Intangible and Intellectual Capital: A Review of the Literature*

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Abstract

This paper reviews theoretical and empirical academic economic studies that discuss what is intangible and intellectual capital and why is it important for society. It begins by discussing issues such as the nature of this capital and how has it changed over time. Subsequently it reviews measures of the importance of intangible and intellectual capital, whether optimal levels of investment in intangible and intellectual capital can be said to exist and, accordingly, whether governments should intervene in the market. On balance, theory favours the view that for reasons associated with uncertainty, non-mortgageability and economies of scale, there is an under-investment in these types of investment. However the extent to which this holds will differ according to the prevalence of uncertainty, non-mortgageability and scale economies for each type of capital item. The most common policies to stimulate the production of intangible capital, especially intellectual capital, are government grants, especially for basic research, patents and other forms of intellectual property, subsidies and research consortia. Optimal policies adjust the incentive to produce so that the marginal costs to society are equal to the marginal benefits.

Contents

1. Introduction

This paper reviews theoretical and empirical academic economic studies that discuss what is intangible and intellectual capital and why is it important for society. It begins by discussing issues such as the nature of this capital and how has it changed over time. Subsequently it reviews measures of the importance of intangible and intellectual capital, whether optimal levels of investment in intangible and intellectual capital can be said to exist and, accordingly, whether governments should intervene in the market.

It is assumed in this paper that intellectual capital refers to the stored knowledge and cognitive abilities of the workforce. Excluded are primarily social forms of capital that emanate from households rather than the market-based system of production. Included are the results from investments in both the skills and knowledge of a firm's workforce and the invention and development of new products and processes. Enterprise level intangible capital is a broader concept than intellectual capital, as it comprises all forms of capital not embodied in matter. While it includes enterprise level intellectual capital, it also embraces access to distribution networks and markets, systems to optimise the rate of innovation and structures that improve workplace and enterprise efficiency.[1] However, invention – the novel, non-obvious creation of knowledge – and innovation – the introduction of new methods and products into a firm – represent dominant areas in the intangible capital literature and this review will accordingly be biased towards them.

Most studies (tacitly) adhere to the theoretical foundations of either the neoclassical or the evolutionary schools of thought.[2] The neoclassical school assumes a linear, sequential, one-time transfer of knowledge to technology, while the evolutionary school regards the process as an ongoing, path dependent interactive course. The neoclassical approach assumes knowledge is singularly generated through exogenous R&D and is transmitted costlessly through codified blueprints, whereas evolutionists speak of embedded knowledge[3] and argue that a great deal of useful knowledge is tacit, context specific and informal. Transmission is not costless and often requires complex relationships between people. The neoclassical school assumes all risk is based on repeated occurrences and can be portrayed as a stochastic process while the evolutionary school

[1] Rent seeking behaviour is also an intangible investment from the firm's perspective.
[2] This represents a summary of Blankenburg (1998).
[3] Embedded in the organisation rather than individuals.

emphasise non-actuarial based uncertainty. Finally, the thrust of neoclassical policies is the establishment of correct incentives while the evolutionary approach favours government support for regionally based competencies.[4]

While the less mature evolutionary school is generally considered to be more descriptively accurate, it is less tractable and less analytically precise compared to the mathematically encrypted neoclassical method. At issue for the analysts however, is whether by simplifying the issues, the neoclassical school has achieved false precision at the expense of accuracy and insight or whether it has succinctly reduced the problem to fundamental issues.

Related to these different approaches is an inconsistency – common in economic and enterprise performance studies – between analysis which assumes that firms are always behaving 'as if' their profits are maximised and those which assume that firms vary behaviour according to how successful they have been in accumulating profits. In the first (neoclassical) case, firms' revealed behaviours are used to uncover optimal relationships, the classic examples being between price and output, investment and growth. In the second (evolutionary) case, an examination of the range of firm strategies will reveal which ones are more successful than others; an example being the relationship between R&D intensity and profitability. Authors cannot have it both ways, and there is some obligation on them to make their assumptions clear.

This paper is organised into four main sections. Section two discusses the concept of investment in economic theory and the subsequent third section considers what is intangible capital and why it may be important. The fourth section looks at studies that measure its value to enterprises and the fifth section considers the definition of socially optimal levels of investment and whether a case can be mounted for government intervention in the provision of intangible capital in a competitive economy. A conclusion follows.

2. The concept of investment

In the early political economy literature, the undertakers' or capitalists' primary role was to provide working capital, (that is short term finance), to sustain the production cycle. In return, they received an expectation of a future surplus or profit. Ricardo's corn model embodies this early concept of investment, which was, if not similar to the mode of early agricultural production, akin

[4] While the Human Capital literature is voluminous, there is comparatively little research on it as a form of firm investment.

to the prevalent putting out system of cottage production at the time. Fixed tangible capital – tools and machines – were not an essential part of his analysis.

The literature in the nineteenth and early twentieth centuries focussed more closely on the means, motive and method of investment in tangible (fixed) capital – plant and equipment. Presumably this reflected the prevailing managerial philosophy of the time. Investments in new ideas, inventions and worker skills by contrast were largely regarded as by-products of production rather than outcomes of direct and deliberate company decisions and were accordingly not subject to analysis. It was not that intangible capital at that time was unimportant, for without even the most basic form of intangible capital (knowledge), goods could not have existed at all. It was more simply that intangible capital, as it is known today, was not regarded as part of the firm's profit seeking strategy.

The latter half of the twentieth century saw the emergence of dedicated R&D laboratories, and marketing, distribution, training and human resources divisions within large companies. Associated with this was the emergence of theoretical disciplines in industrial engineering, management, human resources and marketing.

The causes of transformation in the nature and composition of firms' investment activities are less clearly established. It is possible that firms' awareness of the scope of investment activities has changed, for what can be seen or felt grasps our earliest attention, and this is no less true for company managers than for scientists. Long before particle physics and gravity were even conceived, scientists were observing and theorising about the stars. Would a dedicated R&D laboratory during the eighteenth century have been as profitable as one today?

Alternatively, it is possible that there has been a more fundamental change in the way society produces and the implied capital requirements, brought about through declining relative costs of tangible and intangible capital over time. Falling costs of plant and equipment relative to intangible capital costs would allow firms to assign less of their investment budget to tangible capital, which then releases more resources for intangible investment. It is not the use-value of tangible capital that has fallen but its exchange-value.

Compared with economic research generally, the investment literature has generated few postulates and stylised facts. There are as few as two acceptable postulates (or axioms[5]) in the literature. The first is that firms invest for profit, and the second is that some level of intangible capital is a pre-requisite for all forms of production. The profit postulate has been assumed by economists as a way of theoretically abstracting from entrepreneurs' non-economic and non-systematic motives.[6] The necessity of intangible capital on the other hand has been deduced because it is almost impossible to conceive of a production process that can exist without some form of prior investment activity. Even fishing with bare hands requires a level of skill and prior knowledge to succeed. [7]

On the other hand, there are two main opening suppositions that many authors adopt but do not explicitly substantiate. First is the stance that a higher rate of investment in both tangibles and intangibles will raise society's welfare level regardless of current levels of investment. The second is the assumption that the production of intellectual capital is subject to market failure and therefore not only requires government intervention but usually more intervention than the status quo (Klette *et al.* 2000, Hall and Van Reenen 2000, Martin and Scott 2000, Rogers and Dowrick 1999, Jones and Williams 1998, Gutterman 1997).

3. The nature of intangible capital

Intellect (or knowledge) and raw physical labour are the only two basic factors of production in existence. Since the amount of physical matter in the world is fixed, what passes for production, or the creation of goods, is simply a re-arrangement of matter. In general, the higher our level of knowledge or intellectual capital, the more labour saving devices and subsequently the less reliance society needs to place on physical labour for this re-arrangement of matter. While the conditions and behaviours for the use and allocation of physical labour has been studied extensively in economics, the factor market for knowledge has been comparatively overlooked. Some of the differences in treatment of the nature of intellectual capital depend on how broadly it is defined. At its most narrow, intellectual capital as an idea is the ultimate non-excludable,

[5] Axioms are self-evident assumptions for which no proof is required, postulates are assumptions for which no proof is given.
[6] See Mill (1936).

indivisible and jointly consumable public good. At its broadest, intellectual capital includes the capacity of the workforce to understand, apply and implement new and more valuable ways to reconfigure matter. This extended notion is more excludable than simple blueprint type knowledge and is certainly not jointly consumable from a profits perspective. These extremes depict the breadth of intellectual capital and in practice most types of capital will lie somewhere within this range.

Compared with the tangible economy, it is widely accepted on *a priori* grounds that the production and sale of knowledge and intellectual capital is dominated by the three classic forms of market 'failure': uncertainty, inappropriability and indivisibility.[8] Knowledge creation is fundamentally uncertain because it often arises from situations, which are so singular or unlike past cases that no estimate, which is meaningful or reliable *ex post*, can be made before the fact. Reliable expected values can only be made when there is enough data upon which to make actuarial calculations and consequently, it is not possible to derive reliable *ex ante* rankings of knowledge creation projects by their expected rate of return. Pooling many projects together may reduce the actuarial risk associated with their success rates but cannot eliminate uncertainty.

With respect to the second failure, many analysts regard knowledge capital as highly inappropriable since any purchaser can reproduce it at minimal cost and thus reduce the inventor's ability to extract quasi-rents. The extent to which this proposition is accepted depends on how broadly intellectual capital is defined, for as will be discussed later, there are considerable costs and hindrances to the process of diffusion of intellectual capital. Finally, a given piece of information is indivisible and according to Arrow (1962), this poses problems since people cannot buy only as much as they need.

Of these three attributes, uncertainty is arguably the primary distinctive attribute of the production of intellectual capital. Uncertainty depends first on how often the process has been undertaken before, and thus how standardised the process has become, and secondly, the extent of direct labour involvement, because mechanised investments produce more reliable outcomes than

[7] As pertinently put by Menger, without knowledge it is not even possible to distinguish between nutritious and poisonous berries (Loasby, B. J. (1991) *Equilibrium and Evolution*, Manchester University Press, Manchester, New York.).

[8] These failure do not automatically imply that the production of intellectual capital will be under-invested in. It is possible for example that uncertainty or indivisibility leads to an over investment. Lack of full appropriability occurs for tangible investments as well.

those which are dominated by people. These factors govern the position each type of investment activity holds on the uncertainty spectrum.

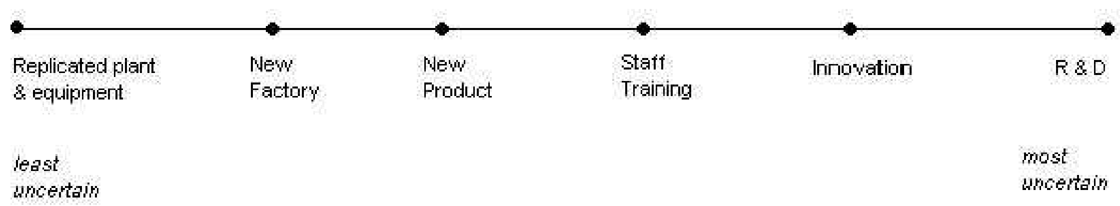

Figure 1. Uncertainty spectrum

The most uncertain form of investment represented in Figure 1 would be R&D because of its novelty and high level of human involvement and the least would be an extension of plant and equipment in an existing production unit. A major study by Hall and Hall (1993) of 11,032 company observations 1964 to 1991 estimated the effects that different ratios of R&D, advertising, tangible investment and debt had on the share markets' rate of discount on future profits. They found that companies with higher levels of R&D, and tangible investment had lower discount rates. In the case of R&D this may reflect low depreciation rates on the created knowledge and in the case of tangible investments it may reflect lower premiums for uncertainty. While they found that advertising intensive companies faced higher discount rates, this may reflect high depreciation rates for advertising investments rather than high premiums for uncertainty.

It is not clear from the literature what motivates firms to invest in each form of capital, however it would seem reasonable to deduce that there are diminishing returns to each type. Once firms have installed the latest equipment, and are meeting market orders there would be limited benefit from continuing to invest in plant and equipment. Profitability would be better enhanced by better trained staff, better access to markets and new techniques of production – in short – intangible forms of investment. To the extent these different forms of capital are complementary, it is not possible to assign a specific individualised value to the investment. A recent study of small and medium Australian enterprise by Loundes and Bosworth (2002) has found that R&D was complementary to increases in training expenditure and marketing expenditure but there was no correlation between tangible investment and R&D or marketing expenditure.

Appropriability is always an issue in the investment literature in part because it is assumed that ‘full’ appropriability is desirable. However full appropriability (which occurs when marginal social benefits are equated to marginal private benefits) is not sought-after for tangible capital and it is not clear that it is desirable for intangible capital either. In general, consumers as well as producers benefit from new inventions or a parallel expansion of productive capacity through the provision of more and new products to buy. A new factory and a higher level of production will lower prices, reduce rivals’ profit margins and benefit consumers. In this respect, duplicate investment in tangible capital is no different from duplicate investment in intangible capital.

How firms seek to maximise their appropriability will be influenced by whether it is predominantly embodied in labour, in material goods or in written text. If capital is embodied in the incumbent workforce then it will seek to protect its investment through staff retention; if it is embodied in goods then it will use security devices such as locks and theft devices; if it is embodied in written text it will use patents, and copyright laws or seek to keep the knowledge secret. Alternatively, it may treat a new system or process as a intermediate input into the production process and regards ‘the ability to keep ahead of the game’ as capital. The latter form of capital will reside in its human capital.

Characteristics of enterprise intangible investment

Investment motives, and the ensuing investment activities, may be classified according to whether they vary over time or across firms. Over time, a firm’s level and mix of investment activities is expected to vary according to their need for more productive capacity, their need to compete and their need to contain uncertainty in either their external or internal markets (see Webster 1999 Ch 4, 5). Variation in motives across firms will depend on the type of products produced, processes used and the nature of the markets it serves and draws upon.

The commercial production of tangible capital has, over time, developed standards and processes so that most items of plant and equipment are mass produced and identical. This was not always the case. When equipment was handcrafted, each component of the machine had to be tailored to suit each other and there were no interchangeable parts. This standardisation of production parts means that each piece of equipment can be produced over and over again at a constant cost. Furthermore, over time, the gains from learning are likely to reduce the costs of production and the production of new machines becomes a predictable affair subject only to actuarial risk.

The production of intangible capital by contrast is more heterogeneous. Whether this is because R&D, methods of training etc have not evolved to a stage of mature mass production or because it is inherently heterogeneous is not clear. A considerable portion of intangible capital is embodied in employees and because of this, it is unlikely that intangible capital will ever achieve the same level of replicability as tangible capital. There are of course famous examples of contemporaneous discoveries in the field of knowledge: Newton and Leibniz (differential calculus), Keynes and Kalecki (effective demand) for example. But these coincidences are comparatively rare and details of the invention are not usually the same. For the main part however, the production of intangible capital will be subject to non-actuarial uncertainty.

Related to these issues is the structure of the industry. Most plant and equipment is produced for the firm by a separate specialist business. Most intangible capital is however produced in-house. Some specialist services in R&D, training and management may be bought-in but a lot of R&D, skill development, marketing and management strategies are undertaken within the firm for its own immediate use. This difference between tangible and intangible capital is possibly associated with the heterogeneous nature of both the firm, their employees and the way firms use intangible investment as a competitive weapon.

There is a large and well-documented literature which has examined why and when firms vary their tangible investment to fulfil their productive capacity motive (see for example, Jorgenson 1971, Kalecki 1954, Part IV). However, questions about the motivations for different types of firm investment, using the broader intangible notion, are largely unanswered and theoretically ill-defined.

Empirical work in the area of enterprise performance and intangible capital has thrown up a very limited number of acknowledged stylised facts. In addition to the three deduced assumptions discussed above, it is well accepted that patterns of investment by type vary by industry. Malerba and Orsenigo (1997) have created an invention typology derived from patent data in four European countries. They find that industries are clustered according to whether invention is industry widening (though low appropriability and high rates of entry and exit) or industry deepening (through high levels of appropriability and low rate of entry and exit). The chemical, vehicle and electronic industries form the latter group while the former include the metal and machine manufacturers. Common to both clusters is the persistence over time of the main inventive companies. Industries dominated by highly qualified workers tend to invest most heavily in enterprise training, industries affected by current technological trajectories invest most in R&D and some industries, for reasons that are not often clearly stated, tend to have higher patent rates. Furthermore, there is some evidence that the ratio of intangible capital to tangible capital in business has risen over the last half century (Webster 1999, Lev and Zarowin 1999).

The determinants of intangible investment

Other features of intangible investment are more contentious. Two opposing explanations of the determinants of inventions exist. Either inventions are stimulated through exogenous advances in science and technology or they are demand induced. Schmookler (1966, p 12) has argued in defence of the latter that while we cannot invent all we want, it is improbable that we invent all we can, and so what we do invent is roughly speaking what we can, tempered by what we want badly enough.[9] Dosi (1988), in a review of the empirical literature, claimed that invention and innovations are selective and cumulatively directed into precise directions. These he called technology trajectories or ‘innovation avenues’.[10]

Schmookler (1966, Ch VII) examined 14 US manufacturing sectors over the period 1899 to 1937 and found that capital good patents were largely determined by investment demand (lagged 3-years) emanating from the industry sector that purchased the patented capital goods.[11] He argues that the apparent observation that advances in science stimulate inventions arises from the way the data is classified (Ch VIII). If inventions are classified according to their scientific field then, inventions appear to be supply driven. However, if the question is why they are invented, not how they are invented, a demand side explanation dominates. The rise of the chemical and engineering inventions in the first half of the 20th century is not solely due the growing science base but was also due to the needs of large scale industries for standardised materials. The development of

[9] Demand side factors were also emphasised earlier by Nelson (1959).
[10] I believe he mainly refers to invention rather than innovation.
[11] Over this period, Schmookler is confident that most inventions in manufacturing were patented.

different science bases is also heavily influenced by demand 'subject to the constraints imposed by man's [sic] innate abilities and by nature' (p 176).[12] While firms may have a role in introducing a new product to the consumer market, they still must comply with generic demands by consumers for leisure, labour saving or basic survival needs.

Despite this, technological opportunity is commonly cited as a determinant of invention in most applied studies of the determinants. Adams (1990), for example, looks at the links between basic scientific research at universities and productivity in US manufacturing. He found long lags but a positive effect. Evangelista and Sirilli (1997) interrogated a 1992 Italian innovation survey and reported that technological opportunity appeared to be the most important determinant of innovation (several measures of the latter were employed). Aerospace, office machinery and telecommunications had the highest innovation rates, however firm size, geographical location and whether the firm was a member of an industrial group were also significant. Levin and Reiss (1984) believed that a firm's innovation rate is determined jointly by industry differences in market size and technological opportunity. The rate of growth of the industry was observed to be a more important determinant of R&D than the firm's individual growth.

Finally, Malerba *et al*. (1997) and Breschi *et al.* (2000) found that technical performance is strongly associated with the emergence of stable groups of innovators who invent consistently and continuously over time. Market concentration and firm size was found to be less important.

By contrast, Symeonidis (1996) has found evidence that more concentrated industries have higher invention rates (adopting a more neoclassical reasoning) and has maintained that this is probably because they are better able to appropriate the benefits. Although, he also argues that since industry concentration tends to be correlated with firm size, it is not possible to disentangle the effects of size (through higher levels of retained earnings and the ability to bear fixed costs) from concentration per se. The same lack of distinction also arises from the collinearity between concentration, industry and technological opportunity. Symeonidis notes that it is not obvious that the invention rate is either positively related to firm size or highest for the smallest and largest firms. These apparent stylised relationships may be caused by the selection of the dependent variable (patents, R&D expenditure) or the sample population (listed companies, low response rate

[12] He notes (p199) that science may limit inventions in three ways. (1) it can limit what inventions are made (some inventions are not possible until some prior knowledge is developed), (2) formerly under-utilised knowledge may be

samples) than any true underlying factor. He suggests that there may be a threshold effect but that otherwise, size is a red herring and technological opportunity is the most important factor. Bosworth and Rogers (1998) suggest in their review that the direction of the relation between firm size and R&D intensity depends on the sector the firm operates in.

Cosh *et al*. (1998) hypothesised that new firms are less constrained and inflexible than mature firms are, and thus more likely to innovate. However, they do not find conclusive evidence for this. Lawson *et al*. (1997) examined the factors contributing to the geographic clustering of firms around Cambridge and Oxford in the UK and found that while direct formal links with the universities were few, cited reasons included informal networking, shared labour markets and proximity to customers.

Finally, recent Australian studies on innovation and inventions have found systematic relationships between firm characteristics and innovation and invention rates. Bosworth and Rogers (1998) found that R&D intensity was highly correlated with industry and level of enterprise diversification but not ownership (foreign/domestic), firm size or industry concentration. Loundes and Bosworth (2002) in their study of 3569 small and medium Australian companies found that whether or not a company was an innovator was positively related to lagged R&D, lagged change in training, company size, small market share and a few indices of active contemporary management practices. There was no correlation with expenditure on tangible capital. Rogers (1998a) observed that while small firms are less likely to undertake R&D, those that do have higher R&D intensities. However, this pattern may say more about incentives to report R&D than to undertake it. In addition, he found that high spending R&D firms exhibited more intertemporal volatility during the early 1990s.

Studies such as those cited above do not over turn Schmooker's demand thesis for the contemporary custom of classify inventions according to the firm that produces them, rather than the firm that uses them, leads inevitably to the finding that inventions are driven by supply induced technological opportunity (Griliches 1990).

A limited number of studies have looked at the determinants of other forms of intangible capital, workplace re-organisation and advertising. The paper by Rogers (1998b) considered some characteristics of management, organisational and technological change using a two-wave panel

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better exploited when demand conditions change and (3) each addition to knowledge acts as stimulus to further data set of 698 Australian workplaces. Two-thirds of workplaces in 1990 reported at least one type of change, compared with four fifths in 1995. Types of change were correlated, so firms who have undergone one sort of change are more likely to experience other sorts of change. Firms that were experiencing change pre-1990 are more likely to experience change five years later. With respect to innovation in new products, work organisation and new technologies embodied in tangible equipment, Rogers (1999) found that this was more prevalent in workplaces with better employee-management relations and higher levels staff training. In addition, Chauvin and Hirschey (1993) used data from 1548 US firms over the period 1988-1990 and found that advertising and R&D expenditures were not positively correlated between firms but appeared to be used as alternative means of product differentiation.

There are several other untested possible factors in explaining the mix of investment activities firms undertake. If we accept the uncertainty spectrum depicted in Figure 1, then it is possible that there is a hierarchy of capital needs. Subject to a given level of entrepreneurial knowledge, firms satisfy their need for productivity capacity first. Once the marginal returns to more productive capacity starts to fall, they begin their investment in marketing, staff skills, and organisational efficiency. Finally, as the returns to these types of investment begin to fall they launch into the most uncertain investment, R&D.

Diffusion of intangible capital

Diffusion of intangible capital to competitor firms is dual edged. One set of studies takes the negative line and assumes that diffusion undermines appropriability and thus the rewards to invention, while the other regards diffusion through innovation as fundamental to improving the material standard of living of a country or area. Of course diffusion associated with ‘proper’ compensation for the inventor may reconcile these two concerns but it is not clear that the optimal rewards for invention will necessarily be equal to the deterrents to diffusion. For the same reasons that firms benefit from forming production cartels, it can also be beneficial to firms to promote diffusion and networking within a common group, to develop research consortia and form joint ventures while at the same time limiting external diffusion.

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developments in the same line of thought.

Two types of transfer can be distinguished: vertical technology transfer – the transfer of knowledge from basic research through to applied research, development and production – and horizontal transfer – the transfer of the same technology from one context to another (Mansfield 1975). It is also important to distinguish between technology, which is common to the whole industry, system-specific technologies that arise from a specific item of production and firm-specific technologies that are tacit but firm-based. Mansfield also speaks of three types of transfer – material transfer, design transfer of blueprints and capacity transfer. The latter is the capacity to adapt a new item to local conditions and is much more complex than the other two. Capacity transfer generally requires the transfer of people who bring tacit information and can adapt processes to unforeseen contingencies.

Diffusion or intangible capital transfer may also flow through to down stream companies and consumers. According to BIE (1994a), the extent of downstream spillovers (or diffusion) is limited by industry depth and in Australian, depth is only present for a few industry sectors. In niche markets therefore, spillovers from Australian industry largely benefit overseas firms.

While the education and training sectors are the classic technology transfer agencies, the term technology or intellectual capital diffusion traditionally limits itself to the costs of transfer of applied information and complementary plant and equipment from one firm to another. Diffusion may occur inadvertently through the interchange of people, though professional meetings, through suppliers and customers, through published patent applications and reverse engineering[13], via foreign direct investment (FDI), the transmission of written and codified books and manuals, educational services and though international trade; it may be promoted deliberately by governments, industry bodies and firms through subsidies for FDI, tariffs, networking, personnel exchange, joint ventures and consortia and licensing; but it may also be deliberately hindered by the same parties through the use of patents, trade secrecy and labour contracts. Cited determinants of diffusion include the competitive process in the product market, the skills of staff, level of R&D spending, networks, uncertainty, opportunities for personal contact, and cultural and language heterogeneity of the population.[14]

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[13] Mansfield et al. (1981) found that while it takes considerable time to invent around a patent, the knowledge contained in the patent application is of considerable value to rival companies.

[14] Mansfield and Romeo (1980, p83) claimed that an increase in a country's R&D expenditure by 10 percentage points reduce imitation time by 2 to 3 years.

FDI has long been the major vehicle for the transfer of intellectual and intangible capital across national boarders (see for example Hymer 1960, p25, pp41-46, Magee 1977, Grabowski and Mueller 1978, Buckley 1985, Mansfield and Romeo 1980). Multinationals bring intellectual capital, marketing strategies and a critical body of skilled managers and workers to complement the (usually) tangible assets base in the recipient country. For the large corporation, it allows them to maximise the use of their intangible assets (in new fields) without spoiling their existing domestic market. According to Mansfield *et al*. (1979), inventing firms are more likely to transfer new technologies via foreign subsidiaries and their older technologies through licensing and joint ventures.

Controls limiting FDI have been used in the past to prevent the loss of intellectual capital from nation states. Britain, for example, prohibited the export of technology and artisans in the nineteenth century to continental Europe. The US had anti-technology outflow policies during the 1980s, as did many Second World countries during the twentieth century. Foreign patent treaties have been, and are still, used to protect a country's intellectual capital and these are harmonised and standardised by international agreements. To estimate the time taken for technology to leak out through FDI, Mansfield and Romeo (1980) surveyed 26 US-based multinationals and found an average estimated time of 4 years. They believed that deliberate transfer itself had had only a minor effect on the non-deliberate leakage process.

Mansfield has also undertaken considerable work on the *speed and costs* of diffusion within national markets. In 26 case studies Mansfield (1975) found that technology-copying costs were about 36 per cent of the original establishment costs in machinery and electrical equipment sectors and they were 10 per cent in chemical and petroleum refining. In a further 1981 study of major inventions in 48 firms, Mansfield *et al*. (1981) found that on average imitation costs were about 65 per cent of invention costs. Furthermore, imitation time (to invent a product or process that has a similar function but does not infringe the patent (if applicable) and to establish a new facility) was only 70 per cent as long as the original invention. In about 15 per cent of cases however, the imitation was more costly and took longer to effect. Levin *et al.* (1987) found that the median cost was over 50 per cent and the median time was 1 to 5 years.

While these studies have measured the relative speed and costs of imitation, a further branch of literature has tried to model the structural factors that determine these relativities. A major obstacle for these applied studies is finding a measure of diffusion, which is not in itself an effect or a determinant of diffusion. Several authors have suggested patent data as an indicator of knowledge flow (Eaton and Kortum 1996b, Bosworth 1984).[15] [16]Studies of discrete, identifiable pieces of capital are more tractable and Mansfield has undertaken a number of such studies. In one example, Mansfield (1963) traces the spread of a specific piece of machinery over 35 years in the US railway system. He found that the rate of diffusion within each firm became faster over time and was also related to the profitability of the innovation and the imitator's liquidity position. In Mansfield *et al.*, (1981), imitation costs were found to be greater if patents were filed and the original expenditure on research by the inventor was high.

Most empirical studies on the rate of technical diffusion have accepted its measurement on *a priori* grounds and used this as an explanator in models to explain phenomenon such as international patenting and productivity growth. Eaton and Kortum (1996a) and Eaton and Kortum (1996b), for example, estimate the determinants of international patents using the model:

$$p_{ni} = f\left(r_i , \frac{c_n}{m_n}, s_n , \frac{g_i}{g_n}, \varepsilon_{ni} \right) \qquad (1)$$

[15] But not patent citations (see Jaffe, A. B., Fogarty, M. S. and Banks, B. A. (1998) 'Evidence from patents and patent citation on the impact of NASA and other Federal labs on commercial innovation', *Journal of Industrial Economics,* **XLVI,** 183-205.).

[16] Eaton and Kortum (1996a) suggest that people may patent in countries where they believe an idea will diffuse there naturally, and thus international patents can indicate the likelihood of copying in the recipient country were the patent not to exist. However, it has been suggested by Andrew Christie that the natural incentive is for people to patent in countries where they want to sell.

Where p_{ni} is patents taken out in country *n* by residents in country *i*, r_i is the level of R&D in country *i*, c_n represent the cost of taking out a patents in country *n*, m_n represents the size of the potential market in country *n*, s_n represents a measure of the strength of patents protection in country *n*, g_i represents the rate of growth in country *i*, ε_{ni} represents country *n*'s natural ability to adopt *i's* inventions – the rate of diffusion.[17] ε is proxied by the absorption characteristics of a country such as its level of human capital, geographic distance and inter-country trade. Eaton and Kortum (1996b) estimated (1) using data from 19 countries and found that the geographic distance, level of IP protection in the recipient country and relative productivity were significantly associated with international patenting but international trade was not. Mansfield (1985) used the direct survey method and asked managers about how quickly they believed rivals knew about the development of their new products and processes. His 1985 survey of 100 US manufacturing firms gave an average time of 1 to 1½ years, a shorter time than it took firms to introduce the new invention.

Eaton and Kortum (1996a) and Eaton and Kortum (1996b) also use deductively derived measures of diffusion to explain inter-country productivity. They use the model

$$g_n = \theta \sum_{i=1}^{N} \varepsilon_{ni} \alpha_i \left(\frac{A_i}{A_n} \right)^w \qquad (2)$$

Where g_n is productivity growth in country *n*, α_i represents country *i's* inventiveness, ε_{ni} represents country *n*'s ability to adopt country *i's* inventions – the rate of diffusion, $\frac{A_i}{A_n}$ is output per worker in country *i* relative to country *n* and this is meant to approximate relative technical know how. If ε =0, then there is no technical diffusion and growth depends only on the inventiveness of the domestic economy. The rate of growth of a given country's productivity thus depends both on the level of domestic inventions and its ability to absorb other countries knowledge. This model does not explain diffusion but may be used to estimate parameters θ and *w*,

[17] Estimates of country's IP protection have been derived from Rapp and Rozek (1990) as cited in Maskus and Penubarti (1996).

once estimates are made for the g, ε, K_i and A. They suggest that α is estimated from the number of business research scientists and the total labour force. The same model can be used for inter-industry or inter-regional diffusion. Eaton and Kortum (1996b) test equation (2) using data from 1988 and found that the variable which represents technological diffusion rates accounted for more than 90 per cent of all productivity growth for all countries but the USA, Japan and Germany. All three ‘diffusion’ variables – human capital, geographic distance, trade relationships – were important.

4. Measuring the private value of intangible capital

Many applied studies, which have investigated the interrelationships between firm’s investments in intangible capital, are seeking to establish that like tangible assets, intangible assets contribute towards company profits and value. Under a neoclassical stance, each firm is (very close to) using resources in its profit maximising combination and consequently, differing combinations of tangible to intangible capital reflect differing market and technical conditions. The evolutionary school would regard the given combinations of capital at any point in time as outcomes of a path dependent process that is guided but not strictly controlled by competition. As such, different but equally efficient technologies may operate side by side as a result of the different historical conditions of each firm.

Studies, which assume the neoclassical method, regard company differences in profitability as different snapshots of quasi-rents arising from temporarily scarce assets. Alternatively studies, which have adopted the evolutionary mould, look for evidence that higher (or lower) levels of intangible investment, or inventive activity, are associated, for substantial periods of time, with more or less profitable companies. In this last case, applied studies need to include a range of firms that are investing under, at, or above the optimal rate of intangible investment in order to identify the position of preferred input mixes. Since the relationship is expected to be have an inverted ‘U’ shape, a clustering of firms around the top of the ‘U’, or a model that assumes a monotonic relationship, will tend to find no apparent relationship between intangible investment (capital) and profitability. The faster the pace of competition and less uncertainty about future profit flows, the shorter the quasi-rent horizon and the faster non-optimising firms are driven out of the market, the more likely a random sample of existing firms will produce a clustering around the top of the ‘U’.

In this case, the actual market more closely approximates the neoclassically competitive market model with all firms just receiving normal profit and following the same investment strategies.

Several studies have used stock market value as a measure of performance and have accordingly limited their scope to listed companies. Since market value is the capitalised value of the future stream of profits, a positive relationship implies that the investment contributed more to expected revenues than actual costs. Apart from reassuring readers that investments, in both tangible and intangible means, raises the value of (surviving) companies, this does not tell us whether market value would have been higher had the mix of investments been different and the interpretation is subject to the same caveats as for profitability studies. Some studies regard their results as an indicator of how myopic or foresightful stock market investors are (for example Hall and Hall 1993).

Finally, changes to labour profitability are also a common performance measure. However, this generally requires panel data or pooled cross sectional-time series data. Because many things may affect productivity, there are considerable demands on the data set.

Measuring invention, innovation and firm performance

Commonly used measures for inventive output include:

1. Direct survey questions on new inventions or innovations, such as new products and processes introduced, the number and amount of investment into staff training, R&D, workplace organisation and marketing.

2. Officially reported R&D expenditures from accounting data. While this indicator is supported by well-documented national and international accounting standards, in reality the boundaries are fuzzy. Fuzziness, is of course, not particularly confined to R&D expenditure, and should not bias the results if there are no systematic tendencies to mis-classify expenses over time and across firms. An increase in tax concessions for R&D however can introduce a bias as it gives firms a greater incentive to classify marginal activities as R&D. Larger firms, which have more sophisticated administrative support services, and the potential for more formal R&D programs, are expected to classify more of the R&D activities as R&D. If R&D is expensed and not capitalised, then the temporal allocation of costs will not reflect the 'true' investment process and the data will need to be adjusted.

3. Administrative data from patent applications or grants, tax applications and other forms of government compliance. Pakes (1985), for example, has tried to explain the incidence of company patenting on the assumption that the latter represents inventive output. This assumption is becoming less common in the literature as industries have been found to vary their rates of patenting. As early as the 1950s, Schmookler (1966) was noticing the divergence in manufacturing between inventions and patents rates. Sanders (1962) has also cautioned against the uncritical use of patent data because of its uneven relationship with inventive activity over time. Schmookler (1962) specifically argues against the use of annual patent data (which may be influenced by many non-invention related factors) preferring instead 5-year periods.[18] US studies from the 1980s using cross-sectional firms and industry data generally find a high correlation between patent and R&D activity rates (see Griliches 1990, p1673), however this correlation is considerably weaker at the firm level. Several authors have highlighted the erratic and often irregular time lags between R&D and patents at the firm level, and have suggested that they arise less from the nature of the inventive activity than administrative and environmental factors.

Estimating private returns to intangible investment

The question of the private returns to invention and innovation hinges quite critically on the efficacy of firms' appropriability mechanisms. This section does not attempt to assess appropriability means but rather looks at studies that have measured private returns given whatever the conditions for appropriability were at the time in the markets under scrutiny.[19] A discussion of mechanisms to enhance intangible investment through raising appropriability is presented in the following section.

While a few studies have estimated the private return to firms from investment in intellectual capital, remarkably fewer have estimated enterprise returns to investment in worker skills,

[18] The divergence between patent rates per expenditure on R&D during the 1970s (USA) sparked a considerable debate in the USA literature. While initially it was thought to be due to a fall in the efficacy of R&D, later studies believed it was due to the number of patent examiners (Griliches, Z. (1990) 'Patent statistics as economic indicators: a survey', *Journal of Economic Literature,* **XXVIII,** 1661-1707.) or the type of R&D undertaken (Kortum, S. and Lerner, J. (1998) 'Stronger protection or technological revolution: what is behind the recent surge in patenting?', *Carnegie-Rochester Conference Series on Public Policy,* **48,** 247-304., Kortum, S. and Lerner, J. (1999) 'What is behind the recent surge in patenting?', *Research Policy,* **28,** 1-22.).

[19] Patenting rates vary across process and product lines and accordingly, patenting rates are a biased indicator of intangible investment. The now outdated evidence by Schmookler (1966, pp 44-47, Ch VII) has shown that the

organisational change and marketing. Accordingly, most of the discussion in this section is concerned with the former. The most common type of study has estimated R&D's net impact on enterprise market value (equities plus liabilities), profit-turnover ratios or sales growth data. The specific approaches (excluding individual and time sub-scripts), which are presented below, are intended to measure the private returns to the investment.[20]

Three of the current approaches are reviewed below: the rate of return approach, the production function approach and the market valuation approach. Without significant time lags in the model, attributing a causal relationship to significant empirical correlations is problematic. It is quite possible that separate common factors may cause, for example, both higher profits, productivity and patents or investment.

The rate of return approach (using the formula for an infinite series)

The typical equation used to estimate the rate of return from an investment is

$$r = \frac{\Pi}{I} - (\delta + x) \quad (3)$$

correlation between patenting and manufacturing sectors in the US had been falling over time as a lower percentage of inventions are patented.

[20] Extending this to embrace externality effects from other businesses is usually undertaken by adding variables for intangible investment activities in adjacent firms or industries. Related firms are identified by how closely they lie on the product type, R&D type, location or labour market spectrums. A weighted index to represent a composite spillover source firm is usually calculated and included in the estimating equation. A summary of some studies that have tried to measure spillovers is found in Klette *et al*. (2000). Most studies find positive effects on adjacent firms but the results are not unanimous. Klette *et al* warn that positive findings may reflect other factors that could correlate with firms' performance. If firms have to perform their own R&D in order to receive others' spillovers, then delineating empirically (and theoretically) between own and spillover effects of R&D will not be possible. Furthermore, it is probable that evaluations, which do not report significant effects, are less likely to be published.

Where r is the rate of return, Π is the perpetual net addition to profits (or productivity) that depreciates at the rate of δ over time and x is the discount factor for the projects uncertainty. I is the cost of the investment. BIE (1994b) and Nadiri (1993) summarise the results from over 60 firm and industry level studies from major OECD countries and finds that most private rates of return (returns to the business only) range from 20 to 30 per cent and social rates of return (return to the business, consumers and other businesses) vary up to over 100 per cent.[21] Changes to total factor productivity are often used for Π.

One difficulty with using the rate of return approach, especially for estimates of externalities, is defining the counterfactual. As stated above, in very competitive markets, high R&D may ensure only survival and normal profits. In addition, if market boundaries are not defined properly, or there are very few cases in each market, then it is possible that no apparent relationship between R&D and rates of profit will be obvious.

A production function approach

The typical equation used for the production function approach is

$$Y = f(K^s{}_t, K^s{}_i, L^s) \tag{4}$$

[21] However, BIE (1994b) The Economics of Patents, AGPS, Canberra. note that given the serious methodological problems with measuring social returns these estimates should be treated with caution.

Where Y is output, $K^s{}_t$ is services from tangible capital, $K^s{}_i$ is services from stock of intangible capital (a compounded sum of past R&D for example) and L^s is labour services. Production function studies generally find that returns to the stock of intangible capital, as proxied by cumulated past R&D, is positive but the size of these effects varies considerably. One difficulty with the production function approach, and the derived productivity of labour approach, is that they do not indicate whether intangible investments provide more benefit to the firm than it costs. That is, higher productivity may arise through excessive R&D costs to the firm.[22] This limitation has been avoided by the market valuation approach, which uses the valuation of a third party (institutional and private shareholders) to judge how rational the firm behaviours have been. How exogenous and rigorous this is depends therefore on the credibility of these third parties and whether the company is traded regularly.

A recent 4-year panel of 3569 small and medium size business units in Australia by Loundes and Bosworth (2002) found that value added was related to the tangible capital stock and employees but not lagged R&D or lagged changes in training. It was however related to whether or not the firm innovated in the previous year and some indices of management practices.

The market valuation approach

The market valuation studies use the identity

$$V \equiv q(K_t + K_i)^{\sigma} \qquad (5)$$

where V is the market value K_t and K_i represent the stocks of tangible and intangible capital and q represents the ability of the firm's management to convert the firm's assets into profits and market value. q may be permanent and time varying. This equation uses R&D or patent data to proxy for K_i and is estimated in log format.

[22] It is not simply possible to assume that if the firm has traded more R&D for higher productivity then it must be profitable to do so, for whether firms intangible investment behaviour is consistent with profit maximisation is the essence of what we are testing.

$$\log V = \log q + \sigma \log K_t + \sigma \frac{K_i}{K_t} \quad (6)$$

This form is appropriate if, and only if,

$$\frac{K_i}{K_t} \text{ is small such that } \log\left(1 + \frac{K_i}{K_t}\right) \approx \frac{K_i}{K_t}$$

An obvious drawback is that the ratio(s) of intangible to tangible capital $\left(\frac{K_i}{K_t}\right)$ may not be small and thus the approximation produces biases. A difficulty with these studies in application is the choice of variables to proxy for the firm's level of intangible capital. If R&D and patents and designs are included in the equation, then considerable double counting may occur as most patents will derive from past R&D activities. Including R&D with recorded intangible assets is not double counting as normal accounting standards only allow for intangible assets that have been brought from outside the firm to be recorded in balance sheets.[23] However, studies that do include R&D with patents not surprisingly appear to run into collinearity problems. While researchers have included R&D, patents, trade marks and intangible assets as a way to capture the many dimensions of inventive activities, the alternative appoach of using factor analysis to derive an intermediate variable which represents firm's intangible investment or capital may yield better results.

Chauvin and Hirschey (1993) examine 4600 listed US companies in 1988-90 to find that both higher R&D and advertising expenditure are associated with higher market values. However, the magnitude of these effects varies by industries. Feeny and Rogers (1998, p 40) using a sample of 118 Australian companies over the period 1996 to 1997, find that patents, tangible assets and trademark applications have a positive effect on the firm's market value. R&D expenditure was not significant due perhaps to the collinearity problem referred to above. This was also found in Bosworth and Rogers (2001) using a slightly different sample of Australian companies.

The broad evidence from these studies indicates that intangible capital does affect market values but this does not mean that more (or less) intangible investment by firms will affect their profits or value. The main criticism from these cross-sectional studies is that it is difficult to establish cause from effect. It is possible that high value or high profit firms are more likely to undertake R&D

[23] R&D expenditure is conventionally expensed.

because of better access to retained earnings or because they react to the uncertainty embodied in R&D by using rules of thumb to decide R&D budgets. Alternatively, it is possible that an independent third factor, such as industry or technology class, has led to both industry concentration (and also large firm sizes) and a necessity to undertake R&D for survival. Consequently, it is not possible to infer from the experience of a firm in one technology class or industry as to what might happen to another.

This criticism is partly supported by some of the more recent studies using panel datasets. When firm performance measures are regressed on their own lagged or contemporaneous R&D expenditures, no relationship is generally found (Pakes 1984). In a subsequent Australian study of 35 firms covering the period 1991 to 1994, Bosworth and Rogers (1998), found that reported intangible assets, but not reported R&D, was related to company value. They included lagged revenue growth as a proxy for accumulated intangible capital not captured in the other variables, but this factor may also directly influence market value because of its influence on share traders expectations. The panel data study of 146 UK firms from 1990 to 1994 by Bosworth *et al*. (2000) estimated a market value model with R&D variables and found that stock measures of intangible assets failed to explain market value but that firm-specific effects had a large and systematic effect. Hall (1993) found that stock market measures of the value of intangible capital, and accordingly in her case the returns to R&D, had fallen in the US between 1979-83 and 1986 to 1991. She suggests that this may be due to an underlying reduction in the productivity of R&D, however, it is unlikely that the 1987 stock markets crash was unimportant. The latter had little to do with the fundamental productivity of R&D.

Other pooled time-series cross-sectional models are more supportive of a causation thesis however most cannot rule out reverse causation as they do not specify dynamic models. Griliches, (1986) modelled data from 883 large US firms over the period 1967 to 1977 in a production function and found that R&D did have a positive effect on productivity but that basic research was more influential than other R&D. He also found that privately financed R&D was more effective than government funded R&D. Ben-Zion (1984) used a panel data set of 94 USA firms from 1969 to 1977 and found that productivity was positively affected by a firm’s R&D expenditure. However, his model is less cleanly specified as he includes both patents and R&D in the same equation, and thus partially double counts and also includes earnings as an independent variable.

Non-relationships in these studies may be due to the considerable noise in the data and the relative shortness of enterprise datasets, particularly in Australia. Aside from noted difficulties inherent in obtaining consistent measures of fuzzy concepts such as R&D, the inherent uncertainty involved in R&D, the long and variable lags in return to ultimately useful R&D and the imperfect measures of firm performance, all suggest that the issue is far from being settled. A cross-section time-series study by Geroski (1991) on the effects of major innovation on UK productivity in 79 industry sectors over the period 1960 to 1979, revealed that innovations tend to take 10 to 15 years to have their full effect. If firms are using rules of thumb to decide R&D budgets or there is a dependency in R&D expenditure, then a lack of intertemporal variation in the independent R&D variable may conceal a true casual relationship. The volatility of R&D expenditures is still a matter of dispute and may vary by industry, country and government policy regime shifts. Australian data for the 1990s analysed by Bosworth and Rogers (1998) suggest that these expenditures are relatively volatile on a year-by-year basis for a minority of firms.

Aside from conventional performance measures such as market value and profitability, patent counts have been used as an indicator of the 'success' of R&D expenditures. Even when differing industry propensities are taken into account, this approach is beset by problems arising from the randomness associated with the timing of successful R&D and the decision to patent (Ben-Zion 1984).

The literature on the effects of other forms of intangible investment is more meagre. While there are many studies, which have examined the householder's returns to education (see for example, Borland 1996, Miller *et al.* 1997), very few studies have been undertaken on enterprise returns to investment in staff training (see Blandy *et al.* 2000 for a recent attempt). Several studies such as Acemoglu (1998) and Kahn and Lim (1998), have noted that the strongest rises in productivity over the last half century have been concentrated in the highly skilled industries but these observations are several steps removed from strong evidence about the returns to enterprise training.

5. Socially optimal levels of investment

Intergenerational optimising models

While the social *raison d'être* for investment is rarely made explicit in modern literature, it is well acknowledged that without the waiting inherent in investment, it would be difficult to organise complex production processes that need lapsed time to sustain them (that is, processes that imply dated sequences of labour). Investment funds are the essential ingredient which the capitalist or rentier brings to the production unit – whether the funds are used for working, tangible (fixed) or intangible capital. To collect profits without investment reduces the rentier to an agent of arbitrage.

Investment activities are accordingly necessary for production to occur but how much of societies resources should it utilise? The main guiding principle – to maximise society's welfare through altering the pattern of consumption over time – has a limited practical translation. Consequently, when policy advice is called upon, analysists rely upon the unjustified but common assumption that more investment is better than less.

The desired rate of net investment has also been referenced in the early neo-classical Keynesian synthesis literature to state of the macro economy. If unemployed resources exist, then it was argued that additional production through more investment activity has no opportunity cost, and current investment, by definition, is sub-optimal. However, Kalecki (1943) argued that end-use expenditures such as household and government consumption need to be in balance with profit seeking expenditures, such as investment, for it is not possible for the latter to create the demand and sustain profits on its own. In short, high or successively higher rates of net investment are unsustainable without parallel higher household, export or government consumption demand. Hence it is only acceptable to argue that investment and consumption demand, together, should be raised if there is unemployment in the affected labour markets.

Where skill or employment barriers exist however the main determinate of the optimal level of investment relates to the desired distribution of intertemporal consumption. This presupposes however that the optimal allocation is unique and exists. The Ramsey model of optimal growth forms the genesis of the study of the optimal rate of accumulation (investment) and it shaped the course of the debate on this issue from the 1940s to the 1960s. Under highly restrictive assumptions which excluded technical progress, population growth and non-zero intertemporal discount rates, Ramsey deduced that the welfare maximising level of investment (per person) should equal the difference between the maximum attainable level of utility and actual utility (per person) divided by the marginal utility of consumption.

Mirrlees (1967), in one of the last papers in this genre, argued that once these assumptions are dropped, the results change and it is no longer possible to obtain explicit solutions without adopting specific functional forms. He found that asymptotic optimal investment paths differ in complicated ways according to the formulation of the three assumptions. Furthermore, these real world additions introduced the question of whether a hypothetical path for optimal accumulation exists at all.

Externalities in the provision of intangible capital

Since then, comparatively little has been written on optimal investment paths and the main surviving theorem from this time is the tautology that investment should proceed until the marginal gains – enhanced future welfare – fall far enough to equal the marginal loss to current societal consumption. If it is assumed that profit-seeking firms will ordinarily extend production until marginal private returns equals marginal private costs, then the issue for analysts is reduced to detecting and measuring non-infra-marginal externalities.

Marginal benefits, or the marginal rate of return, include the flow of benefits to society from the addition of more efficient forms of production or the introduction of new products. Marginal costs represent the cost of funds used to finance intangible investment or the benefits forgone from not using these resources elsewhere.

The main externality found in the cost of producing intangible capital arises from the uncertain nature of intangible investments and its essential intangibility and thus non-mortgageability.[24] Finance markets are said to 'fail' when risk averse lenders demand an excessive interest premium to compensate for their lack of knowledge about an investment. This effect is greater for intangible investments as they are more subject to high levels of uncertainty. According to Arrow (1962), the moral hazard issues imply that the problem of uncertainty does not simply arise from the absence of the full set of contingent markets. It is not possible to on-sell uncertainty when the sale may dull incentives and affect outcomes. In addition, while tangible investment usually produces a mortgagable asset (which can be used to offset some of the investment risk), only a limited variety of intangible assets can be bought and sold as entities separate from the firm as a going concern. Arrow (1962) has also argued that because it is often not possible to assess the value of information

[24] Investment markets are also subject to a further externalities, which is common to the tangible market. Equality between social cost and private costs assume that default free rate of interest set by central banks reflects the collective consumer's intertemporal discount rate and accordingly, the cost of funds includes the future return that is needed to compensate contemporary consumers for today's loss of consumption. However, it is debatable whether this represents how central banks actually set interest rates. Many economists would argue that the central bank rate is set by political concerns or issues associated with prevailing rates of inflation, neither of which have anything to do with consumers intertemporal discount rate.

(the simplest form of intellectual capital) until it is consumed, risk averse individuals will demand less information, at any given price, than they optimally should. That is, Arrow questions whether the *ex ante* private benefits function are a reasonable estimate of the *ex post* benefits.

However, there are grounds for not using this marginalist approach for it assumes that society, and firms, as private entities, are able to monotonically rank unknown and future investment projects in declining order of social or private returns. Because of uncertainty, it is possible that there are many potential projects that will turn out (were they to be undertaken) more socially or privately beneficial than projects actually undertaken. In this case the marginal approach may well deliver a sub-optimal local maximum.

Finally, marginal values, whether financially enumerated or not, are dependent on the prevailing structure of production and incomes distribution. Any change to these parameters can potentially change the ranking of beneficial investment projects, their assessed net benefits and consequently, whether the economy is producing above or below the socially optimal level. Multiple equilibria may result.

Falling costs of production

The marginal approach above assumes that compensating for externalities arising from either production or consumption should be enough to cause a competitive market economy to invest at the optimal rate. However, this assumes that firms are able to marginal price. If the production of the good or piece of intellectual capital is subject to economics of scale then it is not possible for firms to marginal price and cover costs. An extreme example would be the discovery of some piece of knowledge, which was costly to create but could be diffused or replicated at zero cost. In these cases the sale price for invention will always be above its marginal cost (the cost of transmission), which results in a below optimal level of consumption. Incentives for production should be associated with the total benefit to society of its creation while incentives for transmission should be determined by the scarcity of the commodity. If an invention is costlessly replicated and transmitted, it is not scarce and charging a price has no economic function. Theoretically, the incentive system for production, in this case knowledge creation, should be unrelated to the charges for users (Polanvyi 1944). Charging a price for that portion of a good or service that embodies zero marginal cost intellectual capital lead to under-investment down stream and a below optimal level of household consumption.

However, not all forms of intangible capital or intellectual property are costlessly replicated and transmitted. Indeed, the very premise of the literature of technology diffusion is that know-how is costly to transmit and takes time. Nevertheless, as discussed above, the empirical studies by Mansfield indicate that transfer costs were some where between 75 and 50 per cent of the original creation costs.

The case for encouraging the growth of intellectual capital

There appear to be four cases where an *a priori* case can be made for encouraging more investment in intangible capital. First, when uncertainty combined with risk averse financiers results in less investment than would be warranted *ex post*. Secondly, when the non-mortgageability of intangible capital reduces the level of borrowed funds that can be accessed to finance investment in intangible capital. Thirdly, when uncertainty combined with risk averse purchasers results in less purchase of the capital than would be warranted *ex post*. Fourthly, when falling costs of production or reproduction results in a pricing policy above marginal cost and thus a sub-optimal level of diffusion or consumption of the end-product, which uses intangible capital. When there are unemployed resources in the intangible input markets, then a case for expanding investment and end-use expenditures can be made.

In addition, there are other distortions in the economic system that make it unclear whether society is producing too much or too little intangible capital. First, when there is uncertainty about the values of *ex post* investment but financiers or purchasers are risk loving, then potentially there may be an over investment. Secondly, any inability to accurately rank the value of investment projects can potentially lead to an over or under-investment and finally, the presence of multiple equilibria can mean that economies operating at a local maximum may be above or below the global maximum.

Policies to increase intangible investment

While it is relatively easy to establish a case for promoting investment in knowledge capital beyond the laissez-faire level, it is less easy to establish how far these policies should be extended, and accordingly, whether existing policies should be modified. Leaving however this issue to one side, this section examines four main forms of policy to raise the level of investment in intangible forms of capital. Most relate to intellectual capital but others can be applied to other forms of intangible capital such as staff training, marketing and work organisation.

To reiterate from the previous section, the optimal pricing structure rewards the inventor according to how much is required to bring forth the invention to the market, subject to this being less than the social value of the invention, but the consumption price depends on the cost of reproducing and transmitting the invention. However, this first-best solution is difficult to quantify and apply in practice and second-best solutions are more commonly used.

The first and possibly oldest method for enhancing the private returns to inventive activities is patent, copyright and design laws. Patents laws were introduced in Venice in 1474. The next oldest form of public support is direct grants from government. Another common 20^{th} century mode of intervention has been tax concessions. Finally, a more recent form of intervention, which has been popularised in Japan over the last few decades, is the establishment of externality endogenising research consortia. These consortia aim to pull together complementary R&D to raise learning opportunities and stimulate more R&D for given research budgets.

Patents

Patents, trade secrets, copyright and design laws confer limited monopoly rights on the applicant or inventor. This raises private returns at the expense of otherwise spillover beneficiaries (rival firms who would imitate and consumers who would benefit from lower prices). The more basic and fundamental the level of research, the more uncertain and unpredictable the social uses for the new knowledge and thus the greater the monopoly costs from patenting the ‘good’. According to Nelson (1959b), for these reasons scientists have long advocated the free and wide communication of ideas. The full social use comes often from unexpected quarters and cannot be predicted *a priori* . Patenting is only likely to be profitable at the applied end of the spectrum where the technological base narrows.

Whether a firm applies for a patent depends on, first, whether the invention is a significant, non-obvious improvement on the existing ‘art’, secondly, the administrative and professional fees to support the application, and finally on the level, length and cost of protection it affords. In addition, patents are sometimes cited as strategic tools for bargaining during information exchanges or for controlling research territory by creating ‘patent fences’. According to a 1994 US survey of 1478 firms by Cohen *et al*. (2000), blocking rival patents and prevention infringement suits were two of the three top reasons given by firms for patenting. In complex product industries where a single company cannot control all the essential technologies and spheres of knowledge, patents are used for cross-licensing and horse-trading information. If many patents are required to permit the use of certain technologies, then each patent holder has the power of veto and a high level of mutual co-operation is required for production. Cohen *et al* (2000) claim that when this occurs, rents accrue to the industry group rather than the private firm.

While some industries or particular types of markets may have a greater propensity to produce non-obvious inventions, it is generally considered that it is the extent of afforded protection and the technical conditions of the invention with respect to imitation costs and ability to cleanly define the invention, that determines the propensity of inventions to be patented. Studies by Levin *et al*. (1987), Mansfield *et al*. (1981), Mansfield (1986), Cohen *et al*. (2000) found that patents were a secondary means of appropriating returns from inventions.[25] According to Mansfield (1986)’s survey of R&D managers in 100 US manufacturing firms, patent protection was essential for the innovation in 30 per cent of cases in pharmaceutical and chemicals, but only 10 to 20 per cent of cases in metal manufacturing and less than in other sectors. Small contained inventions appears to be patented rather than more complex integrated systems. Levin *et al.* (1987) found that patents more than doubled the cost of imitating patented processes and products.

Since Levin *et al*. (1987), Cohen *et al*. (2000) have found that while patents appear to have become more valued, the importance of secrecy had also risen. The Mansfield (1986) and Cohen *et al*. (2000) studies ranked lead-time and secrecy as the main means of protection followed by complementary sales and service and complementary capabilities. Patents were only more popular than ‘other legal’ mechanisms. Nevertheless, they found that the various methods of protection should be viewed as complementary rather than alternatives. The main reasons cited for not patenting were the ease of inventing around a patent (technically and legally), the required level of information disclosure and the difficulty firms experience demonstrating novelty. According to Lanjouw and Schankerman (1998), the high costs of litigation seriously decreased the value of patents and reduced their usage by small firms. If one party cannot afford to contest a case the

[25] According to Mansfield *et al*. (1981), 60 per cent of patented inventions were imitated within 4 years.

rights are determined not by law but by financial resources. McCoughey *et al*. (2000) provide an interesting case study of a family of inventions that rely for their protection on the ability of the company to continually improve, and also the complementary technical (tacit and codified) service support that cannot be easily copied. Despite these findings, the number of patent grants in the major developed countries rose steeply over the last 15 years of the twentieth century (see Hall 2002, Table 3).

Since patent laws in countries with common technologies and cultures are generally similar and pervasive, there are few natural experiments which could enable researchers to assess the effects of the patent system on an economies inventiveness. Several methods however, have been employed to determine whether the protection afforded by patents add value to the firm's set of inventive capabilities and thus should, on *a priori* grounds, stimulate private investment in invention. Patents are not often sold and it is difficult to obtain market values. Under the one thread of logic, it can be deduced that since firms must spend resources to obtain a patent, they must confer some value.

Possibly the oldest type of study on the value of patents, beginning with Schmookler in 1952, has been to relate industry output or firm value to the number of new patents or the stocks of patents held. A more recent Australian study by Feeny and Rogers (1998) used regression analysis to estimate that patents and trademarks raised average market values by A$7.3m and A$1.4m respectively.

The typical equation, which is based on (3) above, has similar problems to the estimated value of R&D. Studies that have included both R&D and patents generally find that the patent variable dominates R&D in terms of the level of significance (see Feeny and Rogers 1998). However, this may arise because the most valuable outputs from R&D are patented rather than because of the profit generating effects of legal protection.

Patent renewal data has more recently emerged as a possible way to calculate the dual (legal and inventive) value of patent.[26] Lanjouw *et al*. (1998) and Cornelli and Schankerman (1998) have argued that initially the application for and renewal of patents represents the firms desire to maintain an option over a research domain and that half of patents in the US are not renewed

[26] Strictly speaking, patents derive their value only from the legal protection they afford the owner of the invention. Accordingly, very valuable inventions will not be patented if the potential legal protection is very small. However, the maximum value of the legal protection is restricted by the intrinsic value of the invention. Even if IP laws are 100 per cent effective in stopping copying, the value of the patent cannot exceed the value of the profit enhancement

beyond 10 years because by this time, they have been revealed to be of low value. Patent values, using this method, vary by industry[27] and the distribution of values approximates a log normal distribution. According to Lanjouw *et al*. (1998) annual rates of obsolescence run at about 25 per cent.

Most analysis broadly accepts that the level of inventive activity would be sub-optimal without patents, however there is less agreement that patents represent the best solution or that the current institutional arrangements are optimal. Policy makers should balance the marginal effects on inventive activity of patents per se, with the loss of consumer surplus to infra-marginal consumers and loss of benefits to other firms. The latter may include lost profits from now obsolete prior inventions and loss of infra-marginal spillovers.

Results from research in this area to date have not been precise enough to enable us to effectively quantify these lost or gained benefits. Accordingly, most suggested changes to the system are deduced through *a priori* logic as it is difficult to fine-tune the current system using empirical estimates. Nevertheless, of all the second-best policies, rewards to the inventor under a patent system (compared with grants, subsidies) are more likely to vary systematically with the social value of the invention (BIE 1994b). R&D subsidies rewards inputs spent and grants do not intrinsically bear any systematic relationship to value. However, BIE (1994b) note that patents do not generally provide sufficient inventive to correct the externality.

Government grants

Direct government grants are an obvious solution to under-investment and the major advantage of a public grant scheme is that it recognises the distinction between mechanisms providing the incentive to invest and the pricing mechanism to allocate it among users. The invention or acquired knowledge can be made publicly available and monopoly distortions inherent in patents are avoided.

Direct grants are the most common way to fund basic research ni universities and public and private research institutions. Patent buy-out is an old but largely forgotten form of public grant. In 1839, the French Government bought the patent for the (photographic) Daguerreo type process (Kremer 1997). This eliminated monopoly distortions while maintaining R&D incentives. It led to a

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afforded by the intrinsic merit of the invention. Thus the value of legal protection tends to be higher the more valuable is the invention.

[27] Pharmaceuticals, wood products , machinery and chemical are among the highest patent value industries in the US.

rapid transfusion of this technology throughout the world and resulted in its establishment as the world standard. Patent buy-outs are today being advocated as a government financed initiative to simulate inventions (see Polanvyi 1944, Kremer 1997, Thurow 2000) with an intermediate aim being to circumvent expensive and time consuming infringement litigation, industrial blackmail, and ‘paper-patents’. Polanvyi (1944) has argued that a commercially based grant system can be devised that is no less equitable than the patent system. He proposes introducing ‘licences of right’ supplemented by government grants which are generous enough to satisfy inventors. Licences of right would be low cost patents which require the licensor to permit use by third parties at an agreed fee. The government would subsidise this fee thus ensuring an ample reward for the licensor. An assessment of what is an appropriate level of government subsidy can be gauged under a parallel system of licences of right and patents. As the subsidy rate rise, a progressively higher and higher proportion of inventors will chose licences over patents. Government prizes were introduced during the early 19th century and since then invention or innovation awards have continued to stimulate intangible investment in part by acting as signals to the market (Klette *et al.* 2000).

One of the major difficulties in all these public grant schemes is devising an efficient formula to distribute R&D funding. Ideally, the grant should equal the amount that is required to induce the effort which results in the invention, subject to the proviso that this amount is less that the value to society from the use of the invention. Estimating this for each would-be inventor is especially difficult given the highly uncertain, and long term nature of potential benefits. It is not clear what role a third party should have in assessing R&D projects. Public grants based on past performance have been advocated by Arrow (1962). Dosi (1988) has suggested that governments should support innovation through supporting the infrastructure and environment that is conducive to entrepreneurship. Private companies can compete for public money to fund their innovative projects and in return they would offer royalties or success payments. Many authors are sceptical about the ability of government employees to predict projects that produce high private or social returns, but are implicitly confident about the stock markets abilities to do this and about private companies to know what should be patented. At its most extreme, complete government funding is a solution to projects that are likely to have limited opportunities for private appropriability but nonetheless, significant net social benefits.

Finally, a less direct way government can lower the cost of R&D or raise the returns to R&D is by subsiding knowledge infrastructure by promoting education and skill development, facilitating mechanisms for industries seeking research partners, assisting with the commercialisation of inventions, subsidising of financial intermediaries for R&D, directly stimulating demand for R&D output, and providing other forms of legal and technical assistance for companies at the early highly uncertain end of the value chain.

Government subsidies

Tax/subsidy schemes are a traditional form of government correction for externalities. Australia, the US, Canada and France have the most generous tax treatment of R&D (Hall and Van Reenen 2000). The Australian Government introduced R&D tax concessions in 1985 at 150 per cent, but since 1996 this has been reduced to 125 per cent. The effectiveness of deduction schemes depends on the taxing entities current profit situation, and many Australian entities pay no tax. These differences across firms make it difficult to clearly model on both the firm or industry level.

The usual methods for evaluating the effects of government subsidies include direct surveys of R&D managers, time series industry studies and panel data analysis. Similar to all evaluations, a major impediment is establishing the counterfactual.

One common firm level model uses first order conditions derived from a standard production function, such as:

$$g_{it} = \alpha + \beta\rho_{it} + \gamma y_{it} + \eta_i + u_{it} \quad (7)$$

where g is the log of the stock of R&D knowledge (computed via a perpetual inventory method), ρ is the log of the user costs of R&D, y is the log of firm's output, η are other firm specific effects and u is the error term. The size of the β coefficient determines how effective any tax concessions policy changes should be.

This basic model has been estimated for several countries, including Australia, using firm panel data sets and these are summarised in Hall and Van Reenen (2000). They conclude that empirically β is about –1 so any tax concession that reduces the cost to the firm of R&D by 10 per cent, will raise the level of R&D activity by 10 per cent. Essentially this means that firms keep their own contribution to the R&D budget constant *ceteris paribus*, and the results are also consistent with theories that suggest that R&D budgets are determined by rule of thumb.

Research consortia

By sharing research information, research consortia aim to internalise spillovers, reduce the free rider effect and raise private returns closer to social returns. They may do this by reducing research duplication or by enhancing knowledge flows among complementary programs. Consortia are more likely to occur when the partners sell into different markets as the loss of revenues will be expected to be less. According to Hall (2002), research partnerships grew significantly during the last two decades of the twentieth century. She estimated that during the last decade there were over 5000 such consortia mainly within the US or between the US and Europe and mainly in the ICT field. Research consortia are usually assumed to involve on-going relationships, either through formal contracts or informal alliances, however many discussions include once-off purchase arrangements by commercial producers for research information or by researchers for commercial expertise.

There are limited evaluations of the success of these partnerships. Irwin and Klenow (1996) evaluated the SEMATECH program using a panel data covering the period 1970 to 1993. The aim of this program was to raise the R&D rate. While they did not find that firms in the consortium had higher R&D, rates of return on assets or productivity growth, they did have significantly higher rate of growth of sales. An evaluation of Japanese consortium by Branstetter and Sakakibara (1998), using an unbalanced panel of 226 firms cover the period 1983 to 1989, found that membership of the consortia raised patent rates by 5 per cent.

The generic model specification for many panel data evaluations is

$$y_{it} = \alpha_i + \lambda_t + \beta P + \gamma x_{it} + u_{it} \qquad (8)$$

where y is a measure of firm performance, α are fixed firm specific effects, λ are common effects on all firms, P is an indicator of involvement in a program, x are control variables and u are the i.i.d. error terms representing the effects of unsystematic factor on the firm's performance.

If program selection is based on how well a firm is performing in any year, then u can be correlated with P and estimates can be unbiased. Alternatively, since there is usually self-selection into all joint ventures, α will be correlated with P. Incorporating a large numbers of pre-program x variables may reduce both these biases. Heckman et al. (1998) argues that the difference in difference method typified in equation 4. is preferable to his parametric selection correction method from Heckman (1979).

$$\hat{\beta} = \Delta y^s - \Delta y^n \tag{9}$$

where y^s is the average before and after difference in the performance of firms in the program, y^n is the average before and after difference in the performance of firms not in the program. $\hat{\beta}$ is the mean impact of the treatment on the treated.

There have been several difficulties with these evaluations. According to Branstetter and Sakakibara (1998), research consortia are often viewed as having longer-term benefits and since most evaluations are limited to short time periods, they will not reveal any effects. Even if programs are shown to be beneficial, Klette *et al*. (2000) point out that it is not possible to infer from this that the past impact of the program will continue if the program is extended. Like all other areas of program evaluation, analysists require randomly assigned program participants, or at a minimum, matched control groups for more definitive results.

One major complicating issue is the treatment of spillovers. If spillovers are large, then the difference in the performance of firms that do and do not participate in the programs will under-estimate the true effects of the program. This problem will be greater the more likely matched firms are to be the subject of the spillover.

Finally, research consortia between universities and industry are not without their hidden costs. Poyago-Theotoky *et al.* (2002) have argued that there is anecdotal evidence that habitual relations between these parties may compromise both the university culture of open and frank disclosure of knowledge and the freedom of academics to creatively follow their own research agendas.

6. Conclusion

The main research questions in this field are concerned with whether the rate of intangible investment, especially in intellectual capital, is appropriate and if not, what are the best policies to ensure it is.

On balance, theory favours the view that for reasons associated with uncertainty, non-mortgageability and economies of scale, there is an under-investment in these types of investment. However the extent to which this holds will differ according to the prevalence of uncertainty, non-mortgageability and scale economies for each type of capital item. The most common policies to stimulate the production of intangible capital, especially intellectual capital, are government grants, especially for basic research, patents and other forms of intellectual property, subsidies and research consortia. Optimal policies adjust the incentive to produce so that the marginal costs to society are equal to the marginal benefits.

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