances.[5]

Obviously, knowledge spillovers are not the only possible form of agglomeration economies. Access to input suppliers, a labour force, or final customers, may all be subject to agglomeration economies, and hence play a role in influencing location decisions. (See Harrington and Warf, 1995; McDermott and Taylor, 1982; Fujita and Thisse, 1996.)

It should be noted that there is an older tradition in the area of urban concentration and innovative activity, some of which is documented in Bairoch (1988). Studies from the 1960s of American urbanisation and technological innovation cited by Bairoch include that of Pred (1966) who found a distinct concentration of patenting (measured by patents per capita) in large cities in the late 19th and early 20th centuries; and Higgs (1971) who noted a close and significant relationship between the level of urbanisation and the number of patents pending.[6] After discussing other studies, Bairoch (p. 325) states "Empirical analysis, then, fully confirms the predictions suggested by deductive reasoning, which has in just about every case assigned the city a leading role in technological invention." Bairoch also discusses the issue of particular relevance to a discussion of spillovers: the role of the city in the diffusion of innovations. As he states, the notion that innovations will diffuse more rapidly and widely in an urbanised context seems so self-evident that there is very little empirical work on this actual question.

However, in terms of spillovers, the question of concern is less about the difference between diffusion in urban versus rural areas, and more about the role(s) of the twin pillars of industry concentration and market structure in facilitating growth in and between cities. The hypotheses recently tested in the economic literature involve static and dynamic externalities—spillovers—which may be intra-industry or inter-industry in nature. These externalities are (it is then argued) key determinants of where industries choose to put themselves. In the static view, externalities, such as immediate information spillovers about

[5] Of course this "common sense" view of the importance of distance has become increasingly less relevant with the proliferation of electronic communication.

[6] Jaffe, Trajtenberg, Henderson (1993) on patents and geographic diffusion is a more recent example which will be discussed later in this paper.

current market conditions, influence location choices, where firms trade off agglomeration benefits with congestion costs. In the more dynamic view, these location choices then feed back into growth and city development through time. That is, longer term interactions and spillovers improve current productivity and foster growth. This is the subject of the next section.

3.c. Location, Spillovers and Growth

With the increased recent interest in the role of innovation and spillovers as a primary engine of economic growth, there has been a related increase in the economics literature in studies of city *growth* and industry location. The motivation of this literature is that cities provide fairly natural "laboratories" for empirical assessment of some of the "new growth theory" propositions.

The important distinction introduced in the literature examined in this section is that the theories tested here—of *dynamic* externalities—have implications not only for industry patterns within cities (eg. of specialisation) along the lines of Henderson (1988), but also for city *growth*: that is, which cities or regions would we expect to see growing faster than others.

As summarised in Glaeser, Kallal, Scheinkman and Shleifer (1992), we can summarise the different views on what drives locational choice and innovation using the following classifications.

3.c.1. Intra-Industry Spillovers

These are known otherwise as *localisation economies* (that is, an agglomeration economy in which firms within an industry cluster together). At its most visible, this behaviour is evidenced in the formation of industrial districts. Such industrial districts of linked firms, often quite small, have arisen organically in Europe, notably in northern Italy. A discussion of industrial districts, predominantly European, is presented in Pyke and Sengenberger (1992).

More recently, we have seen the formation of a particular form of high-technology industrial district, sometimes referred to as a "technopolis" (see Preer, 1992). The most obvious example is the cluster in Northern California known as Silicon Valley. (The interesting question is why there is a cluster in the very industry in which one might expect that the technical level of the industry would make location irrelevant. This does suggest, among other things, the importance of personal contact, a theme taken up in Gaspar and Glaeser, 1996.)

In fact, Silicon Valley is only one of a number of "technopolises". Preer (1992) documents various high-technology clusters in the United States with differing core industries: semiconductors and microcomputers in Silicon Valley; minicomputers in Massachusetts (Route 128); supercomputers in Minneapolis-St. Paul; aerospace and electronics in Orange County; biotechnology in Salt Lake City; and microelectronics in the Research Triangle (North Carolina).

Glaeser et al. describe two main hypotheses to explain why firms within an industry might choose to locate together. Both involve spillover effects between the firms within the industry: that is, the transfer of ideas and techniques within the geographic cluster.

- The first is the **Marshall-Arrow-Romer (MAR)** externality, whereby knowledge spillovers between like firms are encouraged by proximity, and these knowledge spillovers in turn promote economic growth (see Marshall 1890, Arrow 1962, and Romer 1986). Implicit in this (according to Glaeser et al.) is a view consistent with Schumpeter, that increased monopoly power within the industry increases innovative activity (as more of the benefits from innovation can be appropriated by the innovator) and therefore acts as a stimulus to growth. (This will be discussed further in Section 3c.)[7]

- The second is the **Porter** externality, after Porter (1990), which is similar to the MAR in positing increased spillovers as a result of proximity, but different in regarding competitive pressure within an industry as a spur rather than a hindrance to innovative

[7] There is a curious potential internal inconsistency in the MAR case (where market power is assumed). What is the connection between *enhanced appropriability* resulting from market power (therefore increasing innovation), and *spillovers* (which lead to market failure in innovation by reducing appropriability)? What kind of trade-offs, if any, exist between innovation resulting from appropriability, and the spillovers we are interested in seeing? In Glaeser et al. (1992, p.1127), they say that "local monopoly restricts the flow of ideas to others and so allows externalities to be internalised by the innovator. When externalities are internalised, innovation and growth speed up." But by internalising the externalities, is not the scope for growth-enhancing knowledge spillovers then reduced? This may not be the case if we presume the spillovers occur at a broader level than the specific "blueprint" which the inventing company can legally protect and appropriate the direct benefits of.

activity (or to *adoption* of innovations), so that increased competition within a localised industry, rather than increased monopoly power, will result in greater growth.

The difference between the Schumpeterian and Porterian views of the incentives to innovate hinge on market structure, although there may be several different dimensions to how this distinction actually operates, as discussed in the previous section. While there are various arguments as to why imperfect competition might lead to greater R&D expenditure, the Porter view, by contrast, seems to embody an implicit assumption that the incentives for managers to innovate are greatest when the competitive pressures on them are greatest; that a less competitive environment provides a temptation for the managerial "easy life", whereas firms facing competitive pressures must continually innovate or go under. Neither view is inconsistent with the picture of firm innovation as rent-seeking behaviour, ie. firms attempting to appropriate monopoly quasi-rents by successfully innovating. But if Porter is correct, then it is the pressure of competition that leads managers to act more like textbook profit maximisers.

3.c.2. Inter-Industry Spillovers

Here there is one key hypothesis, according to Glaeser et al., sometimes referred to as *urbanisation economies*.

- The key notion here is labelled a **Jacobs** externality, after Jacobs (1969, 1985), who argued that the important spillovers come from outside rather than inside the core industry. In this view, there is a build-up of knowledge arising from industrial *diversity* rather than from industrial clustering.

This is basically a hypothesis about cross-fertilisation: location and growth are determined by the movement of ideas, techniques and tools into new and different applications or end-uses.

A simple taxonomy of the externality types can be represented as in the following table, where the horizontal axis shows the industry structure, while the vertical axis shows the industrial characteristics of the geographic locale of the firm benefiting from the externality.

	COMPETITIVE INDUSTRY	MONOPOLISTIC INDUSTRY
INDUSTRY CLUSTER	*Porter*	*MAR*
DIVERSE INDUSTRIAL BASE	*Jacobs*	–

In the case of industry clusters, spillovers are argued to result from transference of "in-house" R&D, and human capital/skills of local labour. The transference may be deliberate/cooperative in that the firms involved allow or invite it, or incidental (external). Glaeser et al. talk of "spying, imitation, and rapid inter-firm movement of highly skilled labour" as leading to the dissemination of ideas across similar firms.

Examples of the alternative (Jacobs) view—that spillovers arise from the adaptation of ideas from one industry setting to another, or that specific needs of an industry will lead to the development of a new local industry to meet those needs—are also provided in Glaeser et al., such as the financial services industry arising to service the grain and cotton merchants who wanted to make national and international transactions. In the Australian context, Stubbs (1968, page 117) states: "Some industries obviously contribute much more to innovation in other industries than they receive as feedback for innovation. One of the most obvious cases is the chemical industry...Both the chemical companies in the survey were mentioned by the other companies as having had important influences on their innovations, illustrating Williams'[8] 'gate effect', by which the innovations of one industry open the door to innovations in other industries, which may in turn kindle further innovations elsewhere."

It should be recognised that these theories of the dynamic effects of spillovers are not theories of how given industrial regions become established in the first place (as discussed in, say, chapter 9 of Chapman and Walker 1991). Rather, the MAR/Porter/Jacobs theories as

[8] The reference in Stubbs is to a paper presented to the ANZAAS Congress in Sydney in 1962, by B. R. Williams entitled "The Conditions of Industrial Innovation".

presented above provide hypotheses about the nature of the industry base we would expect to see (diversified or concentrated), and which type of industrial base is likely to grow faster.[9]

4. Empirical Work

To date, much of the empirical work in the economic growth literature has been concerned with the issue of "convergence" as a test of the neoclassical versus the new growth models; that is, with attempting to determine whether there are decreasing or increasing returns at the aggregate level. (See, for example, the treatments in Barro and Sala-i-Martin, 1995 and Mankiw, 1995; it is not clear how well empirical analyses of convergence actually discriminate between the two hypotheses; on this, see Kocherlakota and Yi, 1995, and Leung and Quah, 1996.)

4.a. Evidence on Spillovers

At a more disaggregated level, there is a substantial literature in which authors test for spillovers by examining private and social returns to innovation. These studies are in two broad categories (Griliches, 1992; Harris and Lloyd, 1991): those that focus on particular innovations (the "surplus" approach), and those that analyse aggregate productivity change with respect to some index of R&D inputs or expenditures (the "regression analysis" approach). While the former method, in principle, allows the calculation of the extent of specific spillovers, it restricts its focus to "successful" inventions or improvements. The latter method involves the derivation of a return to overall R&D effort: thus it indicates whether spillovers exist in the aggregate as well as for specific innovations.

In principle, the regression method can also provide measures of *marginal* returns to innovation, while the surplus method only produces returns on the average dollar of expenditure (Harris and Lloyd, 1991). However, the measures of output and R&D "capital" used in these studies can be problematic (Griliches, 1992). A more recent trend in spillover studies involves using patent data to develop measures of the "direction" of spillovers, where direction may mean either industrial or geographic "distance" from the origin. Jaffe,

[9] Related papers on agglomeration effects include those by Puga and Venables (1996) on spatial agglomeration, and Rauch (1993) on the connection between agglomeration effects, the costs of moving and the link with "history dependence" in industry location.

Trajtenberg and Henderson (1993) is an example of a study examining the issue in geographical terms.

Griliches (1992, p. S43) summarises his overview by saying "In spite of all these difficulties, there has been a significant number of reasonably well done studies all pointing in the same direction: R&D spillovers are present, their magnitude may be quite large, and social rates of return remain significantly above private rates." This is similar to the conclusion reached in Harris and Lloyd (1991) regarding the returns to agricultural research.

A set of recent studies that has gained attention is that of Caballero and Lyons (1989, 1990, 1991, 1992), who investigated empirically the existence of external economies for both US and European manufacturing. They find that returns to scale are consistently greater at an aggregate level than they are at a disaggregated level—the two and four digit level for the USA and the two digit level for Europe (West Germany, France, UK and Belgium). They find constant returns at the disaggregated level, but increasing returns at the aggregate level. This they attribute to the presence of a social externality, the prime source of which is the increased ease of matching between relevant agents as the aggregate industry expands. The externality, they argue, is primarily driven by the relation between an industry and its customers in the short run, and by the relation between an industry and its suppliers in the long run. However, they do not rule out the possible presence of traditional Marshallian technological externalities ("trade knowledge" as per Marshall, 1920) which we are describing here as knowledge spillovers. (Oulton and O'Mahoney, 1994 produce rather more modest estimates.)[10]

The Bureau of Industry Economics (1994) has conducted a series of innovation-specific case studies looking at the spillover issue. Of the sixteen innovations they examined, only three were regarded as having high technological spillover value. Eleven had low spillover value, and two very low value. When examining the value of aggregated consumers' surplus plus any broader community benefit (such as a health or environmental improvement), the aggregate value of any potential spillovers was assessed as: five moderate, ten low, and one very low.

[10] Geroski (1995) and Griliches (1992) both discuss the issue of the level of aggregation at which spillovers are looked for.

Another recent report on innovation in Australia was undertaken for AusIndustry by the Centre for Strategic Economic Studies at Victoria University of Technology and the Strategic Industry Research Foundation (CSES/SIRF 1996). The value-added in the report comes primarily from discussions with 29 companies (the questionnaire around which these discussions were framed is included in the back of the report).

Regarding the benefits of R&D, the authors of the study came to four main conclusions:

- There are substantial net private benefits to the firm from conducting R&D. Moreover, they say virtually all firms surveyed regarded themselves as constrained from doing potentially profitable R&D. That is, even *privately* profitable R&D opportunities are foregone (whereas in the literature, all privately profitable R&D opportunities—where the risk adjusted rate of return to the marginal project equals the cost of the project—get taken up while further *socially* profitable R&D opportunities may be foregone due to inappropriability). One of the key constraints was perceived to be lack of funds.

- Networks (with customers and clients, and more generally within the industry) and spillovers are important. At the strategic level, innovation is primarily about maintaining or increasing market share, generally via improving product quality or extending the product range. There is less emphasis on reducing costs or creating entirely new products.

- There are broader, less tangible benefits to R&D, other than the immediate problem-solving or product-improving task itself, which can accrue to the firm and to the economy more broadly. There is an increased capacity to absorb and/or disseminate new ideas and technologies, recruit and maintain high quality staff, and so on. (See their Figure 3, page 7 of the Summary Report.)

- They argue that higher export-oriented R&D relaxes the "balance of payments constraint" surrounding national economic growth and thus provides an indirect national benefit (by raising the "growth ceiling").

They contrast their analysis with the recent studies by the Industry Commission and the BIE, which (they claim) assume that all privately profitable projects will be taken up by firms. They further distinguish their analysis by arguing that the aforementioned studies treat spillovers as sporadic episodes of market failure, rather than as a fundamental element of innovative activity. Finally, their assumption of a BOP constraint—and the logical presumption that exports are thus a good thing in themselves—distinguishes their analysis from the previous ones.

On the basis of these distinctions, they note that *ceteris paribus*, their assessments of the benefits of R&D, and of programs which would succeed in increasing R&D, will be higher than in these other reports.

They point out that econometric evidence of returns to R&D (average rather than marginal) is consistent with their story ie. markedly high measured private rates of return, in excess of the cost of capital, are inconsistent with the IC/BIE presumption that all privately profitable projects are undertaken. Instead, they argue, it lends support to their hypothesis that firms are constrained even with regard to potentially profitable R&D. (The standard interpretation of these studies, as per section 4.a., comes from comparing the *social* to the *private* rates of return to assess the magnitude of spillovers. Here instead, the focus is on comparing private returns with capital costs.)

The report also argues that Australian operations of foreign firms tend to be larger, and (collectively) dominate their respective markets; but that they have relatively low R&D/sales ratios, and export less than their Australian-owned counterparts. Thus, they argue that access by foreign-owned firms to policy instruments designed—essentially—to subsidise R&D is an issue which needs to be discussed explicitly.

Some of these conclusions will be examined at the end of this paper.

4.b. Recent Empirical Work on Location

In this section, recent empirical findings from several key articles are summarised, and some other results briefly mentioned.

Glaeser et al. (1992) base their results on a cross-section of what they call city-industries (industry clusters in given cities), focussing on 170 standard metropolitan areas between 1956 and 1987, and the six largest industries for each city in 1956. In general, they find support for the Jacobs view of dynamic externalities. Particularly, they find that, as measured by employment, industries grow slower in industries where they are over-represented. They also find that industries grow faster in cities in which firms in those industries are smaller than the national average size of firms in that industry (compatible, they argue, with the view that competition, rather than monopoly power, is the key spur to innovation). Finally, city-industries grow faster when the rest of the city is less specialised, again favouring the Jacobs view.

In response to the obvious question that then arises—Why do we observe industry clusters within cities if MAR externalities are not important?—they argue that there are other localisation externalities that may well be playing a role. Static externalities may be influencing location but not growth, or there may be key input suppliers or customers for which proximity is an advantage.

Henderson, Kuncoro and Turner (1995) test similar hypotheses to Glaeser et al., using data for eight manufacturing industries in 224 metropolitan areas between 1970-1987. Five of those industries are "traditional"—primary metals, machinery, electrical machinery, transport equipment and instruments—and three are "new" high-tech industries—computers, electronic components and medical equipment.

They argue their methodology is distinct from previous work in three important ways: they find it is critical (1) to distinguish between industries, and to include newer industries in the sample, (2) to include for each industry the entire sample of cities and (3) to incorporate other traditional considerations besides externalities that affect local industry growth (such as local labour market and regional product demand conditions).

Their results differ from those described above, in that they found evidence of MAR externalities for more mature industries, and both MAR and Jacobs externalities for the newer industries. That is, they paint a firm life-cycle picture which suggests newer high-tech firms will take root in cities with a history of industrial diversity (a diversified skill base?), but matured product lines, subject to MAR effects, will decentralise to smaller and more specialised areas.

Other work on spillovers examining the geographical/technological spread of innovations includes Jaffe, Trajtenberg and Henderson (1993), who find evidence of geographically localised patent citations. The localisation effect fades over time, according to their analysis, but not as fast as they profess to expect. The technological dispersion is wider, in that they find approximately 40 percent of citations do not come from the same primary patent class. (This is consistent with earlier work by Jaffe, 1986.)

4.d. Cooperation, Collaboration, Networking

The revitalised interest in growth theory and knowledge spillovers has given rise to much interest in the role of "networking". A business network is a cooperative relationship between two or more firms which involves the sharing of information and resources or the joint undertaking of certain activities. Knowledge spillovers may arise from networking between different firms and between firms and other institutions. The Bureau of Industry Economics (1995) undertook an assessment of business linkages and networks throughout Australia. The BIE report concludes that inter-firm cooperation is found to be clearly beneficial for the majority of cooperating firms. The observed benefits related to improved capabilities and competitiveness through access to new customers and markets and to knowledge spillover effects. The report identified knowledge spillovers relating to production processes, technology, market knowledge, product development and product quality. They note that firms can be myopic; in particular, those that enter into cooperative arrangements may do so for quite specific reasons, and then find to their surprise that their are unexpected spin-off benefits from the arrangement, which may involve market knowledge, improved production processes, product development and improved quality.

The BIE concludes that there is a role for government in facilitating cooperation by encouraging the development of closer inter-firm linkages and business networks. The report recommends that government agencies be established to provide information for firms and to establish networks for the diffusion of information.[11]

5. Policy Discussion

5.a. Policy Interventions: Reasons and Methods

In a simple "Pigovian" view of innovation, the ideal benchmark is the first-best world in which all socially profitable projects are undertaken. The actual world fails to achieve this principally by virtue of the lack of complete appropriability by the innovator for all the benefits generated by the innovation: this leads in turn to the existence of a prima facie case for corrective intervention. The policy means by which innovation may be increased include public funding (which may include public subsidies to private R&D); policy actions to increase industry performance of R&D by institutional means (examples are discussed in the next sub-section); and improving the definition and protection of intellectual property rights.

An alternative view might be that uncompensated spillovers are less prevalent, and less of a pressing policy issue, than the holders of the above view would believe. Information about new ideas spills over slowly and imperfectly, and often through deliberate means, which may involve compensation (such as licensing agreements). R&D may be constrained below a first-best level, but enhancing property rights may actually not be even a second best means (in general) to induce higher levels of innovative activity. It may even be worth pursuing policy actions designed to enhance the *diffusion* of knowledge (ie. the spillover effect) rather than the *production* of knowledge (ie. R&D).[12]

If scope exists for public policy to affect the rate of economic growth by promoting or facilitating spillover externalities, then it is important to investigate what forms these external effects take, and what policies are available to foster these effects. Governments can encourage spillover effects by facilitating technical exchange by firms within an industry, such as by promoting technology parks. Spillover effects can also be encouraged through the agglomeration of key decision-making units such as head offices. Finally, the provision of

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[11] See also the discussion of strategic technical collaborations in Dodgson (1993) and Coombs, Richards, Saviotti and Walsh (1996).

public infrastructure and services such as communications and transport systems also facilitates spillover effects.

The incentive issues (whether promoting spillovers discourages R&D activity) are discussed in sub-section 5c.

5.b. An Example of a Policy Response

One policy response to the issue of potential market (and institutional?) failure in R&D can be seen in the recent history of rural R&D in Australia. As surveyed in Harris and Lloyd (1991), there is plenty of econometric evidence to suggest that social returns to agricultural R&D are high on average internationally, and higher than usual market rates of return, indicating an under-investment in research, even (in this case) with an active public research system. The prevalence of public sector research in agricultural R&D worldwide is due to the coordination problems inherent in getting many small farmers to coordinate and fund joint R&D, even without the temptation to free-ride.

At the same time, it is quite plausible that returns *to farmers* from R&D form a large share of the total social returns (Harris and Lloyd, 1991). In such circumstances, the preferred policy response would involve some mechanism to levy farmers, rather than simply funding R&D by taxing the wider public. During the 1980s, the Federal Government implemented a scheme which has evolved to the present system, whereby commodity-specific Research and Development Corporations levied producers of particular commodities, the contributions being matched dollar for dollar by the government. Moneys were then allocated to research proposals submitted by R&D agencies via a board which had some degree of farmer representation.

In other words, the system involved a largely public R&D system, but it also incorporated industry funding at the margin in recognition of the perceived benefits to the industry collectively. The residual public funding was argued on the basis that social returns to the R&D exceeded private returns. This is discussed in the Industry Commission's report on

[12] A working paper investigating the idea of *endogenous* spillovers, inter-firm cooperation and research coordination, and the policy implications of these issues is Katsoulacos and Ulph (1996).

R&D (1995) (which is described below). An evaluation of this scheme is also contained in Alston, Harris, Mullen and Pardey (1997).

Romer (1993) has since outlined a possible model for industrial R&D which has similar features to the actual model used for agricultural R&D in Australia, in which self-funding industrial R&D boards compete with each other for funds generated by industry levies.

5.c. The Industry Commission R&D report

The Industry Commission (1995) inquiry into research and development in Australia developed proposals aimed at "enhancing the contribution of R&D to national welfare by more clearly defining government's roles, improving funding processes and making research more responsive to users and community needs" (volume 1, page 1).

The IC report's recommendations were based on a belief that:

- "returns to individual projects and firms undertaking R&D vary greatly, but often exceed the returns on investments in machinery and equipment:
- R&D has a significant positive impact on an economy's productivity: and
- spillover effects from R&D can be substantial, both domestically and internationally, but vary unpredictably from industry to industry" (volume 1, page 9).

On the basis of this world-view, the report recommended a range of policies that involve government sponsorship of private R&D (programs which, it was emphasised, should be duly controlled and monitored).

In reference to business R&D, the IC concluded that the (then) 150 per cent R&D tax concession had brought net benefits to the economy, and that the IC did not support changing the tax concession, "either to restore the effective value that applied in earlier years, or to match rates that apply in other countries" (volume 1, page 30). Despite this recommendation, the concession rate applying to most categories of business R&D was subsequently reduced to 125 per cent. (The R&D tax concession scheme is described in some detail in Appendix 1 of this paper.)

More generally, the IC report recommendations included the following:

- wider community influence in setting the priorities of the CSIRO.

- enhancing the role of the ARC in funding university research.

- increasing support for smaller companies unable to receive the R&D tax concession.

5.d. Spillovers, Incentives, and R&D Rationing

Might "spillover enhancement" as a policy option create a disincentive to R&D itself? That is, if there is an appropriability problem, would increasing the possibility for spillovers just make matters worse by further encouraging free riding? Geroski (1995) is among those who doubt the seriousness of this disincentive issue for a number of reasons, including the idea raised above that spillovers of knowledge are unlikely to flow freely and costlessly between firms even given weak mechanisms to ensure appropriability. Also, he attaches much importance the more deliberate and systematic information flows that move upstream and downstream between knowledge producers and users, rather than the involuntary spilling over of knowledge in a horizontal direction. That is, networks and cooperative partnerships are the principal source of knowledge transfer, rather than unintended (and uncompensated) spillovers. According to Geroski (page 89): "Conflicting evidence exists on the question of whether R&D spillovers complement or substitute for own R&D efforts, and it is not clear how practical or product/process specific the information which spills over is. This means, of course, that it is not wholly clear that these spillovers actually undermine the incentive to innovate." Langlois and Robertson (1996, page 2) contend that "Spillovers may actually *increase* the firm's incentive to produce knowledge."

The recent CSES/SIRF (1996) report on Australian R&D and innovation argues that evidence shows R&D is rationed, below any level reflecting private (risk-adjusted) optimisation ie. that there is some kind of "capital rationing" and/or managerial short-termism leading to firms under-investing in R&D even with respect to *privately* optimal amounts of R&D. The authors claim that this is not sufficiently recognised by other treatments of innovation and spillovers (such as BIE, 1994) that make the assumption that the only relevant market failure arises from the possibility of inappropriability (spillovers).

It is not immediately clear how compelling these arguments are. It may be that firms are constrained in their R&D. However, the archetypal *homo economicus* of consumer theory would no doubt feel "constrained" in the sense they would like to have their budget constraint relaxed, even while they are optimising (by definition). It is more complicated to make such an argument for a profit maximising firm, as there is no fixed budget constraint. To argue that "potentially profitable" projects are not being undertaken appears to require one of the following conditions to hold. First, *if managers are not profit maximising*, but instead satisfice (or seek managerial rents) they are likely to fail to do all worthwhile projects. Second, managers and higher executives or directors may have *different expectations about the future* and thus their views of which projects are potentially profitable will differ; if managers are more optimistic, they may feel unnecessarily constrained by orders from above. Third, managers and senior executives/directors may have *different attitudes to risk*, and so again may differ in their assessments of which are the potentially profitable projects. In the second and third scenarios, it is not immediately clear that there is a market failure or policy issue here, even with managers claiming they feel constrained in their R&D activity.

Regarding the finding that networks/spillovers are pervasive: They may be. In the broad sense (where spillovers refer to any transfers of ideas or techniques, uncompensated/accidental or otherwise) this is almost true by definition. But this in itself is not indicative of market failure (see Langlois and Robertson 1996). From a policy point of view, the important spillovers are the ones that lead to under-investment. The market may be as capable as any other mechanism of inducing worthwhile R&D activity *and* allowing for its dissemination. Then again, if the first point is taken as given (that firms are R&D-constrained), then it is likely to be the case that increasing R&D by policy means will yield substantial social benefits.

Evidence on these issues is provided by both the results of our survey and the case studies, as detailed in subsequent papers.

6. Conclusion

Let us present two broadly sketched views of how innovation may be viewed from an analytical/policy perspective.

6.a. The Stylised Mainstream View

In what we might label the “stylised mainstream view”, innovation is characterised by market failure and, therefore, this view predicts under-investment in R&D (used here as synonymous with innovation) compared to first-best.

Market failure is driven by, in particular, the “public good” characteristics of new knowledge, in particular, degrees of the following:

- non-rivalry: use of the new knowledge or innovation does not deplete the amount of the knowledge available to others;
- non-excludability: investment in innovation is partly or completely inappropriable by the investor.

These two characteristics sometimes generate the following stylised picture.

1. Knowledge is a "free good", almost like manna from heaven: as soon as an idea is created, it is (potentially) available freely to all. In this sense, the transfer costs associated with diffusion of a new idea are treated as being zero. (From a first-best welfare economics perspective, it is in fact ideal to allow spillovers of knowledge at their marginal cost; if such costs are zero, then it is best to allow everyone free access to new ideas. However, that raises incentive issues.)

2. There is an inherent tension between encouraging the production of new knowledge as opposed to stimulating its use. The optimal use of a new idea derives from allowing its widest possible dissemination (which usually means at zero marginal cost in this stylised view). However, this discourages production of new ideas, since the social rewards to a new idea cannot be recouped by the inventor.

3. The tension described above leads some economists to favour outright subsidies to R&D, as opposed to property-rights-based solutions (involving strengthening intellectual property provisions such as patent laws). While property rights solutions increase the degree of excludability associated with innovations, and therefore provide incentives for production of knowledge, they necessarily inhibit its use by raising the cost of use (not first best).

Furthermore, they may even lead to patent races where different firms invest resources in R&D so as to claim the monopoly (quasi) rents associated with the successful invention. In the stylised view, "patent racing" is inefficient because all the R&D effort of the unsuccessful firms is wasted.

4. For reasons given in 2., any facilitation or encouragement of spillovers (ie. stimulating the wider use of new knowledge) acts as a disincentive to its production. So, while spillover effects are socially beneficial, they provide a significant private disincentive.

5. Available empirical evidence supports the existence of spillover effects, in that social rates of return to innovations appear to be noticeably higher than private rates of return. This supports the prima facie notion of under-investment in R&D.

6. On the Schumpeterian hypothesis, that firm size and market power will be positively correlated with R&D, the evidence is ambiguous. Similarly, even at the theoretical level, the welfare economics of trading off reduced competition for greater innovation are also ambiguous.

6.b. A Stylised Alternative View

The following view is presented as a combination of various alternatives to the above picture of R&D. Some characteristics of such an alternative view are as follows.

1. Knowledge does not transfer freely; thus new ideas cannot be regarded as equivalent to manna from heaven. There are costs involved in comprehending, adapting and assimilating new ideas (figuring out how they work, which ones are worthwhile ones, how to get them up and running etc.); we can label these in generic terms as “absorption costs”, which firms must pay to benefit from new technologies and ideas.

2. Inappropriability is not the key disincentive to innovation, as presented in the mainstream view above. Firms do innovation despite the fact that not all the benefits will be privately appropriable. In many instances, firms are willing to share at least some innovations with other firms. Specifics will vary with the situation eg. some innovations (process-based?) will

be more easily shared than others (product-based?); the competitiveness of the industry will be a factor and so on.

3. The previous point is not incompatible with the fact that many firms will still be active in patenting and other forms of protection of intellectual property. Spillovers (broadly defined here as the diffusion and wider use of new knowledge, whether or not the innovator is compensated) can occur even when intellectual property is defined, through licensing agreements etc.

4. Patents serve at least a dual role in the innovation production and diffusion process. First, as already stated, they provide increased incentives to conduct R&D, by increasing appropriability, and second, they also increase the public information about new ideas, since all patent applications have detailed descriptions of the idea, and go on the public record.

5. Patent races may not be as inefficient as first thought, in the sense that firms are investing in their in-house idea-absorptive or generative capacity which is beneficial in the long term in terms of the wider use and spread of ideas (as well as in generating "by product" ideas and learning by doing with respect to the R&D process itself).

6. Just as the Schumpeterian link between market power and innovative activity is unclear, so is the reverse link between successful innovation and market power. Many industries in which innovation is rapid and ongoing are very competitive (eg. computers, various kinds of electronic equipment). Moreover, when market power emerges as a result of successful innovation, it is not axiomatic that it is due simply to the granting of a patent. It may be due to a more endogenous form of "technological lock-in", where a particular system becomes the market standard. Obvious examples include the VHS video system, and the Dos/Windows standard established by Microsoft. These were not the "only (technological) game in town" in either industry, but they came to dominate their industries. The technology was not simply valuable on being patented (or copyrighted) but on becoming an industry standard through shrewd marketing, not to mention good fortune.

7. Following on from the second point, do spillovers provide a disincentive for R&D, and thus are policies aimed at increasing the spillover effect of new ideas self-defeating? Spillovers

and R&D may in fact be complementary—there is evidence that spillovers are present in high-R&D industries, and that the ongoing innovation spurs other companies, and provides new information for other companies in their own R&D efforts. In this way, spillovers can stimulate rather than impede own-R&D.

8. The policy implication of all this may be that the dissemination and diffusion of knowledge may be a greater policy issue than the production of knowledge, rather than (as in the mainstream view) the other way around. If R&D is seriously constrained, this may be due to the risk and uncertainty associated with R&D (leading to credit/finance constraints), due to externally imposed capital rationing, or internal principal-agent issues, whereby senior management are relatively risk averse regarding investment in innovation. On this argument, policy makers might look toward subsidies, concessions and other inducements rather than property rights mechanisms.

To sum up, making confident predictions based on rigorous welfare economics grounds is extremely difficult. But, firstly, there appear to be good conceptual reasons to endorse policies (such as the 150 per cent R&D tax concession) aimed at increasing firms' research activities (even if only to maintain the absorptive capacities of firms and thus their receptiveness to new ideas generated elsewhere). Secondly, if it is deemed worthwhile to aim at enhancing spillovers and knowledge diffusion, the disincentive effects may well be minimal.

Appendix 1: The R&D tax concession scheme

A key government policy aimed at encouraging business R&D is the Commonwealth Government's R&D Tax Incentive scheme. The scheme enables eligible companies to deduct more than one hundred per cent (previously 150%, presently 125%) of their eligible expenditure on R&D against their taxable income. The scheme is managed by the Industry Research and Development (IR&D) Board, a Federal statutory authority. To be eligible for the concession, firms must be registered with the IR&D Board. The Australian Tax Office also has a hand in operating the scheme.

The Tax Incentive scheme was promulgated under section 73B of the Income Tax Assessment Act 1936. The role of the IR&D Board in relation to concessions under the scheme is set out in Part 111A of the Industry Research and Development Act 1986. When it was established, the stated aim of the scheme was to encourage a significant increase in firms' R&D activity by reducing the after-tax cost of R&D. The 150% concession came into effect on 1 July 1985. On 20 August 1996, the rate was reduced to 125%. The 150% rate applies up to that date, so that firms applying for the scheme for the financial year 1 July 1996 to 30 June 1997 will have a weighted average of the two rates applied to their R&D expenditure.

When the Tax Incentive scheme was established in 1985, it was planned that the scheme would change to 125% deductibility in 1991. The scheme was instead extended several times at 150%, and the 150% deduction was made "permanent" in 1993 (though was nevertheless reduced in 1996).

There have been several changes to the scheme over its life. In November 1987, the Federal Government introduced amendments to the Income Tax Assessment Act and the Industry Research and Development Act to:

- enable joint registration (syndication) of R&D projects;
- require the registration of research agencies;
- introduce Australian content provisions for eligible R&D;

- allow refusal of registration of R&D projects by the IR&D Board; and
- delegate some of the functions of the IR&D Board to the Tax Concession Committee (TCC).

These changes came into effect on 1 July 1988 by way of the R&D Legislation Amendment Act 1988.

Further changes were enacted in 1989 through the Taxation Laws Amendments Act (No. 4) 1989. These changes included the removal of the eligibility of building expenses and other changes concerning the definition of pilot plant and the treatment of the shared use of plant. Specifically, the changes were as follows (unless otherwise indicated, the changes were effective retrospectively to 21 November 1987 and from that date onward):

- companies were permitted to provide other firms access to plant used exclusively for R&D without affecting their deduction entitlements;
- eligible R&D projects that attract Government grants were permitted to qualify for deductions under the scheme. The amount eligible for the concession is reduced through a clawback process (based on the amounts of the grants received);
- eligibility for the R&D incentive was extended to trustees of public trading trusts (effective 1 July 1988) and to partnerships of eligible companies;
- the definition of plant was clarified to include pilot plant; and
- buildings used solely for R&D were restricted to being the basis for deductions akin to depreciation claimed for income-producing buildings (ie. from 21 November 1987 they were no longer claimable under S73B).

Legislation passed in 1990 (Taxation Laws Amendment Act, No. 35 of 1990) introduced further changes effective from 7 September 1989. The main changes in this round were the following:

- expenditure on acquiring (or acquiring the right to use) pre-existing core technology is deducted at 100%, not 150%;

- amounts received from selling or granting others access to the results of R&D are to be included as assessable income where a deduction has been allowed under S73B (this applies to all R&D, not just syndication);

- where investors are guaranteed a return from R&D activity, as the guaranteed return to investors increases, the allowable deduction reduces proportionately (again, this applies to all R&D, not just syndication)

- Section 39P of the IR&D Act was amended to broaden the eligibility of investors in syndicated R&D (ie. the qualifications in IR&D Act S39P (3) (d) and (e) were deleted).

Other changes to the Tax Incentive scheme were enacted in 1991 (by way of the Industry Technology and Commerce Legislation Amendment Act 1991) and came into effect on 15 June 1991. These changes (mainly procedural in nature) were as follows:

- if the Board issues a certificate to the Australian Tax Office (ATO) that particular activities are not R&D activities, or that particular technology is not core technology, the Board must state the reasons for doing so; similarly, reasons for the refusal of joint registration (ie. syndication) must be stated;

- where the Board has made an adverse decision in relation to the registration of research agencies, joint registration, eligibility of R&D activities or core technology, the claimant may within 21 days request the Board to reconsider the decision. If the Board does not confirm, revoke or vary the decision, the Board is taken to have confirmed the original decision; and

- applications may be made to the Administrative Appeals Tribunal for a review of decisions of the Board within 28 days of the final decision.

In addition to these legislative changes to the scheme, the ATO has issued a number of public Rulings concerning how the scheme is to operate. Also, the IR&D Board has set out guidelines on specific aspects of the operation of the scheme.

In addition to the Tax Incentive scheme, an R&D syndication scheme was introduced in 1989 by the Commonwealth Government. Under this scheme, outside investors can access the tax benefit accruing to firms that undertake R&D (in a manner analogous to dividend imputation). This avenue has been utilised by the a number of banks and other professional investors to increase their after tax returns. The syndication scheme is not available to smaller businesses.

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