Innovation: Intellectual Property, Transactions Costs and the Institutions of Idea Trading

by

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ABSTRACT

This thesis addresses the economic theory surrounding innovation. It notes anomalies in existing theory and by resolving these anomalies suggests a new conceptual basis from which to theorize.

The first step is to suggest an economic conceptualization of the innovation process which is different from that commonly used. The new innovation process starts from the simple premise that the application of new ideas towards production generates economic returns. The second step is to apply the new institutional economics to the new innovation process. The sale of ideas is subject to high transactions costs and the new institutional economics is uniquely suited to understanding these costs.

Transactions costs differ according to the characteristics of the idea produced and are partly ameliorated by the institutional legacy surrounding the inventor. (Institutional legacy meaning the general business culture surrounding the industry in which the inventor operates.) In light of these factors, contractual relations governing the exchange will adapt in ways which tend to allow a greater realization of the gains from trade.

The general conclusion is that if an idea is widely applicable, then contractual relations will develop which reduce transactions costs and allow greater gains from trade to be realized. These contractual relations will often involve organizational design or be implicit. Where trading occurs, legal institutions such as intellectual property play a supporting role. If the idea is not widely applicable the inventor will then try to embody it in a product and defend it from imitation. In this case intellectual property fulfills its traditionally assumed role of protecting the idea from imitators.

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CHAPTER ONE
AN INTRODUCTION TO THE ECONOMICS OF INNOVATION

1.1 INTRODUCTION:

This work was motivated by a recognition of the increasing importance of innovation in modern economies. One can see this in the fast changing face of industries such as microelectronics and biotechnology; in governments establishing technological development as a national priority; in corporation heads speaking of knowledge as their lifeblood; in the demise of blue collar labour and the steady decline of trade in commodities as a percentage of total trade. There is talk of new technology leading to the transformation of national economies and their integration into an international economy. Governments are articulating policies which assume that technological advantage translates into trade advantage[1]. New innovations are changing the face of economic structures and yet, despite this, there is an apparent inability on the part of policy makers and economists to arrive at a sound strategy to support technological advance. Strategy based on an understanding of the incentive structure that encourages innovation.

The stumbling block is that the microeconomics of the innovation process is little understood, and even basic questions, such as whether increased patent protection encourages or discourages further innovation, have not been clearly answered. Subtler questions are even less well understood. Economic analysis is only beginning to come to grips with the relationship between organizational form and

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1. For example, the US Omnibus Trade bill which establishes strong penalties on American trading partners who infringe US intellectual property rights. Or the increasingly stringent foreign takeover protection being given to companies with strong technical expertise.

innovative performance and economists do not yet understand phenomena such as consortia and joint ventures or their appropriate treatment under competition and intellectual property laws. It is not clear that economists have fully understood the underpinnings of innovative processes and for this reason our ability to prescribe policies which support technological advance is limited.

This thesis will attempt to address this shortcoming by exploring the ability of the new institutional economics to explain certain key phenomena involved with the economics of innovation. It will not attempt to answer the questions which neoclassical analysis has traditionally posed, so much as it will suggest a new conceptual framework from which to pose new questions. In brief, the implicit neoclassical model of technological innovation will be replaced by a more institutionalist approach which sees innovation as often the result of a process of idea trading. The degree and effectiveness of idea trading depends on the interaction of three factors: the nature of the idea; the institutional setting within which the trading is conducted; and the specific contractual framework within which exchange takes place. This thesis will apply transactions costs based theories of the contract and organization to idea trading institutions in order to generate an understanding of the role of patents, market structures such as joint ventures and consortia, and observed market behaviors. Unlike game theoretic approaches it will not model specific allocation problems but, suggest a general framework within which to set models and evaluate policy.

1.2 PURPOSE:

Traditionally, economists have attempted to model innovation much as they would any other problem. They assumed that an innovation is created by a single firm represented by its production function. Within such models

innovation is seen as an investment in a new process or product which firms may choose to undertake depending on factors such as the cost of the investment, demand conditions, the number of rivals, and, if the model is a sophisticated one, the ability of the firm to prevent the imitation of the new product. Such models are generally partial and static so that when the innovative episode is complete the innovating firm and industry return to an equilibrium condition.

Some of the unrealistic aspects of such model making have been pointed out, but because the objections did not fit into neoclassical thinking they tended to be regarded as largely descriptive and were therefore not considered. Thus, many admittedly important determinants of innovation performance were simply dismissed. This thesis will suggest a conceptual framework that not only allows, but often demands, that many of these determinants be included in the analysis.

The conceptual framework developed in this thesis begins from the idea that innovation often involves a process of idea trading and is not simply an instantaneous, serendipitous, event or the simple and direct outcome of an investment in R&D which is made when market conditions are right. The idea trading which produces innovation takes place both among firms and within firms. This approach also allows the consideration of innovations that are produced through the interaction of firms and other agencies such as universities and research labs.

Idea trading is conducted by a variety of means and occurs both between and within individuals and organizations. It is subject to considerable transactional difficulties and requires a host of organizational and sometimes complex contractual structures to support it. In order to understand the process of innovation it is necessary to understand the role of these institutions for

supporting and conducting exchange. It should also be noted that often they cannot be understood in isolation, but must be analyzed as a group of institutions which interact with one another.

The nature of the contribution made by the framework developed in this thesis can be illustrated by the following set of questions and answers:

1. Why do some firms joint venture and trade research results while others devote considerable resources towards protecting their ideas? With this analysis, inter-firm relations can be considered beyond simply the market exchange of components and products. Firm participation in consortia, joint ventures and licensing arrangements can all be analyzed for their ability to support idea trading.

2. What is the logic of the internal contractual structure of firms engaged in the generation of knowledge? Intra-firm contractual relations (organizational structures) can be analyzed for their ability to support the innovation process. Thus, firm re-organizations incentive plans and labour contracts are all amenable to this type of analysis.

3. What is the role of institutions governing idea trading? The role of institutions governing and supporting exchange can be analyzed within this framework. Old boy's networks, single source supplier agreements, trademarks, customs, reputations, professional organizations, universities, standards and ultimately, cultures can all be analyzed for their ability to support the exchange of ideas.

4. Why do firms continue to research areas in which they do not lead, and what is the economic utility of so-called failed research? Interaction among inventions and the role of complementary research and simultaneous research programs can be considered within this framework. This allows the explicit analysis of a firm's behavior within the context of its industry setting.

5. What is intellectual property used for? Why do firms patent when they do not find it a useful means of protection? Intellectual property can be assessed for conditions under which it is used to protect inventions

from imitation, and also those when it is used to support the trade of ideas.

In addition, the framework developed in this thesis leads on to an analysis of a number of policy areas. In general the analysis of policies to support innovation can proceed beyond considering the financial support to individual firms. The whole process of innovation can be considered and the potential sources of market failure which prevent ideas from earning a return highlighted. More particularly the following areas will be briefly discussed:

1. The uses of intellectual property, and the many contentious issues regarding its proper assignment and specification.

2. The treatment of cooperative research ventures, such as joint ventures and consortia under competition law.

3. Trade policy, particularly the effect trade of knowledge bearing goods and services on intellectual property, laws governing international investment, corporate law and trade law.

4. The modern university in its roles of producing and disseminating research in a knowledge intensive economy.

1.3 OUTLINE:

To achieve these purposes it will first be necessary to survey and critique much of the existing literature. This is not a simple task because the literature pertaining to innovation is both varied and still in the process of development. It draws upon many different aspects of economics including property rights analysis, the economics of information, game theory, transactions costs analysis and institutional analysis. The major lines of research concern (1) The general issue of how firms capture the returns from invention; and (2) game theoretic modelling of the incentives to create and diffuse invention under specific conditions. The essential problems addressed are the relationship between appropriability, diffusion and the

timing of invention and how these are linked to market structure.

After outlining the main issues found in this literature the thesis will move on to the attempt to develop a more general framework; one in which innovation is seen as largely the product of an idea trading process.

The task begins by reformulating the standard economic description of the gains from invention. Economists usually model invention as a cost reducing process in which the innovating firms earn all of their returns from invention through reduced production costs. More sophisticated models might also incorporate qualitative improvements in existing products. This standard approach will be broken with in two ways. In the first place a broader view of invention will be taken, encompassing more than just production technology. Thus, it is not only advances in technology or science which generate economic gains. Advances in management techniques, advances in personnel management or advances in our understanding of how organizations function all may generate economic returns and be amenable to the type of analysis which is developed here.

In the second place, it is argued that the greatest possible potential returns from innovation or any "new thinking" are generated when that new thinking is made available to all those firms who can make use of it.[2] This concept is broader than merely noting the possibility of complete licensing of inventions because it involves the notion that inventions themselves are assembled ideas.[3] While an invention per se may not be of use to a particular firm, some of the ideas which created or are contained

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2. This is a conclusion which has also been partially reached by game theorists such as Shapiro,(1985).
3. This simply chooses to overlook a more fundamental philosophical problem as to what constitutes original thought and what has generated the impetus for developed nations to pursue technological advance.

within that invention may be. The usual approach generally allows only for the licensing of a given invention. The approach developed in this thesis is broader in that it focuses on how resources are allocated to the production of different types of ideas and the various ways in which these different types of ideas are traded among firms.

The use of transactions costs reasoning allows a reformulation of the traditional economic problems related to innovation. Current neoclassical discussion of misallocation problems will be translated into transactions costs problems. This will allow existing questions to be placed within a common framework and permit a more consistent analysis of the issues raised by innovation.

Having reformulated the standard treatment of the gains from invention, the thesis will then apply transactions costs reasoning to the trading of ideas. The reasoning behind this runs as follows: All economic actors produce new ideas based on the potential gains from doing so. If an idea is of economic value there exists an incentive to find some means of realizing these returns. Currently, returns are modelled in one of two ways: (1) either ideas are incorporated into products and rents are earned based on the advantages these ideas generate, or (2) ideas are sold to whomever can make use of them.

The thesis will build on this reasoning in two ways. Firstly, it will identify conditions which determine which of these means will be chosen. This can have important consequences as the two different methods demand very different policy responses. Secondly, the terms under which ideas are traded will be analyzed. This will not consist of a traditional game theoretic approach in which the number of rivals and imitation costs are modelled, but will instead be an analysis of specific exchange difficulties generated by the properties of the idea itself. In this, emphasis will be placed on means of reducing the transactions costs

associated with trading different types of ideas. The study of transactions costs reducing devices will show that the assignment and scope of property rights, the contractual stipulations by which exchange is conducted and the institutional and historical context under which exchange is conducted can all have important effects on transactions costs. This suggests that employee contracts, the rules governing a university, and the stipulations of a patent licensing agreement can all be analyzed within the same terms. The approach can also integrate the decisions made by firms and the decisions made by individuals within the same analysis. In the tradition of Cheung (Cheung, 1983), it can be argued that a firm is a nexus of contracts. Both its external and internal relations are exchanges governed by contract. Both individuals within the firm or the firm itself can be analyzed as economic actors who are seeking to set contractual forms within institutional structures to assure themselves a return for the ideas that they produce. For this reason, the analysis will alternatively draw upon examples of individual and firm behaviour.

The analysis of transactional difficulties in the exchange of ideas leads to the explicit consideration of the various points identified in the previous section. The method will be to consider the nature of the idea itself, the current institutional setting (largely the history of the industry it and the nature of intellectual property rights in that class of invention), and, from this, analyze the contractual stipulations (both historical and market) by which returns are earned.

Finally, some preliminary observations concerning the explanatory power of this approach will be offered. These will be drawn largely from the business literature where many existing phenomena seem to defy standard economic reasoning. It is hoped that by demonstrating how amenable these problems are to the transactions costs approach this

thesis will provide some guide for future empirical testing and suggest new avenues for the application of game theoretic modelling.

1.4 TERMS AND DEFINITIONS:

A number of terms should be explicitly introduced here because they have specific meanings in the context of this thesis. The first three are the idea, the invention and the innovation. An idea will be roughly described as being the new knowledge which suggests an invention is possible. Ideas are the conceptual basis or ingredients of an invention. An invention may be comprised of a number of ideas while individual ideas may or may not be applicable to other inventions. This thesis will use a definition of invention similar to the one used by the Patent Office; an invention is any working prototype or physical embodiment of ideas in some novel way. However, the definition of an invention is not limited to that which is patentable. That which is patentable may exclude certain categories of goods and requires that the invention be describable in a legal sense. This thesis, being a discussion of economic theory, will employ the simple definition that that which is new is an invention. An innovation is the marketed product which embodies an invention. Thus, an invention and an innovation may in some cases be one and the same while in other cases there may be marked changes between an invention and an innovation in terms of design and incremental improvements. In concrete terms the invention of a new pharmaceutical may be very nearly the same as the innovation of a new pharmaceutical while in other cases, such as VCRs, the innovation bears very little resemblance to the original invention.

Property rights in inventions and ideas are generally captured by the generic term intellectual property. Intellectual property takes the form of patents, copyrights,

trademarks, tradenames and trade secrets. Of these only copyrights, patents and trade secrets need be explicitly considered here. Patents have a very strict definition supplied by law but will be defined here as the right to exclude others from an invention. They are not actually property rights over an idea but rather rights over an invention. The right to exclude others from applying the underlying idea in the marketplace is merely their practical result. It should be noted that recent court decisions regarding the patentability of mathematical algorithms and the like have made them much closer to being a formal property right over an idea.

Copyrights are more specific than patents. They are not property rights over an idea so much as they are property rights over a given expression of an idea. Thus, anyone is free to use a copyrighted idea although this generally is acknowledged by a citation. It is generally necessary to obtain permission before using the copyrighted expression of an idea except in the case of academic work. A possible explanation for this exclusion will be made in the course of this thesis.

Trade secrets are quasi-intellectual property. In Canada, the development of full fledged trade secrecy rights is limited by constitutional difficulties. Some provinces however have considered implementing their own trade secrecy legislation but generally trade secrets are afforded legal protection through resort to the common law tradition.

In its simplest terms the process of technological advance can be characterized by three steps; invention, innovation and diffusion. Invention is the development of a new and possibly patentable device or process which employs some new art or is built upon some new knowledge: New knowledge any new idea, new combination of ideas, or use of existing ideas which generates a hitherto unknown application. The second step is the development of an

innovation. This is the process by which the invention is developed into a product or process that is capable of earning returns in the marketplace. The last step is the diffusion or dissemination of the invention. This is the process by which the invention is made widely known. Some theorists propose intermediate steps to these three, such as the commercialization of invention, but for the purposes of this thesis a finer breakdown is not necessary. Management theorists also speak of real time feedbacks among these various steps, and the implications that these feedbacks have for the innovation process, but this need not be developed here. What should be noted however, is that the first step of invention often draws upon basic research or scientific knowledge which was not immediately intended for commercial application. This knowledge may have originally been developed simply to provide a greater understanding of basic scientific principles. The act of invention might be considered in part, but only in part the application of such principles. Often, an invention can itself spark the revelation of new scientific principles and reverse this process (Dosi, 1988). For clarity of expression the term R&D will be used to denote all research activity whether it is basic research, invention, or development. The term innovation has unfortunately taken on a dual meaning, sometimes referring to the intermediate step of making a marketable product from an invention and sometimes referring to the whole process of technological advance. It will be used here in its narrower meaning.

Lastly, some words should be offered about the use of terms such as perfect information and optimality. This thesis is drawn from a diverse body of theory, much of which is rooted in game theoretic modelling of specific transactional difficulties. Within these games, firms generally face an allocation problem that is resolved by one or two stage decisions, at which point some conceptual

equilibrium is imposed (based on a definition of what is optimal within the context of the game). The point is not to argue about the real world validity of these game theoretic models because they are admittedly partial and based on an incomplete specification of the problems facing an actual firm. It is when these results are used in a general analysis of the innovation process that larger methodological problems emerge, particularly in the assumptions relating to knowledge and information.

To circumvent these difficulties it should be noted that by definition there cannot be perfect information in a world where invention is still possible. Likewise, if invention is still possible we cannot be in an equilibrium world, even if much of our understanding of it is rooted in optimization and equilibrium concepts. Perfect information in the context of this thesis should be interpreted only as meaning the absence of transactions costs or a situation in which all gains from trade are realized given a level of technological knowledge.

It should also be noted that while much of this thesis is drawn from equilibrium analyses, innovation implies a world of constant change. One consequence of technological change will be ever changing decisions regarding what information is now relevant and what should now be acquired. This will in turn largely drive the patterns of technological development over time. The complexities of this issue preclude it from being considered here. Instead the analysis will be limited to a more static world of conceptualizing the gains of idea trading and identifying the mechanisms by which ideas are traded and earn returns. The evolution of technologies and trading arrangments in an innovative world would be the subject of another thesis.

CHAPTER TWO

THE TRADITIONAL LITERATURE

This section is not intended to provide a history of economic thought related to innovation. It is instead a brief synopsis of the evolution of economic thinking related to patents, market structure and innovation. The purpose is simply to indicate what has been accomplished, the specific issues that have been raised and to note some anomalies that have arisen in the development of the economics of innovation.

2.1 MARKET STRUCTURE AND INNOVATION:

2.1.1 Schumpeter: The origins of the economic analysis of market structure and innovation are found in the work of Joseph Schumpeter (Schumpeter, 1975). Schumpeter's work is often discussed because he rejected the welfare prescriptions of orthodox equilibrium analysis. Because it focuses on non-static aspects of economic organization it has never been fully incorporated into mainstream economic reasoning. Attempts to do so have been limited to the formulation and testing of some specific hypotheses outlined below.[1]

The greatest distinction between Schumpeter and his contemporaries is probably to be found in his view that non-

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1. These "Schumpeterian" hypotheses were never articulated by Schumpeter. They were instead derived from a reading Schumpeter and were really an interpretation of Schumpeter by the neo-classical economists of the day. There is some argument that these hypotheses cannot be properly attributed to Schumpeter as Schumpeter can only be understood if placed in his own context. Kamien and Schwartz, for example, argue that the term Schumpeterian hypotheses is not an accurate one (Kamien and Schwartz, 1982). Certainly, reinterpretations of Schumpeter go on to the present day. For example, Nelson and Winter argue that their evolutionary framework is really an extension of Schumpeter (Nelson and Winter, 1982).

perfect market structures are more supportive of economic welfare. This argument is linked to Schumpeter's view that to truly understand the workings of a modern economy it is necessary to focus not on the forces of stasis but instead on the forces of change. Schumpeter disregards resource allocation at a given point in time and concentrates instead on the sources and effects of technological innovation.

According to Schumpeter, the consequence and the source of technological innovation are non-perfectly competitive market structures. A degree of monopoly power is something individual firms try to achieve through innovation and is also a necessary condition for investment in innovation to proceed. On this basis Schumpeter rejects the orthodox welfare prescriptions that favour perfectly competitive markets. He notes that their focus on static price and output decisions ignores dynamic effects, effects that in the long run have a far greater impact on overall economic welfare. To Schumpeter, the strength of capitalism arises not from static efficiencies but from its ability to support constructive change. Capitalist efficiency is created by successful innovation. Schumpeter uses terms such as "creative destruction" to describe cycles of technological change which destroy old monopolies and create new ones. Needless to say this work directly challenges static welfare economics and its principles of welfare maximization. This is put quite forcefully by Schumpeter in the following passage.

> A system that at every point in time fully utilizes its possibilities to its best advantage may yet in the long run be inferior to a system that does so at no given point in time, because the latter's failure to do so may be a condition for the level or speed of long run performance. (Schumpeter, 1975 pp. 83).

Schumpeter's idea that monopolistic structures are a result and a necessary condition for the support of

innovation became the basis of a number of so-called "Schumpeterian Hypotheses". Although not really Schumpeter's work, but only interpretations of it, they were important for developing an economics of innovation, particularly because of the empirical testing they generated. There are generally three important Schumpeterian hypotheses cited: (1) That there is a positive correlation between firm size and innovative performance, (2) that there is a positive correlation between concentration and innovative performance, and (3) that there is a positive correlation between the diversification of a firm's product line and innovation (Scherer, 1986).

Schumpeter's work also sparked a number of responses to his welfare conclusions. Three important lines of argument can be found. One is that technological innovation is not an economically motivated activity (although this is accepted by Schumpeter as being at least partly true), and that innovation does not therefore require monopolistic structures. However, the establishment of industrial research labs seems to refute this hypothesis.[2] Such labs suggest some innovation is economically directed both from the individual perspective of hired researchers and from the perspective of the firms who hired them and directed their research into potentially profitable areas.

The second line of argument suggests that the policy which produces an optimal static allocation of resources will also produce an optimal dynamic allocation. In this case, even if Schumpeter is right about the importance of dynamic efficiencies, the conclusions of the static analysis still hold. This provides an additional reason for testing the Schumpeterian hypotheses. If no connection is found between innovative performance and market structure, even if

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2. For example, the Bayer lab was established in 1874 and others quickly followed (Kamien and Schwartz, 1982).

the gains generated by increased innovation outweighed those of static efficiency there would be no reason to abandon the pursuit of static efficiency.

The third argument is to concede that the conditions producing a dynamic optimum and a static optimum are different but that this does not matter because the gains from dynamic efficiency are far outweighed by those of static efficiency. This is a difficult argument to assess because economic analysis has not yet developed the tools necessary for measuring the gains achieved by policies pursuing dynamic efficiency.

2.1.2 Arrow: The theoretical foundations of the modern economics of innovation can probably be attributed to Arrow. Arrow's (1962a) paper was the first widely disseminated work to analyze the incentives to innovate under different market structures. Arrow modelled the incentives of both monopolies and competitive firms to buy innovations from independent inventors. In some respects, he provided a finer specification of Schumpeter's earlier arguments.

The Arrow model presents invention as a device which reduces the costs of producing a given product. Thus, invention translates into increased profits for whomever licenses it. Arrow models the different incentives facing monopolistic versus perfectly competitive firms to buy a given invention, and notes that total cost savings will be higher amongst competitive firms due to their higher outputs. Therefore, competitive firms have a greater incentive to purchase an invention. In the inverse case, Arrow also notes that an inventor who licenses to a competitive industry could earn greater returns than an inventor licensing to a monopolistic industry. Thus, invention is probably directed towards more competitive industry structures.

However, in Arrow's view, neither a monopolistic nor a competitive firm captures all the social returns from

invention and underinvestment in R&D results (Arrow, 1962a). He considered problems such as non-divisibility and the need to inspect the idea before selling to be too great. Arrow suggests government intervention as the solution.

This work, while important is based on assumptions too narrow to generate any firm conclusions. Firstly, Arrow hypothesizes that the returns to invention are comprised solely of the cost savings which accrue to the firm acquiring the innovation. He does not model the welfare effects created by new products or new applications of the invention. Secondly, he addresses only the incentives to license inventions. A more complete model would also have to address the incentives required for monopolistic and competitive firms to actually produce inventions.

Harold Demsetz takes issue with Arrow's conclusion regarding the greater incentive of competitive firms to purchase inventions (Demsetz, 1969). Demsetz has two caveats. He notes, firstly, that Arrow makes no allowance for scale effects. Demsetz argues that Arrow confuses the distinction between competitive industries and competitive firms. A purely competitive industry will produce a larger output than a monopolistic one but a competitive firm will account for only a small fraction of this industry output. An individual monopolist firm will therefore produce a larger output than an individual competitive firm and will have a correspondingly higher incentive to license an invention. Secondly, Demsetz argues that Arrow's model contains the implicit assumption that the firm is unable to price discriminate. A monopolist that can price discriminate will have no incentive to constrain output because its maximum profits will be earned by producing all outputs for which price exceeds marginal cost.

2.1.3 Barzel: Barzel addresses the issue of costs in innovation and introduces the "rush to invent" thesis (Barzel, 1968). By introducing the cost side there can be

either too little or too much invention within a given time period.

Barzel builds his analysis around the stream of benefits earned by an invention. These can be reduced to a present value by discounting over time. Thus, an invention which is produced later will have a smaller present value than the same invention produced earlier. Barzel then reasons that a firm can choose when to introduce an invention or innovation. The earlier they choose to introduce it, however, the more costly it becomes.[3] Thus, a firm will choose to introduce an invention earlier, and incur the higher costs, only in cases where these higher costs are not more than the addition to present value. The maximum net present value earned by an innovation Barzel terms the rents from innovation.

Barzel's concern is that under conditions of strong competition firms will compete to earn these rents. If a patent is awarded to the firm that is first to produce an invention, so that that firm will earn all the associated rents, firms will have an incentive to speed up the timing of invention so long as rents are potentially earnable. This will continue until inventions are produced so early that all rents are dissipated. The rush to invent is very much like the common pool problem in the economics of the fishery.

Barzel thus reaches the opposite conclusion to Arrow. He finds that too many resources will be devoted to invention and, implicitly, invention will be skewed towards that which is patentable (patent races). Also, because a monopoly retains the incentive to maximize the rents from invention, a monopoly probably came closer to producing an optimal allocation of resources than does a competitive market.

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3. This cost time tradeoff was subsequently verified by Scherer (Scherer, 1986).

2.1.4 Scherer: Scherer's contribution to the understanding of the relationship between market structure and innovation began with his empirical tests of the Schumpeterian hypotheses. Scherer uses patent statistics as proxies for R&D output and R&D spending or R&D personnel employed as proxies for R&D inputs. He regresses these against other proxy measures for firm size such as sales, number of personnel and asset size (Scherer, 1986).

A number of factors such as different science bases among industries complicate the analysis, but Scherer concludes that there is no solid evidence to back the hypothesis that firm size is positively correlated with innovative output. Similarly, Scherer uses concentration measures as a proxy for market power and finds only limited evidence to support the hypothesis that market power is positively related to innovative performance (Scherer, 1965, 1967). He does find supporting evidence for the third Schumpeterian hypothesis that more diversified firms tend to be more innovative.

These tests raise questions related to the data adjustments needed to account for inter-industry effects, and the validity of using patent statistics as indicators of innovative output. Regarding industries, it has been noted that different industries have different opportunities to draw from underlying science in developing their innovations. Differences in the underlying demand also need to be accounted for. This is a recognition of the argument made by Schmookler that innovation is demand driven (Schmookler, 1966). Regarding patent statistics, it is now accepted that the propensity of firms to patent is not uniform through all industries (Scherer, 1983). The consequence of this is that where the propensity to patent is low, patent statistics will underestimate innovative performance, and where the propensity to patent is high they will overestimate innovative performance. It is also the

case that successful patent grants do not necessarily measure the same quantum of invention. If a particular industry or firm is biased towards patents containing a particular quantum of invention then patent statistics will be biased proxies of innovative performance and the Scherer results will not be valid.

Scherer and others such as Grilches (Grilches, 1986) have worked on refining empirical techniques in order to overcome these difficulties. This work attempts to isolate the effects of market structure on innovative performance by accounting for all other factors which might theoretically affect innovation. For example, one commonly isolated factor is the underlying level of science upon which the industry can draw for applied research. The reason for including a science base variable is that industries which can draw upon a substantial body of publicly funded R&D are able to improve the efficiency of their own R&D and thus have a greater incentive to perform it. Closely related to science base variables are measures which account for the closeness of the science to the commercialization stage of production. Also significant are measures which account for the relative maturity of the industry. The hypothesis being that more mature industries are better able to utilize an underlying base of publicly funded science. Market variables such as projected demand growth are also proxied. This again is a recognition of Schmookler's argument that there are stronger incentives to do R&D in industries with strong demand growth prospects.

The studies by Grilches do not always give good consistent results. A general conclusion is that there is a weak tendency for companies to perform more R&D (as measured by budgets and personnel) relative to firm size until a large size is reached, at which point the ratio of R&D expenditures to firm size begins to decline (Scherer, 1986). When patents are used as a proxy measure for innovative

output, it is found that past a relatively small size the return per dollar spent on R&D begins to decline quickly (Kamien and Schwartz, 1982). Studies on the effects of concentration on R&D performance also produce mixed results. Some researchers find a mildly positive relationship while others find it negative (Kamien and Schwartz, 1982).

2.1.5 Game and Decision Theoretic Approaches:. The origins of the game and decision theoretic approaches to the relationship between innovative performance and market structure are found in Kamien and Schwartz (1982). They model the incentives to invest in innovation under various conditions of rivalry, employing different assumptions regarding the ability of rival inventors to duplicate invention and the degree to which investment in innovation is a sunk cost. The basic Kamien and Schwartz model is a "winner take all" race to invent, where the gains from invention are modelled as cost savings in a given production process.

Despite the variations in the assumptions employed one consistent conclusion emerges: Neither pure monopoly nor perfect competition are most conducive to innovative performance. Both structures produce incentive conditions which result in a misallocation of resources to invention. Perfect competition implies that it is not possible to earn above normal returns or rents and therefore no investment in invention will take place. Monopoly allows for the appropriation of rents but a monopolist would always underinvest in innovation because he would be earning these rents over a less than optimal output. Therefore, as structures become less monopolistic, both output and the potential rents grow accordingly and as the potential rents grow the incentives to invest in invention also grow. At the same time, increasing competition would reduce the appropriability of the potential rents from invention and thereby reduce the incentives to invest in invention. While

Kamien and Schwartz identify medium levels of rivalry as better for innovative performance, they could not identify a precise degree of rivalry as being socially optimal. In their models the optimal degree of rivalry changes as they employ different assumptions.[4]

There are caveats to this analysis. The early Kamien and Schwartz models assumed away the degree to which investment in R&D is a sunk cost and the degree to which a firm entering into a patent race can shift the direction of its research. By changing the assumption that investment in R&D is a sunk cost that will either be recouped or lost depending on the outcome of a patent race, these models generate different results.

These new models yield more ambiguous results and in light of this, Kamien and Schwartz hypothesize that there is no determinate causal relationship which leads from market structure to innovative performance (Kamien and Schwartz, 1982). They replace this relationship with a model in which market structure may affect innovative performance while successful innovation may also affect market structure. They go on to suggest that industry structures might be characterized by stages of development corresponding to the life cycles of technologies. This reasoning suggests that each technology has a life cycle and over the course of this cycle an industry evolves from a highly competitive structure characterized by drastic innovation and leapfrog technologies into a monopolistic one with innovation characterized by more routine inventions and improvements. Possibly some industries operate under an oscillating equilibrium which is triggered by successive waves of technological opportunity. The development of the transistor and then the integrated circuit might serve as

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4. For example, the degree to which investment in the invention is a sunk cost is an important consideration. The number of rivals and size of the potential payoff are also important factors.

examples of waves of technological opportunity which affected the consumer electronics industry.

2.2 TRADEOFFS BETWEEN INVENTION AND MONOPOLY:

Closely related to theoretical advances in the economics of innovation were advances in the economic understanding of patents. There are various strands to this literature, although all generally assume that patents protect against imitation and thereby ensure a kind of monopoly protection to the inventor. As will be seen the earliest conjectures concerned the relationship of patents to the incentives to invent. This gradually began to be replaced by an explicit consideration of how patents worked and what their real role in the innovation process was.

2.2.1 Arrow: Arrow's analysis of the innovation process (Arrow, 1962a, 1962b) was a watershed in the understanding of the economic role of patents. Although he does not specifically address the role of patents, Arrow does provide an assessment of the incentives to invent. It is Arrow's view that underinvestment in invention is inevitable under a normal market.

Arrow addresses the issue of how inventions are sold or licensed. He notes three problems particular to the sale of ideas. Firstly, capital markets are not likely to allocate sufficient resources to invention because invention is inherently risky. He argues that devices which theoretically separate risk from investment decisions are not sufficient to overcome this problem owing to indivisibilities. Indivisibility of invention also creates a second problem in that efficient marginal cost pricing is not possible. Once again a number of alternative pricing schemes such as lump sum extraction could in theory circumvent these difficulties but Arrow doubts their real world feasibility (Arrow, 1962a). Lastly, Arrow notes difficulties exist in appropriating the returns to

invention. This is an important point as it has become a critical issue in the economic debate concerning the patent system.[5] In addressing this problem Arrow defines several characteristics of knowledge which make it difficult to sell: it is difficult to measure its contribution to value, it is difficult to exclude others from obtaining knowledge of an invention once this invention is employed, and it can not be assessed without also being transferred. According to Arrow, such difficulties result in considerable underinvestment in innovation. Arrow's solution is direct government investment in innovation.

While in 1962, the analysis of such transactional difficulties was in a very rudimentary state, it is clear that Arrow successfully identified a new avenue of study. To understand the allocation problems posed by investment in innovation it is necessary also to understand the transactional difficulties in the selling of ideas.

Arrow's work also indirectly raises the issue of whether patents do allow inventors to earn a return on their efforts (Arrow, 1962a). Most analysts simply assume the answer is affirmative, assuming that a patent gives the inventor an effective ability to exclude imitators. After Arrow, studies into the efficacy of patent protection demonstrated that this was not usually the case (Levin, 1986). For example, the patent on the FM radio failed to deliver protection from imitators (Iandario, 1988).

2.2.2 Nordhaus: Nordhaus's optimal patent term (1969) attempts to provide a framework for analyzing the misallocation patents impose versus the incentive they create for greater investment in innovation. The Nordhaus model assumes a perfectly appropriable return to invention, with no dissipation of the rents from invention or social

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5. See Richard Levin, Alvin Klevorick, Richard Nelson and Sidney Winter (1987) for an account of the pivotal role played by various appropriability conditions in determining appropriate patent policy.

benefit generated from wider diffusion of the patented invention. Nordhaus models the gains from invention as a cost reducing process. He uses these gains as a benchmark for a comparison of the losses and gains generated by patents. According to Nordhaus, a patent creates a greater incentive for invention and therefore welfare gains but also creates welfare losses because patent grants cause the firm receiving them to monopoly price. The optimal patent for one industry therefore maximizes the difference between gains from increased innovation and welfare losses from increased monopoly.

To design this patent Nordhaus conceptualizes both gains and losses as flows occurring over time. The sum of cost reducing savings delivered to the firm by successful innovation are compared to the sum of costs imposed by monopoly distortions. The optimal patent is that term which just allows the inventor to earn sufficient returns.

2.3 MISALLOCATION PROBLEMS

By the early 70s three misallocation problems related to innovation and patents had been identified and analyzed: (1) the race to invent which dissipates all the rents from invention[6]; (2) incomplete diffusion of invention because patents create a monopoly over invention and; (3) the appropriability problem.

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6. This was originally modelled as a process in which costs and time could be traded off in producing an invention. Thus an invention could be produced earlier but only at the price of a markedly increased cost. Presumably, this reflected diminishing productivity with regard to researchers and attempting to rush a project before the scientific base was produced. That a time cost tradeoff existed was verified empirically by Scherer (Scherer, 1986). A second strand to this theory noted the increased duplication of research effort which a patent race caused and the effect of this on social costs (Kamien and Schwartz, 1972).

2.3.1 Patent Races: Edmund Kitch and Carole Kitti, (Kitch, 1977; Kitti, 1973) each attempt to deal with rent dissipation by considering the patent system's possible role in forestalling the race to invent. Kitti's model uses the Nordhaus framework and specifically considers the race to invent in terms of a patent race. She reasons that reducing the protection offered by patents reduces the private rents an invention earns and that this in turn, reduces the incentive to dissipate the rents by engaging in a patent race. If patent protection were sufficiently reduced then only the socially optimal level of R&D investment would take place (Kitti, 1973). Kitti suggests two alternative means by which the patent system could be modified to reduce the potential rents: (1) reducing the patent term and (2) awarding a patent with a probability of less than one.

Kitch argues that a patent's primary purpose is not to protect invention from imitation but to create a stable environment for investment in the development of invention (Kitch, 1977). To Kitch, a patent race is analogous to a gold rush, and therefore, the proper metaphor for a patent is a mineral prospect. Just as a mineral prospect gives a miner the sole right to develop and extract ore from a site if a find is made, a patent grants the sole right to develop innovations from an invention should commercial applicability be found. In the absence of a mineral prospect, there would be inadequate exploration and in the absence of a patent there would be inadequate research. In both cases this is due to a free rider problem.

Kitch develops further analogies with natural resource problems. Common pool problems are often associated with natural resources. If, for example, competing firms are all exploiting an oil pool it will be depleted too quickly. Similarly, if competing firms hope to exploit the same technological area they will overinvest resources in its development in an attempt to capture its potential rents.

To support his arguments Kitch notes that patents tend to be given for inventions long before they become commercially viable. He cites examples where a number of years elapsed between the time a patent was first granted and the time in which a product based on the patent became available (Kitch, 1977, pp. 272). Patents deliver to the grantee the sole right to develop an invention. The patentee can invest in the development of the invention with more security because he alone will be in a position to profit from his improvements.

Kitch's analysis of the patent has been attacked. A successful patent grant may trigger races to innovate rather than forestalling them. A successful patent also motivates inventors to acquire "blocking patents" around the new technology[7]. Because of this firms may choose not to patent rather than signal to their rivals that they have found a new area of potential exploitation (Horstmann, MacDonald and Slivinski, 1985). A more analytical answer to Kitch is found in models which demonstrate that patents serving as prospects do not necessarily forestall premature innovation (McFetridge and Smith, 1980). These models show that patents serving a prospect role could simply lead to the rents from innovation being dissipated by a prospect race.

2.3.2 Inappropriability of Invention: Appropriability of invention is the ability of the innovating firm to capture the economic rents from successful innovation. The degree to which an invention is inappropriable will affect the accuracy of the models that assume perfect appropriability.

Within industry the common sense view has long been that patents do not provide for the complete appropriability of invention, but the formal analysis of inappropriability stems from Scherer's work on the Schumpeterian hypotheses.

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7. This is often noted in rapidly advancing industries is one of the issues raised in defining the appropriate intellectual property protection for biotechnology (Buchanan, 1988).

Scherer's studies find that the relationship between R&D spending and patent output is not a constant one (Scherer, 1983). It is not constant either among firms or among industries. As noted above, Scherer's use of patent statistics as measures of innovative performance can be criticized because no adjustments are made to account for differences in the propensity to patent. In response to this, Scherer has argued that differences in the propensity to patent are the result of differences among firms and industries in the degree to which patents protect their inventions from imitators. This, in turn, has resulted in the degree of protection that patents actually offer being scrutinized. One result (which is consistent in studies of this kind) is that, in most industries, patents are only moderately useful in protecting inventions from imitation. Nevertheless, while many firms do not find patents to be an effective means of protection they continue to patent the bulk of their inventions (Scherer, 1983).

These findings obviously lead to the questions: Why do firms patent if they do not find patent protection effective? How do they appropriate the returns to invention when patent protection is not effective? These questions cast the existing theory concerning patents into doubt by suggesting that the assumption that patents are taken out only to protect inventions from imitators is not accurate.

Several theorists have investigated the effects of nonperfect appropriability of invention, but the precise effects on innovative performance and economic welfare are difficult to determine. Firstly, as Kitti (1973) points out, nonperfect appropriability reduces the potential welfare losses created by patent races. By reducing the potential rents that are privately available to less than the total social rents, some social rents are preserved from rent dissipating behavior. Secondly, imitation of invention is also diffusion of invention, and a number of models

suggest that it is the diffusion of invention that produces economic gains (Jaffe, 1986). In layman's terms there is a push-pull effect on invention created by appropriability through patent protection. Effective patent protection may exert a pull effect because it creates an incentive to invent but at the same time it reduces the push effect because the underlying science to support further innovation is made less freely available.

In short, appropriability is difficult to analyze. Appropriability can only be understood in the context of other determinants of R&D performance. It is often noted that innovation proceeds in many cases where patents are not deemed to be a useful means of appropriability. Clearly, while some degree of appropriability is a necessary condition for innovation to take place, the relationships involved are subtler than originally presumed.

Empirical work suggests that patents are seldom an effective means of providing for the returns to invention (Mansfield, 1986 and Levin, 1985, 1987). Only with pharmaceuticals and specialty chemicals are patents found to be an effective means of protection. This work also suggests a number of possible alternatives to patent protection. This overlaps with the industrial organization work on barriers to entry, as barriers to entry can be used to protect invention from imitators in the same fashion as patents. Thus, in industries where patent protection is poor, large barriers to entry are expected. Levin (1985) identifies four specific barriers to entry that also ensure appropriability.

a) Trade Secrecy. Trade secrecy actually falls somewhere between a property right and a business practice. It might be conceptualized as a property right since trade secrets are permitted some protection under the law although these rights are incomplete relative to patents. A trade secret, for example, must be actively defended by whoever

holds it[8] and if it is discovered by a rival who employs legitimate means to do this, this rival may also employ the trade secret.[9]

From the perspective of the individual firm trade secrets have advantages and disadvantages relative to patents. While they are not as exclusive a privilege as a patent they are also not limited by patent examiners who arbitrarily set their scope. A trade secret effectively protects as much knowledge as a firm is able to hide. They are also not limited in their term as patents are and they are not subject to restrictions regarding what is an allowable trade secret. Also, there is no disclosure requirement. Patents are sometimes subject to arbitrary changes in their scope due to a patent challenge, the loss of an infringement case, or court sanctioned compulsory licensing.

Logically, it would be expected that trade secrecy would tend to be employed in cases where an invention is difficult to reverse engineer. However, as neither trade secrets nor trade secrecy licensing agreements are registered it is difficult to verify this empirically. Even the extent to which trade secrecy is practiced is difficult to estimate. Likely, a large number of trade secrets are not even consciously defended but are instead simply part of the corporate culture of the organization. This makes even survey data of doubtful value.

b) Learning Advantage. A firm can protect its inventions if it is prohibitively costly for a rival firm to

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8. To be afforded legal protection in the case of a stolen trade secret the firm holding it must prove that it took active measures to defend its property.
9. For example a trade secret which a rival discovers through reverse engineering is available for that rival to use. If he were to discover the same trade secret through industrial espionage the right to employ that trade secret would not be legally recognized.

acquire the technological expertise needed for imitation. There are two possible ways some kind of learning can make imitation prohibitively costly. First, if the learning curve is steep and the technology in a given industry is very costly to acquire then even a small technological advantage will be very difficult to overcome.[10] Secondly, even where the learning curve is not so steep protection may be afforded by developing expertise in a broad area of related technologies.

This reasoning suggests that where learning advantage is being employed as a means of ensuring appropriation of the returns to invention two distinct industry types are expected. In fields such as the design of microchips where the learning curve is very steep firms might be expected to be constantly innovating but be limited to a narrow field. In industries such as plastics where the learning curve may not be so steep firms would be expected to participate in broader market niches, offering, for example, a full range of materials rather than just single products.

Of course, learning advantage is only an advantage in cases where potential rivals can be assured that this advantage will be maintained. The firms involved will be constantly innovating in order to assure continued dominance of their technological cores.

c) Lead Time. Lead time is a similar concept to learning advantage. Lead time implies that firms appropriate the returns to invention by being the first to bring the innovation to the market. The focus in industries which employ this device will be on time. Firms will seek to minimize the time it takes to translate an invention into an innovative product and will then wish to saturate the market with this product as quickly as possible. By the

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10. The steep learning curve refers to a technology which is very difficult to master and hence to acquire the competence necessary to compete in such a market is prohibitively costly.

time an imitation product hits the market the innovator will have earned a substantial rate of return and have reduced the size of the market remaining for potential rivals.

This suggests that firms relying on lead time as a means of earning the returns on investment in innovation will tend to be vertically integrated into the distribution and retailing of their products. They will be able to quickly saturate the market when the product is ready. Products in such industries will likely have a short design life and be characterized by constant improvements.

The method is likely to be favoured in those industries where inventions tend to be of a routine nature. More drastic inventions will have larger potential rents and will require more lead time to be realized by the innovating firm.

d) Product Bundling. Product bundling implies that firms will use what has been traditionally regarded as a barrier to entry in order to ensure the returns to invention. Firms using this technique will sell their innovations in packages, bundled with other complementary goods, making substitution more difficult. This technique might be expected in conjunction with other methods such as the development of a new industry standard.[11]

Firms employing such a technique might be expected to exert substantial control over the retailing and servicing of their products. Related to this technique would be the heavy investment by the innovator into brand names and other such devices used as barriers to entry.

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11. Compatibility standards are an especially effective means of ensuring product bundling. Standards in this case mean the customer must buy the whole package or none of its individual components will be of use to him. For example, a piece of computer software may only function with a given piece of hardware or parts for a given product may not be substitutable with those of another product.

2.3.3 Diffusion: Traditionally, patents have been seen as restricting diffusion by preventing imitation, but the social gains from an invention depend in large part on the broad diffusion of that invention. The diffusion of technological information affects both innovative performance and economic welfare over time. In the case of the integrated circuit the full benefits were only achieved after the invention was widely diffused. Furthermore, the diffusion of this invention provided a major impetus to subsequent diffusion as knowledge of the invention spread.

Diffusion can take a number of avenues. A successful invention or innovation may create social gains if it does no more than direct subsequent research efforts. For example, the successful discovery of a new superconducting material may spur on new efforts to experiment with similar materials and find means of applying these materials to commercial uses. Diffusion of information can also lead to a better coordination of research among research firms, a critical factor with research that is costly to conduct. Diffusion need not lead to new inventions. It can also lead to the application of new technologies or manufacturing processes to more traditional products.

Diffusion is inherently difficult to model and track because it is often not conducted through a market process. Instead, knowledge is diffused through a variety of both formal and informal means and the study of these means has more often been the realm of communications and business theorists rather than of economists. The economics of diffusion has concerned measuring the flows of technological information (generally proxied by patent and licensing agreements) among firms and sectors.

2.3.4 Alternatives to Patents: The development of the economics of patents suggested that in many respects patents are a flawed means of allocating resources towards invention. While some theorists worked towards modelling

these failures others explored the possibility that there were alternatives to patents which were not so flawed.

One such scheme is government contracted invention. Using this scheme the government raises the sums required to pay for invention through a non-distorting lump sum tax, and makes any invention available at no cost to whomever can make use of it. In theory this creates no monopoly distortions while still diffusing knowledge that has been produced at a zero price. Of course it rests upon the rather unlikely assumption that government could be as effective as industry in directing resources towards socially beneficial innovation.

Another such scheme is the use of prizes to provide an incentive for inventors. Under this scheme successful invention is rewarded with a prize and the invention can then be made available at a zero price.

The static monopoly losses of patents could be reduced if price discrimination is allowed. If perfect price discrimination is allowed, Nordhaus's optimal patent becomes a second best solution. Perfect price discrimination allows an inventor to earn all the social gains associated with invention and still produce no social loss due to monopoly distortion. What this scheme draws upon is the realization that there are no allocative losses resulting from monopoly with perfect price discrimination because the scheme creates an incentive for the monopolist to extract all the gains from trade.

In strictly neo-classical terms all of these schemes produce a superior welfare result to the optimal patent envisioned by Nordhaus. They resolve the dilemma of a patent producing an artificial scarcity over a produced idea. Each of these schemes has been attacked but the terms in which this was done break with the neo-classical assumptions of zero transactions costs and therefore will be considered in the following section.

2.4 CRITIQUE OF THE NEO-CLASSICAL FRAMEWORK:

The neo-classical analysis of patents and innovation generates a number of anomalies. As noted above, Scherer finds that most firms patent their inventions (Scherer, 1983), yet in a number of industries, patent protection is not found to be a useful means of protection (Levin, 1985; Mansfield, 1986). The immediate question becomes "Why do firms patent if not for protection?". This question is important for it strikes at the foundations of a substantial body of analytical and empirical work that simply assumes patents are used for protection.

Questions are also raised regarding the relationship between appropriability and market structure. It is true both that successful innovation affects market structure (Kamien and Schwartz, 1982; Dosi, 1987) and also that different industrial structures create powerful effects on the incentives to innovate by affecting appropriability. The work done on these questions changes the emphasis of the research agenda regarding innovation. The crucial issues becomes the inter-relationships between appropriability, market structure and innovative performance. Levin's work (1987) demonstrates as well that this relationship is not uniform over all industries and this leads to questions concerning what determines appropriability and the different appropriability mechanisms found in different industries.

2.4.1 Appropriability and Market Structure: Building on his discussion of the various means of appropriating the returns from invention, Levin (1987) goes on to identify those industries that make the most extensive use of each method. Patents are found to be a very useful means of appropriation only in pharmaceuticals, chemicals and simple machine tools. Other firms tend to use some mix of the other techniques.

Levin's appropriability studies lead to a question of whether there is any determinate relationship running from market structure to innovative performance. If different business practices, which in turn imply different market structures, are used to ensure the returns to invention, then the relationship could very well go the opposite direction. The need to appropriate the returns from invention could determine market structure. As Levin puts it, innovation could depend on more fundamental conditions than those identified by Scherer. He notes that Scherer finds the statistical significance of market structure as a determinant of innovative performance is significantly diminished when a vector of dummy variables characterizing industries by the nature of their technology is added to the regression (Levin, 1987). What this suggests is that it is the nature of the technology itself which is largely responsible for determining market structure, and that this is because the nature of the technology determines the best means of appropriating the returns from invention.

Levin therefore suggests a new interpretation to many empirical findings. While Scherer notes differences among industries in the relationship between concentration and innovative performance, and ascribes these differences to a different underlying science base, Levin attempts to partially endogenize this same science base. To Levin, differences in technologies mean different means of appropriation have to be found and this accounts for differences in market structure. Differences in the science base reflect both differences in the relative richnesses of different veins of science, and differences in the past appropriability conditions which allowed this science to be developed in the first place.

To support his view Levin notes that in regressions with appropriability proxies added, the significance of market structure variables as determinants of innovative

performance vanishes (Levin, 1987). This strongly suggests that new empirical and theoretical work should abandon the search for the relationship running from market structure to innovative performance and should instead explore the means employed by firms to appropriate the returns from their invention and the relationship of these means to market structure.

2.4.2 Appropriability and Diffusion: Patents have long posed a dilemma in the incentive they create for greater invention and the disincentive they create for diffusion. It may be that the relationship is even more ambiguous than usually thought because while patents may prevent diffusion through imitation they also create a property right which allows for a greater licensing of invention. The strength of this mechanism of diffusion through licensing depends on the enforceability of intellectual property rights (or in other words, the degree to which patents deliver appropriability). Thus, strong appropriability through patent protection could allow more not less diffusion of invention overcoming the traditional dilemma. However, this relationship clearly needs further exploration.

2.4.3 Diffusion and Patent Races: The consideration of this relationship arises from a reconsideration of the problems of the duplication of research, patent races and uncompleted or failed research. Greater diffusion of information could reduce the potential for firms to conduct costly patent races by allowing a greater coordination of research effort. Firms will become more aware of the capabilities of their rivals. This could have the effect of forestalling patent races by making firms more aware of who is likely to win such races.

2.4.4 Appropriability and Patent Races: Lastly, it can be argued that reducing the appropriability of invention also reduces the incentive to enter into patent races simply

because the monopoly returns potentially available are also reduced.

2.5 CONCLUDING REMARKS:

Even a cursory glance at the above suggests obvious interactions among the three misallocation problems discussed in the neo-classical agenda. This means that standard neo-classical economics can make no unambiguous statement about the effects of increased patent protection or different market structures on innovative performance.

The recognition of these interactions suggests a need for a theory which unifies the discussion of these misallocation problems within a common framework and thereby allows the interactions among them to be considered. It would seem that the creation of this framework requires a closer look at the real world processes of innovation. How is research among firms coordinated so as to prevent wasteful duplication of research and what is the consequence of unfinished or failed research? How are patent races forestalled, how are the gains from innovation actually earned and through what mechanisms are ideas diffused?

A new theory must address these questions and also lend itself to some new issues: (1) It must address the role played by a range of organizational phenomena that are seen in highly innovative industries such as research consortia, joint ventures, strategic alliances, and minority equity positions; (2) It must explain why some firms will willingly trade proprietary technologies while others will choose to defend them. Students of management and business often note some regularity to these structures (Bahrami and Evans, 1987) and economists now study the role of organizations in supporting trade, but no synthesis has taken place and the role of patents in the innovation process is still somewhat mysterious.

It is also apparent that an economic theory of innovation must address the informational aspects of business decisions in an innovative industry. How do firms choose what technologies to acquire, and how do they direct and coordinate human resources towards the production of new technology? In short, economics must move beyond considering innovation as an event which a firm chooses to undertake depending on its demand conditions, the appropriability of the invention, and the market structure it faces.

In the next chapter the first steps will be taken towards devising a theory which explains both organizational innovation and how the information needed to direct and coordinate large scale innovations is traded. In so doing, it will reinterpret the neo-classical misallocation problems discussed above and suggest new approaches that might be taken to develop a better understanding of the varied roles of patents.

CHAPTER THREE
TRANSACTIONS COSTS ANALYSIS

This chapter is intended to provide a background to transactions cost analysis with an eye to demonstrating how it might be applied to the innovation problem. This is an interpretative discussion and should not be considered to be definitive. Part of the reason for this is that the transactions costs literature is still emerging and combines many diverse traditions.

3.1 INTRODUCTION

The transactions costs approach is in many ways an extension of neo-classical economics with the assumptions of perfect information removed. However, differences with neo-classical economics also include the unit of analysis (the transaction), a focus on contractual stipulations rather than on price alone, a focus on hierarchical forms as a substitute for market transactions, and a broader institutional context within which problems are framed. Nonetheless, it is removing the limiting assumption of perfect information that is the key to the analysis. If perfect information is assumed there is no economic rationale for having both market and hierarchies. When imperfect information is allowed for, hierarchical and market transactions can be analyzed as alternative devices to overcome informational impediments to improved resource allocation. In fact, by focusing on the transaction or exchange it is soon seen that there are very few cases of pure hierarchy or pure market exchange. Most exchange contracts involve some mix of the two forms.

Generally, the structure (or stipulations) of a contract are analyzed for their ability to reduce specific transactions costs. Usually, although not always, optimization solutions to these transactions costs

minimizing problems are modelled using an equilibrium framework. The model to be presented in this paper will differ in that it will go beyond considering only the stipulations of the contract governing a given exchange and it will not be limited to an equilibrium framework.

3.1.1 Coase: The origins of the transactions costs approach are found in Coase (Coase, 1937, 1960). Coase's often misinterpreted "The Problem of Social Cost", claims that neo-classical misallocation problems are ultimately the result of some kind of transactional difficulty (North, 1988). To Coase, it is barriers to exchange that create resource misallocations. In the absence of such barriers economic gains could always be realized by further trading and rational traders will seek out these gains. Coase therefore implies that optimal resource allocation will always be the end result of economic exchange if it is assumed that there are no transactional difficulties. For Coase, the economic question becomes not one of characterizing misallocations but, instead one of identifying the particular impediments to mutually profitable transactions which prevent optimal resource allocation.

3.1.2 Demsetz: Coase's approach suggests new ways to understand familiar economic misallocation problems, such as externalities. Demsetz takes a property rights approach and suggests that misallocations must ultimately stem from either unspecified property rights or property rights that are too costly to enforce (Demsetz, 1966).

To reach this conclusion Demsetz extends the analysis of Coase. Coase's great insight is to realize that regardless of how property rights are assigned there always exists an incentive to realize all gains from trade. If the hypothetically maximum gains are not realized then there must be some reason. Demsetz rejects the view that specific market structures are the source of resource misallocations.

He notes that under any market structure there still exists the incentive and the means to realize all the gains from trade. Speaking on this matter he notes the following:

> Our conclusions do not depend on the degree of competitiveness. In the absence of exchange and policing costs all monopolists could discriminate freely or be paid by purchasers of their products to act competitively. Exchange surplus would, of course, accrue to the monopolists (Demsetz, 1966, p. 64.)

Instead of market structure Demsetz identifies exchange difficulties as the source of resource misallocation. He notes that in the absence of exchange difficulties, all mutually profitable transactions will take place and therefore an optimal allocation of resources occurs. The exchange difficulties Demsetz identifies are the costs of establishing and enforcing property rights. Property rights are necessary if market exchange is to take place and with no exchange costs all mutually profitable transactions will take place. Thus, if property rights can be costlessly established and enforced, perfect resource allocation will result. Demsetz argues:

> If we assume that it costs nothing to police property rights, it follows that there exists a direct relationship between the degree to which private benefits approach social benefits and the degree to which the conveyed property rights are enforced (Demsetz, 1964, p. 17).

To Demsetz property rights are only specified if the benefits of internalizing an externality exceed the costs. Thus, many misallocation problems are really just cases of unspecified property rights. This analysis, while an elaboration of Coase, advances Coase's work by specifying specific transactions costs (related to property rights) which prevent an economic optimum.

3.1.3 Cheung: Cheung extends the work of Demsetz. While Demsetz points out that property rights could be difficult

to enforce, Cheung identifies specific reasons enforcement difficulties prevent a mutually profitable transfer of property rights. He also adds a new cost to the strict property rights interpretation of exchange difficulties; the cost of negotiating the terms of transfer.

Cheung, like Demsetz, notes that exchange is costly when property rights are difficult to define and police. He also notes that property rights are exchanged under contract and that in addition to the difficulties of defining and enforcing them, the contractual stipulations under which property rights are transferred are often difficult to agree upon. Cheung lumps both property right and negotiation difficulties together under the term transactions costs.

> there are costs of defining and policing exclusivity . . . there are costs associated with negotiating and enforcing contracts for the exchange or transfer of property rights. . . At least two reasons may be offered for the difficulty of separating the costs of this second stage from the first. One reason is that the income derivable from an exclusive right, or the gain of enforcing it, depends on the existence of transferability in the marketplace, for without transfer the highest value option may not be realized. This implies that the lower the costs of contracting for transfer, the higher will be the gain of enforcing exclusivity. A second reason is that the cost of enforcing exclusivity also depends on the existence of transfer and its associated costs. The preferred size of resource holding so as to lower policing cost, for example, can be chosen insofar as the market exchange permits. For these reasons it is convenient although somewhat arbitrary to lump the costs of the two stages into one broad term, namely transactions costs (Cheung, 1970, p. 67.)

To Cheung contractual stipulations result from an economic process: Contractual stipulations are structured so as to minimize transactions costs. Cheung presents cases in which contractual stipulations seem designed to deal with particular indivisibilities or other oddities of the property being exchanged (Cheung, 1983). He suggests that

economic analysis can be extended beyond price determination.

> The stipulations or terms, which constitute the structure of the contract are, as a rule, designed to specify a) the distribution of income among the participants, and b) the conditions of resource use. Under transferable rights, these stipulations are consistent with, or determined by competition in the marketplace. As shown elsewhere, the choice of contracts is determined by transaction costs, natural (economic) risks and legal (political) arrangements. However, the familiar market prices are but one among many of the contractual terms (Cheung, 1970, p. 50).

In other words, market clearing conditions do not depend on price alone. A number of stipulations will be set so as to reduce transactions costs and allow greater gains from trade to be realized. Because contracts are costly to stipulate, they will only be stipulated to the point where the benefits of further stipulation no longer exceed the costs.

Cheung takes his analysis beyond formal contracts to address the transactions costs reducing properties of institutions. He notes that many customs, such as handshakes, have transactions costs reducing properties, thereby suggesting that transactions costs analysis can be extended to the study of institutions.

> There are effects which are trivial and are not transacted with contracts. Examples for this are to say "sorry" for minor damages done among individuals, or to be gentle to the neighbor's dog. Let me refer to this type of behavior as "customs". According to J.S. Mill, "when an activity is a customary practice and not of varying convention, political economy has no laws of distribution to investigate." While the persuasiveness of Mill may yield peace of mind, subsequent economists have frequently employed "custom" as an excuse to avoid analysis. Even a practice that is truly customary may reflect the existence of costs in contracting (Cheung, 1970. p. 56.).

In short, contractual stipulations reduce transactions costs, and so also do many customs or institutionalized trading arrangements. Because these two devices may act simultaneously the structure of a contract cannot be understood without understanding its institutional context.

Cheung also extends traditional analysis by noting that not only market but all economic exchange is governed by contract (Cheung, 1983). Market directed, hierarchically directed and all intermediate forms of economic activity are governed by contract. Because contracts are designed to minimize transactions costs, contracts which direct and reward labour within a firm and contracts among firms can both be analyzed within this framework.[1]

Cheung identifies a number of factors which affect transactions costs. Firstly, there is the volume and history of the business in question. This is important because in the course of their business, traders develop skills and learn about the reputations of other traders. They learn to more economically measure the relevant characteristics of whatever they are trading. (This may be particularly important with ideas of a highly technical nature). As traders develop trust and skill, they do not have to devote as much time to measuring what they trade. Reduced measurement costs mean reduced transactions costs (Barzel, 1982). Secondly, competition affects transactions costs. Cheung notes that competition forces the revelation

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1. This may be especially helpful with a study of innovation because innovation is characterized by a diversity of contracts. Firms are bound by a wide variety of contractual forms such as licensing agreements, strategic alliances and consortia participation and they employ individuals under a wide variety of arrangements including straight salary, contracted research, and a variety of team arrangements.

of alternative contractual arrangements, and the information needed to enforce the contract.[2]

3.2 TYPES OF TRANSACTIONS COSTS

The argument that in the absence of transactions costs there is every incentive to realize all the gains from trade has vast implications for the economics of innovation. It suggests that all existing misallocation problems can be reformulated as transactional difficulties. The importance of this has already been noted but it bears repeating. Reformulating problems so that they are expressed in like terms allows an understanding to be generated of the relationships among misallocation problems that is not possible when they are described as separate problems. Expressing in like terms allows a more fundamental understanding to be used as a policy guide.

To properly characterize the transactional difficulties of innovation two steps are necessary. Firstly, the process by which economic transactions transform knowledge into

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2. This recognition of the role of learning in determining transactions costs and transactions costs reducing trading arrangements is interesting because implicitly it implies that transactions costs economics should not be conducted within an equilibrium framework. There is always new learning taking place and because of this there is always change in what constitutes an optimal arrangement. For example, new information may become widely available regarding the properties of what is being exchanged or better information may become available regarding the contractual stipulations under which it can be traded.

   This indeterminacy in turn suggests that there is an implicit evolutionary argument in transactions costs reasoning. (This may seem appropriate since innovation itself produces change.) The logic of this evolution runs as follows. New information about trading arrangements and product characteristics is constantly accumulating and as it accumulates, economic structures, contracts, customs and other economic institutions evolve. The analysis of the relationship of this process to technological progress, while interesting, will not be attempted here.

value must be understood. This implies understanding how the incentives to produce and diffuse knowledge are actually created. In short, how ideas are paid for, how they are combined with other knowledge to create new ideas and how new products are created which are sold in the marketplace.

Secondly, when the process by which economic transactions transform ideas into products is understood, then the specific transactional difficulties which prevent all mutually beneficial trades from taking place must be identified. The construction of the innovation process and specific transactions costs related to it will therefore be the subject of the next chapter. At this point an outline of the main categories of transactions costs can be provided.

a) Search costs. Search costs are entailed identifying what is useful or what might be needed by a potential transactor. It is actually a complex concept; entailing questions as to what triggers recognition of a need to acquire and how search is organized. These complexities will be disregarded here. Search costs will be generalized as being simply the problems of identifying what is needed and finding a potential trader or, in other words, shopping.

b) Measurement costs: If items of value are to be exchanged their value must be measured so that the terms of exchange can be worked out. Furthermore, the results of this measurement must be made available to both contracting parties. Measurement is often costly to conduct. In fact, measurement costs are often the most significant barrier to what would otherwise be mutually advantageous exchange (Barzel, 1982). There are three means of reducing measurement costs: less exact measurement can be undertaken, steps can be taken to ensure that unnecessary measurement does not take place; and steps can be taken to ensure that

only those with the comparative advantage in undertaking a particular measurement do so.

To be specific this means that measurement costs are reduced if measurement is only undertaken once and all parties can be assured that this measurement is an accurate one. Thus anything which instils trust into an exchange relationship reduces measurement costs. Also, if products are very complex, with attributes that are difficult to measure than it might be expected that long term trading relationships based on trust (or some other device) will generate sufficient savings to supplant the gains generated by more competitive auction style exchange where partners might frequently change and trust will need to be rebuilt. As the number of potential customers grows the return from being able to assure these customers that the supplier's measurement is an accurate one also grows. An extreme example of both these effects is air travel. Air travel would simply not be feasible if all air travellers were forced to undertake all the costly measurements needed to determine the safety of an airplane before deciding on their willingness to pay for an airline ticket.

c) Negotiation Costs: Closely related to measurement costs are negotiation costs. Negotiation takes place during measurement as well as after measurement.[3] Only negotiation occurring after measurement need be considered here.

After measurement is undertaken, the contractual stipulations effecting the transfer of the property must be settled. If the exact measurements are uncertain, negotiation is further complicated because further contingencies must be written into the contract. In general, the more difficult it is to measure the performance

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3. For example, negotiation is necessary first to determine how much costly measurement to undertake. After measurement is undertaken negotiation is conducted to determine the terms of transfer.

characteristics or attributes of a particular item, the more difficult it is to negotiate the transfer of this item.

Complex characteristics raise negotiation costs because contracts must be better stipulated. For example indivisibilities, and uncertainties regarding the potential success or market value of a particular piece of research need to be dealt with. In another example one innovation's market success may be largely dependent on the successful completion of another innovation. Future market conditions may be very uncertain. For example, the market for improved vacuum tubes collapsed after the development of the transistor.

Generally, as negotiation costs rise, flexibility in negotiating agreements is sacrificed in favor of the adoption of a pre-specified rule. Large groups can overcome the costs of achieving consensus by surrendering some of their decision making authority to an independent hierarchy, or by agreeing to use some pre-specified rule for dealing with a particular problem. Such a rule, might not address all contingencies but at the same time it would reduce the need to negotiate. If exchanges are frequent the cost savings generated by a rule could be very substantial.

The proper assignment of authority can strongly affect negotiation costs. For example, decentralization of authority can reduce the extent to which complex ideas have to be communicated and hence reduce negotiation costs. This is rational behavior in cases where decisions need not be made more effectively by senior management. Thus, in these cases, transferring information to senior managers constitutes an unnecessary expense.

d) Enforcement Costs: It is difficult to disentangle negotiation and measurement costs from enforcement costs[4].

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4. In standard terms the problems of enforcement might be best characterized as free rider problems. The issue is how to prevent parties to the exchange from failing to continue contributing once they have received all

Transacted items which are easily measured will generally mean breaches are easily identified and enforcement is made easier. Likewise, contracts which are easily enforced mean duplication of measurement is less necessary and measurement costs are thereby reduced. In fact, quite a complex literature has grown up around enforcement issues and the need to provide an ex ante assurance that all the stipulated terms of a contract will be met before the exchange can go forward. This section is not intended to review that literature or contribute to it. It also skirts the difficult questions of how to delineate or better characterize measurement, negotiation and enforcement costs. It is intended only to outline some common enforcement costs and the devices most frequently used to overcome them.

A contract is enforceable when the costs of a breach by either party outweigh the benefits of a breach to that party. The costs of a breach are difficult to define but the literature suggests they include the termination of a successful trading arrangement, damage to dealer reputation, and legal sanction.

The literature suggests a number of devices which serve to enforce contractual exchange. While not an exhaustive list the following should be considered.

The most obvious of these is the law. Legal enforcement of contracts is provided by sanctions against a breach. This is clearly more easily accomplished in cases where measurement of the negotiated terms is not difficult. It is more difficult as proof of breach becomes harder to achieve. Legal establishment of property rights also provides for the enforcement of transactions.

Contracting parties might also establish an independent hierarchy to administer the agreed upon contractual

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their private benefits from the trading agreement. The other types of transaction cost are those which must be overcome simply to allow trade in the absence of any free rider problem.

transfer. In such a case the parties would agree to the legal transfer of decision making authority from the parent authority to a quasi-independent corporate entity. This technique is successful in cases where enforcement difficulties arise due to incomplete contractual stipulations or moral hazard created in the later stages of contractual fulfillment. For example, one party may receive all its stipulated benefits in the early stages of an agreement and have no incentive to then deliver on its end of the bargain. Delegation of authority to an independent hierarchy might help overcome this problem.

Complementary markets are a complicated device whereby the existence of one market sustains a second. For example, Hall (1986) analyzes the complementarity between claiming races and regular horse races. The claiming race is seen as a market which enforces one of the terms of the contract between the track and the bettor; that the race be honest.

The analysis of hostages as a device for supporting exchange is often attributed to Williamson (1983). Both mutual exchange and unilateral hostage situations are possible. Essentially, the hostage should be a non-recoverable asset which is lost in the event of a contractual breach. Ideally, the value of this asset should exceed the gain to be derived from a contractual breach. Often, a long term trading relationship or trader reputation may serve a hostage role.

Trader reputation is an effective hostage especially in cases where a trader has a valuable reputation for honest dealing. With such a reputation not only is the exchange enforceable but measurement need only be undertaken once. In short, trader reputation translates into the ability to ask a higher price. Thus, if there are repeat dealings or the trader deals with large numbers of other traders and reputation is observable, the loss of reputation created by a contractual breach will outweigh any potential gains.

From this discussion it should be apparent that all visible transactions of brand name firms and all long term trading relationships have an implicit hostage supporting them. In shorter term cases the hostage may be explicit. Equity positions taken in the other firm, brand names or the provision of equipment by one of the transacting parties may all serve a hostage role.

Side payment is more common in large number cases. It is also useful in long term exchange relationships. In both cases situations may emerge where there is an incentive for a party to commit a one time breach of contract despite the fact that greater social benefit may still be derived by continuing the agreement. In these cases, the contract can be saved by pre-specifying some provision for side payment. Of course the terms under which side payment is to be made available must be clearly specified in the original agreement.

3.3 CONCLUDING REMARKS:

This chapter has taken the pioneering work of Coase, Demsetz and Cheung and shown that it worked within a neo-classical framework but abandoned the neoclassical assumption of costless exchange and began to explore the relationship between the nature of a transaction and the costs of exchange. The simplest form of this inquiry is guided by the premise that the institutional characteristics of a transaction evolve over time in order to reduce the costs of trading. From this inquiry has arisen a substantial body of economic literature pertaining to the ability of different contractual forms to reduce the costs of exchange and thereby allow greater realization of the gains from trade.

This type of analysis implies that all neo-classical misallocation problems can ultimately be expressed as the result of transactional difficulties which reflect the

implicit costs of exchange. This means that the allocation questions which neo-classical economics has raised concerning innovation can be expressed within a common transactions costs framework.

The task of the next two chapters will be to develop this framework and to begin assessing the new institutional arrangements emerging in highly innovative industries from the transactions costs perspective.

CHAPTER FOUR
APPLICATION OF TRANSACTIONS COSTS THEORY

4.1 GAINS FROM IDEA TRADING:

Having described the neo-classical analysis of innovation and patents and having made an interpretation of the transactions costs literature, the misallocation problems, identified in Chapter Two, can now be respecified within a transactions costs framework. The first step in doing so is to respecify the economic gains from invention within a framework that recognizes that any application of new productive thinking to production generates economic returns. By better identifying each type of economic exchange which produces gains from trade, some or all of the transactions costs which this process generates can be better identified.

The model used by Arrow to characterize the returns to invention is too narrow for this purpose. Arrow modelled the returns to invention as those costs savings generated by the introduction of a new process. Arrow included the gains accruing only to the inventing firm and only as cost reduction processes, he made no allowance for improvements in product quality. In truth, there is economic gain whenever new ideas are applied to production. If an invention is applied to a product or process, and by so doing, this product earns greater returns, then these returns constitute economic gain from invention. If other firms imitate this invention in their own products or processes and thereby earn higher returns then this too constitutes an economic gain from invention. If these or other firms generate a new idea by studying the invention, and from this idea develop new products or processes, then these returns are also economic gains. In fact, any use of the invention or ideas constituting the invention, regardless of whether these uses were originally intended,

constitutes economic gain from invention. Arrow's model includes only the first type of gain. Ultimately in economic terms, there are gains from idea trading whenever one firm holds the comparative advantage in producing an idea which can be used by other firms, even for purposes beyond those originally intended.[1]

This model is also different because it further specifies the economic process of invention. Invention is the result of many inventive minds producing and combining ideas in new ways. Each of these ideas is paid for although the trading arrangement under which payment is made will differ according to the different mix of transactions costs characterizing each exchange. Ideas are combined to produce inventions and with further ideas incorporated inventions become innovative new products earning returns in the marketplace.

This approach allows a break with most economic characterizations of the invention process. Most analysis assumes that it is the firm which chooses whether or not to produce an invention and whether or not to license it and that the firm bases its decisions on variables such as the number of rivals and the ease with which the invention can be imitated. It is argued here that this characterization is only partially true. It is true that, ultimately, innovative new products are introduced by firms. It is not true that innovative new products are the result of one firm alone, nor is it true that the process of idea trading which produces an innovation is not amenable to economic analysis. The idea trading approach taken here captures the internal

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1. Idea trading produces benefits because it speeds the application of new and often superior technologies to production and because it speeds the development of new ideas and technologies. It does this because firms need not duplicate one another's research; they are able to specialize in producing technologies where they have expertise; and the search costs for new and potentially applicable technologies are reduced.

dynamic which produces invention as well as the market conditions which characterize the sale of the final innovation. It also allows invention to be characterized not as something which occurs internally within a firm but as the product of a more or less coordinated effort among firms. In fact, it captures the movement of ideas among employees and from employers to the firm (governed by employment contracts), from research contractors to the firm, from universities to the firm and among firms. It is argued here that innovative performance will depend just as much on the state of these relations as on the financial incentives to market a finished innovation. While the incentives to market the final product are interesting and will be affected by many things, invention also depends on the many idea trading institutions which produce the realization of what is possible and coordinate research resources towards this goal.

In a transactionally costless world, an economic optimum requires that all ideas generating economic gain be licensed or otherwise exchanged to all who can make use of them. This point was recognized by Shapiro (1985) who conducted game theoretic modelling of the incentives to invent in the same tradition as Kamien and Schwartz. The licensor could then price discriminate, and charge each licensee according to their marginal value product for the idea. All the rents associated with a given invention would accrue to the inventor and the private returns to invention would equal the social returns. However, the model developed here differs from Shapiro because Shapiro acknowledged the possibility of licensing only inventions and not ideas. In this context, clearly the trading of ideas is the fundamental unit of economic analysis.

While a hypothetical licensing scheme applied to ideas generates an allocative optimum, there are obvious difficulties. Firstly, it calls for the licensing of ideas

but ideas per se have no property right attached to them. Generally, ideas are afforded a protection which is incidental to the patented invention. Secondly, licenses may be costly to specify and enforce. Innovating firms will recognize cases when they cannot earn a return through idea licensing and therefore they will devote energy towards preventing the diffusion of those inventions. Transactions costs theory suggests that customs and contractual stipulations will adjust so as to help capture some of the potential gains of diffusion and bring the private returns from invention more into line with the social returns.

It has already been noted that exchange will be conducted under a variety of contractual stipulations and organizational forms depending on the transactions costs associated with the item of exchange. This analysis now suggests that these trading arrangements be studied with an eye to their transactions costs reducing properties for idea exchange. Because there is a large range of transactional difficulties associated with idea trading there will be a large range of possible organizational or contractual solutions. Idea trading industries will be characterized by diverse industrial structures (Cheung, 1983; Williamson, 1986). Considered as a whole these transactions costs reducing devices will henceforth be denoted by the term trading arrangements.

4.2 MISALLOCATION PROBLEMS AS TRANSACTIONAL DIFFICULTIES:

In a world without transactions costs all the socially beneficial ideas constituting an invention would be sold in a price discriminating fashion to anyone who could use them. Having identified the outcome in a transactionally costless world, it is now possible to apply this understanding to the misallocation problems identified in Chapter Two. By restating these misallocation problems as transactional difficulties, it may be possible to identify the specific

transactions costs which prevent all the gains from trading in ideas from being realized. This should establish a new research agenda and possibly new insights into the economics of innovation.

4.2.1 Inappropriability and Inadequate Diffusion: Chapter Two identified three misallocation problems associated with innovation: the rush to invent, the inappropriability of the returns from invention, and inadequate diffusion of invention. Section 4.1 described the hypothetically maximum returns to invention. It suggests that complete returns can only be earned if there is complete diffusion of the ideas comprising an invention. This conclusion is at odds with the conventional wisdom; which asserts that a tradeoff exists between appropriability and diffusion. It also casts doubt on the traditional analysis based on the assumption that such a tradeoff exists and that the economic problem is to strike an optimal balance.

The belief that there is a tradeoff between appropriability and diffusion seems to stem from Arrow's model of the returns to invention, in which it is assumed that an invention is applied to one product only. If the characterization of the returns to invention which was developed in Section 4.1 is accepted (whereby applying knowledge to production generates value), then it is seen that the real returns to invention come from applying new ideas to production broadly and not simply using innovation to reduce the production costs of a given product. From this, it follows that the proper solution to any innovation problem is one which maximizes the net gains of selling ideas. It is the failure to achieve this theoretical optimum that produces both inappropriability and inadequate diffusion of invention.

This reformulation suggests that Nordhaus did not identify the problem properly when he modelled the optimal patent term. It is seen that the optimal patent policy

should minimize the transactions costs associated with idea dissemination rather than balance a hypothetical monopoly/innovation incentive tradeoff. In this interpretation, optimal patent policy is more likely to involve setting the scope of the patent properly, then it is to involve setting its term. If a patent were to properly specify the quantum of an idea, this might enhance the diffusion of invention because this would facilitate idea trading. Patents may actually be less effective than they could be since ideas per se are not usually patentable and not generally identified in a patent grant. Because trade is difficult new ideas may often remain trade secrets long after they have acquired a trading value. Innovation is slowed because trade secrets are more difficult to trade than patented inventions.[2]

4.2.2 The Rush to Invent: Premature innovation or the rush to invent can also be characterized as a transactions costs problem. The root of this problem has often been identified as an unspecified property right over the right to invent. For example, Kitch likens the rush to invent to the common pool problem in natural resources (Kitch, 1977).

In a transactionally costless world ideas would be produced only by those with the comparative advantage in doing so. Once produced, the innovating firm would then use price discrimination to license the idea to whomever could make use of it. Such a scheme would ensure that the highest possible rents from invention were earned.

4.2.3 Implications: The economics of innovation have been reduced to transactional difficulties in the exchange of ideas. In short, ideas produce new knowledge, which

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2. It is easy to imagine the difficulties which are created in stipulating the terms of a contract over property such as a trade secret. Potential litigation would be very difficult because of course it would have never been established just what the trade secret was.

produces economically beneficial advances. By this logic idea trading produces value but ideas are difficult to sell. It is because of these difficulties that the standard misallocation problems have been observed. They are now seen to be not causes of problems but symptoms of more fundamental transactional causes. This also demonstrates that the transactions costs approach and the neo-classical approach ultimately address the same issues. Trading arrangements adjust to minimize transactions costs but they cannot eliminate them and therefore all the gains from a hypothetical costless trading world are not realized or in other words, the standard misallocation problems are observed.

The ramifications of this are vast. Individuals producing knowledge are employed under a diverse range of contracts, ranging from salaried researcher to contractor (including intermediate contractual forms containing bonus clauses) and finally to independent inventor. Trading relationships among firms will also be characterized by a wide diversity, ranging from patent licensing agreements, to organizational linkages to cases where firms will choose not to trade ideas at all but to protect them and earn their returns in the marketplace. The key question in this analysis becomes what determines the choice of these trading arrangements. This is the subject of the next section.

4.3 WHEN TO DIFFUSE AND WHEN TO PROTECT:

Traditionally, firms are modelled as earning the returns on their invention by protecting that invention against possible imitation and earning a differential rent on the product which embodies the invention. This differential rent can come about because the costs of production are reduced or because the invention creates some qualitative difference between the new product and former products. The primary means of defending invention against

imitation is generally assumed to be patents. With the Shapiro model it came to be realized that invention could also earn its returns through diffusion. Shapiro notes that the maximum social returns from invention are earned by licensing the invention to all potential users. This thesis has now been restated to say the maximum returns from invention and indeed the maximum production of invention itself are achieved by the maximum trading of ideas. This more fundamental concept allows express consideration of the difficult question regarding how research is coordinated among firms.

It was noted that due to transactions costs the maximum gains of idea trading are not achieved. A number of means of reducing the transactions costs of idea trading are found, and these differ depending on the specific properties of the idea in question. None will be able to overcome all transactions costs and permit complete idea trading (Grossman and Stiglitz, 1981). As a result, in some cases firms may choose not to disseminate ideas. Instead they will choose to defend ideas against imitation just as the original patent models postulated. This decision can be conceptualized as another form of trading arrangement. The key question becomes what determines this choice.

It will be argued here that the most critical variable is the applicability of the invention or idea. Applicability means the extent to which a given idea or invention can be applied to a multitude of different products or production processes. Those ideas which are more applicable will be less focussed in their end use and will be able to earn a correspondingly higher share of their potential returns by being "sold" in some manner to other firms or people. If ideas are not highly applicable there may not be sufficient potential returns from licensing or "selling" them to overcome the transactions costs of doing so. In such a case, there will either not be a market for

such ideas, or the firm will choose to embody them in a product which it defends against imitation.

Highly applicable ideas and inventions produce large gains from trade. A firm producing a highly applicable invention will therefore have a strong incentive to find some trading arrangement which reduces transactions costs and allows these gains from trade to be earned. If on the other hand, an idea is not widely applicable there will not be such a great incentive to find a transactions costs reducing device. Thus, applicability is asserted to determine both whether and the extent to which idea trading takes place. But the specific architecture of these trading arrangements will depend on specific transactions costs. An analysis of the relationship between specific transactions costs and trading arrangements will therefore be discussed in the following section.

Applicability of invention can be illustrated by an example. Some inventions such as pharmaceuticals have traditionally be produced by a very defined research program. The development and subsequent testing of various molecular structures for their effects on human health. In the course of this process, little new knowledge is generated regarding how to develop new molecular chemicals and seldom is the discovery of pharmaceutical benefits beneficial in other industries. Pharmaceuticals are targeted towards specific health conditions and thus might be said to be of limited applicability. Other inventions such as microprocessors may contain ideas which are very widely applicable. In the course of their invention, new techniques of manufacturing and design may be found and new advanced materials may be utilized. The microprocessor which is ultimately developed may serve as the source of a number of later developments. Furthermore, it might be applied to a number of different uses. Such an invention is highly applicable. Because the invention is highly

applicable, greater incentives exist for trading the ideas which it embodies.

Due to ongoing learning the relationship between trading arrangements and transactions costs is not a determinate one. Trading relationships will always be changing. By relaxing the assumption about learning, an equilibrium analysis of this relationship is possible but it requires two contradictory assumptions: traders possess imperfect information regarding what they are trading,[3] and at the same time they possess perfect information regarding the transactions costs generated by alternative methods of trading.[4] To simultaneously posit that information of one kind is perfect and that information of another kind is not is inconsistent and so this approach will not be used here.

4.4 CATEGORIES OF APPROPRIABILITY:

There are three distinct types of appropriation which direct invention: non-market allocation; appropriation through dissemination; and appropriation through product sale. It is now argued that applicability determines under which of these trading arrangements an invention will earn its returns.[5]

4.4.1 Non-market Allocation: Non-market allocation implies publicly funded research. It is research which becomes

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3. This assumption is necessary in order for their to be any cause for different types of trading arrangement. If all traders possessed perfect information, of course, the optimal licensing scheme described earlier would prevail.
4. This would of course generate a determinate and unchanging relationship between types of transactions costs and different trading arrangements.
5. This is admittedly a simplification of reality. It is likely that specific transactions costs may so differ between two equally applicable inventions that the type of appropriation practiced will also differ. Nonetheless, in the interests of simplicity and because there is ongoing learning about transactions costs reducing trading arrangements this line of reasoning will not be pursued here.

public property when it is completed and as a result non-market allocation allows the widest diffusion but at the cost of not directing research well. It does not direct research well because it is not tied to market signals by the goals of the sponsoring organization.

Broad applicability is likely in cases where the invention is far removed from the market and it is potentially applicable to many different firms. Both these cases means that identifying potential beneficiaries of the research and negotiating individual transfer licenses is prohibitively costly. Non-market allocation foregoes such costs by establishing free access. There is no need to acquire information from the marketing division of a corporation and no need to enforce technology transfer agreements. Firms are simply taxed.

Where research is very widely applicable free rider problems will exist and research will therefore be underfunded. The free rider problem can be characterized as high transactions costs.[6] The imposition of publicly funded or hierarchically governed solution is sometimes necessary. Very broad basic research therefore generally implies publicly funded research although there are cases, such as Bell Labs, which are privately funded.

4.4.2 Appropriation through diffusion: Appropriation through diffusion might be applied where there are large potential gains from trade and manageable numbers of potential beneficiaries. The difference between this type of appropriation and non-market allocation is really only

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6. This is so because if all parties to an exchange were to pay according to their benefit optimal resource allocation would take place. They do not do this however because the costs of stipulating, and enforcing this agreement are too high and thus each party has the private incentive to breach the agreement despite the fact social welfare is maximized by maintaining it.

one of degree with this type of research being "closer" to the market and benefitting smaller numbers.

This thesis has demonstrated that the transactions costs related to idea trading mean that complete licensing is not feasible. The diverse properties of ideas and the different histories of the trading parties generate diverse transactional difficulties meaning that complex contractual stipulations and institutions will emerge to reduce these and permit the maximum number of mutually beneficial exchanges to go forth.

These will include barter among engineers, joint venturing, consortia participation, strategic alliances and complex licensing agreements. Supporting these mechanisms will be customs, personal relations among employees of respective firms, reputations and long histories of business dealings.

In short, a wide variety of potential trading arrangements are available and these will often employ customs and institutions which are not normally the subject of economic analysis (at least in the neo-classical tradition). Transactions costs analysis however, seems particularly well suited to this task. Furthermore, while the exact stipulations of contractual structures will partially depend on specific types of transactions costs (which are not always observable) this will not be a determinate relationship. The history of the industry will have produced different idea trading institutions and different degrees of understanding amongst the traders. Due to ongoing learning, these contractual structures will be forever changing even if the mix of transactions costs does not shift as the technology evolves.

Analysis of these structures is not easy. Transfer of ideas, especially within organizations, is often not observable. The quantum of an idea does not correspond to economic statistics, nor is it always paid for with cash.

Even participants to an idea trade may not recognize the transactions costs reducing properties of particular institutions within an industry. Further complicating the analysis is the realization that individual firms and industries are not exclusively idea trading or idea defending. Thus statistical inferences drawn from industry or even firm studies are difficult. The economics of innovation leads the discipline to an analytical difficulty that other disciplines have already faced. It must make inferences about phenomena which it cannot observe.

Despite these difficulties it is possible to tentatively characterize an industry where the preponderance of invention and ideas are traded.

The industry would have unstable structures, be relatively unconcentrated and contain a large number of strategic alliances and joint venture agreements. The degree to which these agreements were active would be shifting over time. Supplementing these joint venture arrangements would be a variety of quasi-firm organizational innovations such as research associations and consortia. The industry would be characterized by more patent licensing agreements then would an idea defending industry although licensing need not be the most common form of idea trading. Because of patent licensing, vigorous defense of intellectual property rights within the industry need not imply that it is defending its ideas. The degree of vertical integration is difficult to predict. It has already been noted that a vertically integrated firm may have advantages in facilitating the exchange of the marketing and technological information needed to translate ideas concerning technological possibilities into business success but at the same time in very fast moving industries, large size is likely to create bureaucratic inertia. The industry as a whole is more likely to be working on large

scale technological systems than it is on individual high tech products.

4.4.3 Appropriation through Product Sale: Appropriation through product sale is the flip side of non-market allocation. It produces the narrowest diffusion but is very well suited for directing invention towards the marketplace. By foregoing diffusion, no costs of negotiating transfer are incurred (although the firm does incur costs of defending its invention). The method therefore minimizes transactions costs but at the expense of foregoing all benefits of idea trading.

The research areas in which appropriation through product sale is practiced will tend to be ones in which success need not automatically point towards a new research area or lead to different products based on the original invention. Inventive activity, in other words, will not be cumulative. The research will be focussed on end products, products often designed to meet a very specific use. Thus, the idea which produced this product is not likely to be applicable to other uses. The innovating firm, seeing very few potential gains will not choose to diffuse the invention but will simply apply the invention to a new product and defend this product from imitators.

Appropriation through product sale is what economists generally assume when they analyze patent policy or innovation. It is assumed that the innovating firm seeks to establish a monopoly over its invention and thereby earn a monopoly return on the product embodying that invention. In order to ensure that they earn a monopoly return they will take active measures to protect their invention from imitation and this commonly includes intellectual property protection plus those additional measures attributed to Levin (1987). The argument in this thesis is that, in fact, only under special circumstances is appropriation through

product sale practiced, cases where the applicability of the invention or idea to other products or processes is low.

Industry studies which seek to generate an understanding of idea protection share the same difficulties as industry studies related to idea trading. In most industries both techniques will be used. It is therefore difficult to describe the characteristics of an idea protecting industry. However, some characteristics will be more prevalent when idea protecting predominates in a particular industry.

Idea defending industries will have trading arrangements which are different from those which prevail in idea trading industries. Their research and production is far more likely to be internalized with considerably less reliance placed on external acquisition and technology exchange agreements. While an idea trading industry might be characterized by many swiftly changing alliances and joint ventures, an idea defending industry will conduct very few such agreements. It will instead have organizations extended into retailing and distribution and who try to make use of other devices traditionally analyzed by the barriers to entry school of industrial organization. If patent protection is seen as inadequate, this effect is likely to be more powerful and there may also be large scale use of trade secrecy.

4.5 IDEA DIFFUSION AND TRANSACTIONS COSTS:

It has been claimed that applicability will determine which of the type of trading arrangement different inventions or ideas will fall under. It was further asserted that specific types of exchange difficulty or transactions cost will partially determine the exact institutional and contractual form of the trading arrangement.

The exchange of ideas is an economic exchange subject to unusual difficulties due to the characteristics of ideas. Ideas are non-scarce (once produced), sometimes indivisible, cumulative, and are subject to very high measurement costs. Their ultimate value is difficult to determine because the translation of ideas into products takes time and is subject to a substantial degree of risk. In short, almost all conceivable exchange difficulties are present in idea trading and thus an analysis of transactions costs reducing devices is very important for understanding the innovation process.

The properties of ideas create transactions costs and trading arrangements evolve to minimize these costs. Various transactions costs were identified in Chapter Three. These are present in different degrees with different ideas. Now it is possible to relate these to the innovation process which this chapter has developed. Since, different types of trading arrangement are better suited for dealing with different types of transactions costs, a myriad of contractual structures are expected in the allocation of resources towards innovation.

Sections 4.51 to 4.54 will analyze different transactions costs in order to develop an understanding of the cost reducing properties of specific trading arrangements.

4.5.1 Search Costs: Search costs will be lower when a firm's technological needs are well defined and when the technological strengths of potential idea supplying firms are well known.

To illustrate how important defining needs can be consider the different scales of problem faced by the manufacturer of an engine part and an automobile maker. An engine part maker may need a material which better meets some clearly defined and easily measured performance criteria such as a heat resistance-strength tradeoff. On

the other hand an automobile may face n dimensions of potential qualitative improvement. So many that the maker may not even be able to identify all of them or know which are potentially feasible. Far greater resources are expended in defining the needs of the automobile maker and matching these to technological capabilities than is the case with the maker of the component.

Knowing where to acquire technologies can affect search costs. If the number of potential suppliers is small or if the firms are closely tied through contractual arrangements, it will be easier to identify suppliers and search costs will be reduced. Where technical expertise is difficult to identify individual firms should be much more aware of what other firms are capable of doing. Firms may deliberately devise channels of communication amongst themselves to reduce search costs. This could mean hiring consultants or it could mean deliberate connections among firms to convey information. Strategic alliances, research associations, university industry partnerships and research consortia all serve as effective channels of communication. Through these channels information will flow two ways. Firms will be constantly defining their needs while external agents will be constantly adjusting the flow of technological information in response.

Signals reduce search costs by providing information concerning the content of given technological areas. They might be likened to a geological map which signals to mining companies what they might expect to find in a given area. Virtually all of a firm's publications and activities have some informational or signal content. Analysts note that a successful patent grant often serves as a useful signal (Horstmann, 1985). Winning a research prize or advertising might also serve as signals. In academia, signals are given by professional reputation, publications in prestigious journals and the number of publications or citations.

4.5.2 Measurement Costs: For reasons outlined earlier measuring the contribution of new ideas to market value is especially difficult. Cost reduction is therefore especially important for idea trading.

The cost of measuring the value of ideas depends upon the difficulty of measuring their performance characteristics. For example, the relevant characteristics of a new superconducting material may include only the malleability of the substance and the maximum temperature at which it continues to superconduct. These parameters are relatively easy to measure. Measuring the performance of a new artificial intelligence system, is on the other hand, very difficult. Such a system may have so many performance attributes that only through exhaustive use and testing can they be effectively measured.

The uniqueness of an idea or invention will also directly affect measurement cost. Examples of inventions whose ultimate value was either under or over estimated are commonplace. Generally, the more radical or unfamiliar an invention, the more difficult its value is to measure.

This generates a further argument that the more removed from commercial application that an invention is the higher will be its measurement costs. Extra steps must be taken to translate the characteristics of an invention into a market measure. For example, the market value of a new mathematical algorithm will be more difficult to determine than that of a specific software application. The market value of the Coase Theorem would be more difficult to determine than a study into the optimal extraction schedule of a mine.

Measurement cost in the trading of ideas and inventions will be affected by the state of intellectual property law in that particular area. A patent grant provides a legal and impartially determined measurement of just what is novel in a given invention. This will in turn reduce costs. In

the absence of the grant, the bounds would have to be set through negotiation. If patent examiners acquire skills in a specific area over time this will also reduce measurement costs over time. Thus Hall's contention that patents reduce transactions costs (Hall, 1986).

Measurement costs are reduced when measurement is undertaken only by those with a comparative advantage in doing so.[7] Thus, if there are stages to a measurement problem, this may call for a division of labour. For example, consider the difficulty of translating the performance characteristics of a particular component into some estimate of the contribution to market value that component will make to a given end product. The first step of this measurement problem would involve engineers determining the technical performance characteristics of the component. These engineers would then pass this information on to other technical personnel who would determine how these performance characteristics improve the performance of the product as a whole. This information would in turn be passed on to still other personnel who would determine how improved performance affects the marketability of the product. Thus, a question such as how a new advanced material which is used in automobiles translates into a higher asking price for the car might be a very complicated measurement problem and significantly affect a firms willingness to pay for that material.

4.5.3 Negotiation Costs: Negotiating agreements to transfer ideas and technology will be difficult because of

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7. The reason this is comparative advantage is because in the total trading system there will be different gains to be realized from measuring the attributes of different traded items and also differing levels of skill employed by those undertaking the measurement. Because those undertaking the measurement are a scarce resource, full gains from trade are only realized when they are used according to the principles of comparative advantage and specialize in measurements of the highest value.

the public, non-observable properties of ideas. In addition the informational requirements of a transfer agreement are quite large. This can be compounded by widely applicable invention. Widely applicable inventions create a need for many negotiations. Generally the more contracts which must be negotiated, the higher will be costs. In the absence of separate agreements large number problems such as free riders will occur.

As an example of how significant this can be, consider the transfer of a complex technology. A complex technology cannot be simply described as a blueprint or a formula. It will also consist of a considerable body of tacit knowledge, concerning idiosyncrasies and means of use that may be scattered among a large number of personnel. A formal licensing agreement would require that all this information be gathered and codified and that a price then be negotiated. After negotiating price, the receiving organization would then have to diffuse this body of information throughout its organization. To better appreciate how difficult this task could be consider only the considerable energies devoted to train a single employee on the use of an already known technology. The transfer of a new technology would entail far greater costs.

Redundant gathering and encoding of information can be reduced by the decentralization of authority. Two types of decentralization might achieve this. Firstly, engineers may be allowed to informally trade ideas. Such a transfer need involve no one except the engineers themselves and thus costly vertical transmission up through the organization is minimized. Also, because only engineers themselves are involved, substantial costs which would be incurred explaining engineering concepts to non-engineers are avoided. Also avoided are costs of trying to translate the exchanged idea into a price. Instead it is tacitly agreed that the exchange will be a reciprocal one.

Another form of decentralization is a joint venture arrangement. In a joint venture counterparts deal with counterparts. This removes the need to formally collect and encode information and also ensures that specific information is transferred only to those who need it.

In sum, negotiation costs are intricately bound up with measurement and enforcement costs. As technologies become more complex or as their lifespan or development times increase, the more uncertain the appropriate price becomes and the more complex become the contractual stipulations dealing with future contingencies. Because at some point fully stipulated contracts will become too costly to write it is predicted that as uncertainty of outcome rises, fully stipulated contracts will be replaced by rules of conduct and hierarchical structures.

4.5.4 Enforcement: The intangibility and public nature of ideas makes enforcement issues important in their transfer. For example, intellectual property infringement is difficult to prove and intellectual property is costly to define. Because, it is generally inventions and not ideas which are patented, legal sanction is a blunt instrument. For all these reasons it is very costly to employ, and often does not provide effective assurance that a contract will be enforced. Rational firms knowing this may choose not to enter into contracts which have been satisfactorily stipulated for this reason. Unless an alternative means of enforcement can be found the exchange will not be transacted.

One such alternative means is to supplement intellectual property protection. IBM and Fujitsu had several longstanding disputes regarding the licensing of IBM patented technology throughout the 1980s. IBM contended that Fujitsu had exceeded the terms of the licensing agreement. Neither party wanted to terminate its dealing with the other but clearly the costs of litigation were too

high and the certainty of outcome needed to negotiate was not provided. Quite simply, the vagueness of intellectual property law was proving to be an impediment to exchange. Rather than forego their mutually profitable exchange relationship the two parties chose to establish an independent arbitration board which would resolve future disputes between the two regarding the scope of intellectual property protection. The arbitration board, quite simply, reduced the costs of inadequate intellectual property protection and provided a low cost way of enforcing future agreements.[8]

Other agreements require either hostages to support exchange or signals to indicate this is a party with something to offer in trade. Hostages are quite common in exchanges and generally a hostage is a non-recoverable asset which will be lost in the event the exchange relationship fails. Within the context of idea trading arrangements, hostages might include equity arrangements, investment in facilities or commitment of personnel to a joint venture.

A commitment might be needed in the case of a party which is seeking entry to a patent pool or research consortium where all parties would be free to use whatever technologies the acquire. Before granting the party access to their technologies the other members wish only to be assured that they will receive something in exchange. This could involve an up front commitment of cash or it could involve some proof that the firm has viable ideas of its own to contribute. A patent portfolio might serve this role. Patents serve as an impartial third party assessment of a contracting party's ability to contribute to such an agreement. Other common devices include releasing a

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8. For a detailed discussion of this case and the details concerning the composition of the arbitration board there are a number of news sources. Best detailed coverage was probably provided by the Wall Street Journal in issues throughout Sept. 1987.

proprietary technology or committing key personnel. The Sematech research consortia, for example, was given a tremendous boost in terms of credibility by an IBM decision to release valuable proprietary technologies.[9]

Another potential enforcement device is the provision of side payment. Long term "free access" relationships may depend on this device to even out any imbalances which develop over time in the flow of ideas. In the absence of such provisions a situation could well develop in which the private benefit of one of the parties is best served by a breach although the social benefit of the group is best served by continuing the exchange relationship.

4.6 CONCLUDING REMARKS

This chapter has redefined the process of innovation. Innovation does not emerge from a black box with levels of investment in R&D depending only on market structure and external demand. Instead, it is the product of economic exchange; exchange which reflects both imperfect information and the unique characteristics of ideas themselves. Three general approaches towards invention were identified, the choice of which depends on the applicability of the ideas involved. With narrowly applicable ideas there will be few gains from trading ideas and so firms will protect them from imitators. Patents play the traditional role of protection in these cases. Industries that produce a preponderance of narrowly applicable invention will be characterized by strong barriers to entry and broad patent grants. By contrast, when an industry is characterized by widely applicable ideas the potential gains from trade are greater and firms will seek a means of earning them. Because idea trading is subject to large transactions costs, often a non-

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9. Once again an excellent account of the events leading up to this are found in the Wall Street Journal issues throughout July and August of 1987.

standard contractual arrangement combined with formal and informal institutional structures will be needed to support exchange. The exact nature of this trading arrangement will be indeterminate owing to the role of prior trading arrangements in the industry and ongoing learning about idea characteristics and alternative trading arrangements. This chapter noted some specific transactions costs and how they related to idea trading. The chapter has also noted the existence of a third kind of research which is very broadly applicable and whose ultimate beneficiary may often not be known even after it is produced. Owing to the exchange difficulties which it creates it will be undertaken only by large corporations with a very broad range of products of it will be publicly funded with provisions made to ensure its free dissemination.

It is not easy to demonstrate when idea trading is taking place or to measure the extent to which this is happening. Ideas and invention do not always correspond to firm and market exchange. This casts doubt on much of the statistical analysis of invention, (especially that which is based on patent counts). Even case studies are difficult to conduct because ideas do not necessarily correlate on a one to one basis with products. A new product will often embody a whole matrix of ideas and inventions which were produced by a number of different firms.

The next chapter will recognize these difficulties and will apply the transactions costs approach on a case study basis to see how principles of appropriation through diffusion rather than standard analysis can explain many existing phenomena related to innovation. Of particular interest will be the appropriate framework for understanding new structure and forms of organization that characterize many innovative industries.

CHAPTER FIVE
APPLICATIONS

5.1 TRADITIONAL APPROACH:

Most policies supporting innovation are based on the standard economic analysis of the innovation process. Within this approach all idea transactions can be accounted for by patent licensing agreements and the explanation for different market structures and collaborative research efforts among industries must be either economies within the production process, or collusion. This understanding leads to a policy focus that revolves around reducing the costs and risks of innovation while simultaneously preserving the benefits of competition.

The theory developed in Chapter Four concerning the transactions costs of idea trading could be seen as a special form of the cost reduction argument because alternative contractual structures are all used to reduce the costs of producing and diffusing technical information. It is different from the cost reduction argument which is generally used, however, because the focus of cost reduction is on transactional and not production economies. Because of these differences, reducing the transactional costs yields very different explanations and implications for the economic phenomena associated with innovative industries from reducing production costs. The latter is generally related to the scale of the capital and labour employed within a physical production process and delivers a different policy approach concerning the means of best supporting innovation.

A quick analysis of current legislation and policy thrusts reveals that standard economics underlies most innovation policy. For example, the Competition Act provides an exemption for cooperative research ventures but the thrust of this policy is that cooperative research must be directed towards reducing production costs. Hence, the

exemption generally requires that any cooperative venture develop a prototype invention in order to qualify. This recognizes that a larger share of the costs of innovation are usually incurred during the development stage of innovation and serves as a kind of proof that the cooperative arrangement was not being used to facilitate collusion.

Similarly, patent policy seems designed to provide the inducement necessary to encourage innovation while minimizing possible monopoly distortions. Hence, the unease permeating relations between patent and anti-trust law and the use of compulsory licensing to minimize the extent of monopoly distortions.

The focus on production costs extends to industrial development policy. The most commonly offered solutions for poor Canadian R&D performance are increased government spending, tax credits to defer the costs and risks of innovation and direct grants and loan guarantees. All the above programs presume that the source of innovative performance lies in the production costs of innovation. If the costs (and risks) of R&D can be reduced through the appropriate policies then presumably R&D performance will improve.

What this approach does not allow for is the costs of transacting ideas. Thus, non-standard contractual forms and customs are not related to the nature of the underlying technology. While the increasing cost of research is often accounted for, little attempt is made to address differences among industries, differences in their underlying technologies and to relate this to the resultant innovative performance of the industry. Little attention is paid to any need to coordinate increasingly complex technological systems or for firms not to produce but to acquire and apply technology. The need to acquire technology is becoming increasingly recognized in the business literature.

> Thus we have (1) pressure from the inexorable increase in the cost and complexity of technical progress, (2) relevant technology produced outside the corporation growing more rapidly than the increase in technology generated inside the corporation, and (3) each company that generates technical change generating a greater demand for further change. (Fusfeld, 1987, p. 32)

5.1.1 Aircraft Patent Pool: A typical example of the traditional policy approach to innovation is the case US anti-trust authorities brought against the aircraft patent pool. The aircraft patent pool was formed in 1917, challenged by the US Department of Justice in 1972 and dismantled in 1975. It arose out of a 1908 patent infringement case between the Wright Brothers and the Curtiss Aircraft Company over the scope of a Wright Brothers patent on a device which controlled the lateral movement of wings. The Curtiss Company had invented a different mechanism from that used by the Wright Brothers while the Wright Brothers argued that their original patent covered all devices used for the same purpose. The resolution of the case was that a patent pool was formed among all existing aircraft manufacturers.

The 1972 case put forward by American anti-trust authorities argued that the patent pool was a conspiracy designed to slow innovation and thereby harm social welfare. In the view of the Department of Justice it constituted an insurance policy for firms against a rivals successful innovation. Because no firm could hope to earn a monopoly return from its invention, the incentive to innovate would not be present.

At first glance, this argument that this was a conspiracy designed to slow innovation seems odd because the American aerospace industry has long been one of the most innovative American industries. It progressed from the first flimsy Wright Brothers aircraft to jet liners in sixty

years and generated the Space Shuttle and Stealth bomber and other aircraft which still lead the world. Certainly, it dominated foreign competition for the life of the patent pool. In fact, the European challenge to American dominance of commercial aircraft manufacture arose from a consortium of European aircraft producers who formed Airbus in the mid-60's in an attempt to match the technological achievements of the Americans.

Recently, Bittlingmayer analyzed the aircraft patent pool to test the validity of the Department of Justice charges versus the theory that the patent pool was a valid means to facilitate the trading of ideas and support technological advances in the industry (Bittlingmayer, 1988). He studied the structure of the agreement testing the ability of the anti-trust explanation for the patent pool to explain the contractual stipulations governing it.

The core of the patent pool was the agreement struck between the Curtiss and the Wright Brothers which allowed entrants to have access to what was then the dominant technology for controlling the lateral movement of wings. All that was required was that they pay a licensing fee. The agreement did not seem to have entry deterrence as its prime objective.

Successive inventions by member firms entered a common pool for use by all members. Only in the case of a particularly drastic invention was a licensing fee paid for any of these inventions. An independent panel was established to determine what constituted a drastic invention in these cases. The patent pool was limited to aircraft structures and did not include engines, braking systems or other peripheral technologies.

This analysis does not seem consistent with the anti-trust but rather with an idea trading explanation for a number of reasons: Firstly, the industry was a highly innovative one. Secondly, aircraft structures were a

technology that was broadly applicable and a technology where all the advances would be generated within the industry. Other innovations, such as engine improvements, were often produced by other industries and applied to aircraft. Aircraft manufacturers would be less able to measure the value of peripheral technologies and allow for reciprocal transactions if peripheral technologies were included. Additionally, there would be far fewer gains to be realized from the greater coordination and non-duplication of research. Thus, limiting the agreement to aircraft structures guaranteed broad applicability of traded inventions and reduced measurement costs. Additionally, because the traded inventions were useful only to aircraft manufacturers no inventor would have the incentive to breach the agreement and sell outside the patent pool. The provision allowing the licensing of drastic inventions helps ensure the long term viability of the agreement. It reduces the incentive for innovating firms to hold out when they produce an especially important invention.

Under the terms of the patent pool only small costs were incurred measuring the value of ideas and negotiating agreements transferring patent rights. There were no enforcement costs because of the common property provision of the agreement. Patents did not seem to be used to establish a monopoly and deter outside entry because Bittlingmayer noted that one of the intents of the agreement seemed to be the reduction of the scope of patents. This is not very consistent with the theory of the aircraft patent pool as an anti-competitive device but is very consistent with the theory that the agreement was structured to prevent holdouts.

The Bittlingmayer analysis suggests that the aircraft patent pool was misunderstood by antitrust authorities. While standard theory suggests that the non-standard structure of the agreement must have been the result of

collusion, the Bittlingmayer analysis demonstrates that the collusion argument is not well supported but that the agreement can be explained as a means of minimizing particular transactions costs in technology trading.

In the next section, this theory will be applied to the pharmaceutical and micro-electronics industries to determine if their structures can be explained by considered the possible benefits and transactions costs of trading ideas.

5.2 CASE STUDIES:

Standard theory argues that differences in market structure between industries result from either economies in the technical costs of production or from collusion. The new theory is that organizational forms and different market structures (differences in contractual structures) change, in addition to the reasons listed above, to reduce the transactions costs of trading different kinds of ideas. Under the new theory the characteristics of an R&D process and its relationship to other technological advances are important. This section will consider two innovative industries and discuss how the new approach might be applied to them.

5.2.1 Pharmaceuticals: Pharmaceuticals are a good base case because they are a highly innovative industry and one of the few in which patents are found to be an effective means of protection (Levin, 1985). Levin suggests that this is because pharmaceuticals are chemical formulas which are easily described making patent infringement relatively easy to prove. This thesis suggests a different hypothesis. Pharmaceuticals are well served by patent protection because the scope of the protection they offer can be very broad without incurring large costs from deferred diffusion (or phrased differently there are few gains from trading ideas in this industry). Protection is broad because a patent on a pharmaceutical covers not only the new chemical but also

similar structures which the inventing firm did not actually produce. It is also uniquely broad because the patent encompasses an entire consumer product.

There are few gains from trading ideas because the research method is largely routinized.[1] Pharmaceutical research does not generally build on earlier research results, nor do revolutionary improvements in the production process often occur. The research method consists of constantly reapplying the same techniques in order to develop new chemicals and then testing their properties. Not surprisingly the industry is far less characterized by the cross-fertilization of ideas and the leap frogging of revolutionary technologies than is, for example, micro-electronics. The potential gains from idea trading are further reduced because there is little need to coordinate invention. Pharmaceuticals are not produced in large scale systems composed of many mutually dependent parts. For all these reasons, broad patent protection which would otherwise inhibit idea trading does not pose a large cost.

This is an idea protecting industry and because in such industries the ability to monopolize invention becomes the critical determinant of innovative performance, the new theory implies that pharmaceuticals should also be characterized by other devices (such as those identified by Levin) for preventing the imitation of invention. Despite the high costs of research, collaboration is not necessary. High production costs of research will be met by larger firms. Because there are few gains from trading ideas, cooperative research should not be expected. The argument against cooperative research ventures is one of the main differences in prediction between the new and old theories.

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1. The application of biotechnology to new pharmaceuticals is an exception to this rule and should create considerable change in the industry.

Most case studies confirm that the industry is organized as an idea protecting industry should be. It is highly concentrated, integrated into distribution, characterized by strong investment into brand names. All of these are characteristics of an industry which earns returns on its invention by preventing imitation. As the following quote indicates it also engages in relatively few collaborative research efforts, despite the expense of developing new drugs:

> For example, venture autonomy was rare where joint ventures were part of the strategies of global pharmaceutical firms. Such ventures were primarily marketing arms of their global owners and were undertaken because of local governments' requirements. This pattern was supported by the relatively stronger competitive advantage afforded by patents in the pharmacuetical industry. (Briefly, control over patents is a more enduring source of competitive advantage than market access in the ethical pharmaceuticals industry. In most other industries the short half-life of technology makes market access a more enduring source of competitive advantage than technology based strengths). Few firms formed joint ventures for basic research in pharmaceuticals (except in genetic engineering an embryonic industry where firms hedged their bets concerning the most successful chemical routes) (Harrigan, 1988, p. 155).

The issues raised by genetic engineering are interesting in this context because in biotechnology there are potentially large gains from idea trading. This is indicated by the controversy currently surrounding "second generation rights" and product-by-process versus product patents (Buchanan, 1988). The ongoing application of the new technology to pharmaceuticals should therefore be accompanied by some growth in the kinds of joint venture, inter-firm equity arrangements and non-standard licensing arrangements which have been rare in the industry up until now.

5.2.2 Micro-electronics: The micro-electronics industry is described as a fast moving one in which the participants

must make continuous and substantial investments in R&D in order to remain competitive. The industry is like pharmaceuticals in that it constantly seeks to introduce innovative new products and it is unlike pharmaceuticals in that it is characterized by large potential gains from idea trading.

The industry is idea trading industry because it is dependent on many diverse technologies; advances in any one of which can affect other segments of the industry. Such advances include new materials, new designs and new components. Thus, leapfrogging and displacement of technologies is much more common than is the case with pharmaceuticals. Additionally, the breadth of potentially applicable technologies is much wider and there are large scale systems dependencies (the success of any one innovation may be particularly dependent on the success of others).

Because there are both large potential gains from idea trading and diverse types of invention the industry should be characterized by diverse trading arrangements. It should see a whole range of cooperative research ventures and complex licensing agreements which do not occur within the pharmaceutical industry. These cannot be explained away as simply constituting different means of achieving economies of scale. Firstly, the concept of economies of scale is weak in innovation because there are no like factors of production. Secondly, an economies of scale argument only begs the question of why the firms do not simply grow larger as is the case in the pharmaceutical industry.

A two fold explanation is offered by idea trading considerations. Firstly, the industry depends on a diverse range of technologies and trading the constituent ideas of these technologies requires a diverse range of trading arrangements, including hierarchical and market contracts coupled with their supporting institutions. Secondly, the

diverse range of technologies creates instability within trading dependencies which means the parties to trading arrangements may often shift. Shifting trading arrangements are difficult to accommodate within large hierarchical structures because of the high costs of continuously restructuring. Therefore non-hierarchical structures will be expected. Most case studies confirm that this is the case within the micro-electronics industry including the following:

> there is ample evidence that various kinds of inter-firm agreements, collaborations, and partnerships have mushroomed in some industries, in an unprecedented fashion. Firms are seeking to combine their strengths and overcome weaknesses in a collaboration that is much broader and deeper than the marketing joint ventures and technology licensing that were used in the past.
>
> These developments not surprisingly are particularly common in high technology industries (Powell, 1988, p. 72)

5.3 NEW APPROACH TO COOPERATIVE RESEARCH

Cooperative research is a rapidly growing phenomena. Today, all advanced economies have accepted that collaboration in research is a key for improving innovative performance. Canadian, European, Japanese and American governments all support the creation of research consortia and foster the development of research joint ventures by removing existing barriers to cooperation in research. European efforts are often coordinated at the level of the EEC and have led to the formation of research consortia such as ESPRIT, EUREKA, RACE and BRITE. Each of these has targeted specific technological areas for development. The U.S. government has sponsored research consortia such as the Microelectronics and Computer Technology Corporation (MCC) and Sematech in an attempt to regain the lead in computer and semiconductor manufacturing technology. Between 1984's

passage of the National Cooperative Research Act and 1987 more than 50 American research consortia were formed. Dr. Bruce Merrifield, former head of the U.S. Commerce Department cited 100 regulatory and anti-trust barriers needing removal in order to sponsor still further collaborative research (Merrifield, 1987). His successors have continued in this direction. Attorney General Richard Thornburg has pushed for an expansion of the National Cooperative Research Act in order to stimulate a greater commercialization of technology (Chow, 1989, p. 10).

In Japan there is a long history of cooperative research dating back to a conscious industrial strategy pursued since the 1950s. Perhaps the most well known was a government sponsored consortia effort to develop a Very Large Scale Integration (VLSI) chip which subsequently helped establish the Japanese position in computer technology. Today, ministries such as MISSIS (Ministry of International Trade and Industry) and the NSA (National Science Agency) are actively organizing consortia involving universities, government labs and industry. Between 1984 and 1987 they sponsored the formation of more than 200 research consortia (Rogers, 1987). Furthermore the Japanese are now initiating an ambitious "technopolis" strategy in which whole research cities will be created and devoted to cooperative research. As of 1987, 22 sites had been approved for development as technopolis centers (Tatsuno, 1987).

Cooperative research is not only a government sponsored phenomena. Industry is undertaking its own independent efforts. They are seeking to fill gaps in their own product lines and technological capabilities. The general consensus is that reliance on external technology acquisition is growing.

> Friar and Horwitch contend that there has been a marked shift in technology strategy: a general trend

> toward greater reliance on external sources for R&D, and more cooperation among competitors. In interviews with members of a sample of 15 Fortune 500 companies spent at least $80 million on R&D in 1982, they found external sources of technology had grown in relative importance at the expense of the central R&D lab. There was a significant increase in contract research, acquisitions, licensing, joint ventures, equity participation, the marketing of other companies products, reciprocity agreements and multiorganizational collaborations (Powell, 1988, pp. 73)

Four possible explanations exist for this growth in cooperative research: collusion, diversifying risk, reducing production costs of research, and idea trading. Undoubtedly an anecdotal example of each motive could be found. However, this analysis will demonstrate that cooperative research is generally limited to the types of idea trading predicted by this thesis and that the idea trading institutions tend to be structured so as to reduce transactions costs. The following points out the fallacy of the production cost reduction argument.

> But the real value, the true function, of this growth in technological linkages is not simply that more research is done. In fact, when we examine the amount of R&D which is conducted through some form of alliance or cooperative mechanism, it makes up a very small part of all industrial research, probably less than two percent. Thus, all the activity I have been discussing does not add substantially to total R&D, although it can be of great value for specific projects.
>
> But these linkages and cooperative mechanisms do far more than generate technical outputs; they create networks for efficient access to, and distribution of, technical advances throughout our technical system (Fusfeld, 1987, p. 33).

Because less than two percent of industrial research is conducted within a cooperative mechanism the research cost reduction or risk diversification theories do not seem

substantive enough to explain such phenomena. Moving information more than reducing research costs is the real motive for cooperative research ventures. Moving information or ideas implies reduction in the costs of research but it is not simply the production costs associated with a specific project. It is the often unseen reduction of costs associated with the duplication of research and the non-specialization of research personnel.

> In particular, when the task at hand is complex or uncertain, contractual agreements will be difficult to specify and monitor, and post-contractual opportunism will be common. In such a case, the same parties can more efficiently govern their relationship with one another if they submit to the close and intimate supervision of a commonly agreed upon hierarchy (Ouchi and Bolton, 1988, p. 15).

The importance of understanding idea trading is growing because as technological systems grow in scale and complexity it becomes increasingly difficult to produce them within a firm. The need to coordinate their production through a larger number of firms using some kind of idea trading mechanism therefore grows. With increasing technological complexity there should therefore be a commensurate growth in various idea trading mechanisms. Swiftly advancing industries working on broad technological systems will see strong growth in idea trading structures. This prediction is borne out by most students of business and innovation.

> There is unquestionably, a new wave of corporate activity in the use of external technology. We see it in increased licensing, joint ventures, cooperative research programs, university-industry cooperation, and research consortia. The common motivating factor in all of these is the declining technical self-sufficiency of every organization that carries on research and development. It may not be referred to or even thought about in that way. Nevertheless, more and more business plans and strategies will logically

> and deliberately call for the use of external technical resources (Fusfeld, 1987, p. 32).

The business literature is an excellent source of information regarding contractual relations. Although they do not always conceptualize them as "transactions costs" business theorists deal with transactional difficulties head on and a considerable body of anecdotal evidence now exists. This evidence can be used to test theories regarding the relationship between specific transactions costs and alternative trading arrangements.

According to the analysis developed in Chapter Four a number of difficulties exist in trading ideas. Trading should be accomplished through cooperation rather than licensing when the scope of information to be transferred involves a great deal of often subtle learning, when the information cannot be contained as a blueprint or protected by a patent, or possibly in cases where there is a great deal of moral hazard present in the negotiation stage of the licensing agreement. Licensing will work best only with very specific ideas and know-how, which closely correspond to inventions and patents. Most know-how is tacit and unpatentable. It is difficult to codify and transmit without the interaction of people. Thus cooperative research efforts will be expected to replace licensing in cases where the information to be transferred involves not only a description of an invention but complex knowledge regarding its potential use and subtleties. Thus, rising complexity and a growing need to understand how inventions relate to larger systems suggests that cooperative research efforts will replace licensing agreements. Likewise, as the research becomes more basic, more difficult to price, and more broadly applicable, cooperative research which obviates the need to negotiate and measure contribution to value will tend to replace licensing agreements. Cooperative research will be a preferred method of technology transfer when the

state of intellectual property rights is uncertain, incomplete or in flux. Cooperative research can be a useful means of reducing opportunism in cases of ongoing research coupled with technical uncertainty. Consider the following two cases: (1) A technology exchange agreement is made. If this is an agreement to merely transfer research results made by arms length labs, there will always be an incentive to breach the contract and not share a breakthrough if it is particularly drastic. If this research is undertaken cooperatively in common premises the breakthrough results will have already been shared. (2) If some technology is transferred but its ultimate price depends on the results of ongoing research not yet completed, under a cooperative research arrangement both parties can be assured of the results, whereas if only one party undertakes the subsequent research it will always have an incentive to claim the results are such that the lower price for the transferred research should prevail. Thus, cooperative research may provide a low costs means of reducing moral hazard.

With transactional difficulties in mind different types of collaborative research can be analyzed.

5.3.1 Joint ventures: Joint ventures establish a jointly administered hierarchy among two or more firms for the achievement of some mutually agreed upon goal. Business analysts report that joint ventures are commonly entered into to fill some gap in technology or expertise by the participating firm.

They are describable by a whole range of structures and obligations for the partners. For example, some joint ventures specifically detail the rights obligations of each party and others are quite open ended and may simply state vague goals and create an arbitration mechanism for any disputes which may arise. Some operate under a mutually determined, pre-specified governance structure and others are governed directly by the participating firms. Some

involve a considerable equity involvement by one or more of the partners and others do not.

These different contractual structures can be partially explained by analyzing specific transactional difficulties. Consider, for example, the role of technical uncertainty. With technical uncertainty it is difficult to identify all possible outcomes and write the necessary contractual stipulations for a licensing or research contractor agreement. Transactions costs theory suggests that rather then incur the costs of writing and administering complex contractual stipulations firms will seek a hierarchical solution. Future contingencies will be dealt with through a previously established hierarchy or arbitration board. By contrast, with low technical uncertainty, such as a case of putting together existing technologies into a new product, the costs of establishing a separate governance structure need not be incurred. The costs of negotiating and measuring every possible contingency will be small.

Equity involvements in a joint venture serve as hostages supporting exchange. A number of transactional difficulties could create the need for such a hostage. For example, joint venture partners may be of unequal size or one partner may have better access to financing. In such cases, moral hazard may result because the larger partner may be able to appropriate the smaller partner's technology by simply delaying payment and forcing the smaller partner into bankruptcy. The smaller partner may also have no means of marketing any mutually developed technology or it may not have the resources to stage a legal battle over intellectual property rights. Once the technology is transferred from the smaller to the larger partner the incentive is created to breach the contract. Knowing this, small firms will have no incentive to enter the contract unless a hostage is offered. This theory is supported because this type of arrangement is particularly common between large established

firms and small start-ups (Harrigan, 1988), notably large pharmaceutical companies and biotechnology start-ups. Biotechnology start-ups are particularly illustrative of the nature of the motives for this type of arrangement because intellectual property rights in bio-processing are uncertain or in flux. Such uncertainty reduces the start-up's defenses and increases the incentive to transfer technology through a joint venture with a hostage to support exchange.

Joint venture partners may also seek to transfer only a small subset of all their valuable ideas. This will entail structuring the joint venture so that unintentional technology transfer does not take place. This may be difficult because of the considerable interaction taking place between the researchers involved in a joint venture. One means of doing this is to set up joint venture operations as a complete stand alone firm with limited physical proximity between the joint venture operation and the parent firms. Also scientists participating in a joint venture are often trained not to unintentionally divulge valuable trade secrets. This is consistent with the theory that only specific types of idea will be traded.

What is interesting about this phenomena is that it demonstrates how firms will simultaneously protect some ideas and diffuse others. This also indicates that joint ventures are not structured so as to protect the partners against a rival's innovation or strictly for collusion. In fact, cases of unintended technology transfer often result in bitter court battles indicating the intensity of the competition that can be going on even between joint venture partners. For example, Andrew Grove of Intel notes that his company is involved in a fierce copyright dispute with NEC over the instructions in two of its microprocessors. Nevertheless it continues to maintain a number of cooperative research arrangements with NEC (Potts and Behr, 1987).

It is noteworthy that it is not generally inventions that are being exchanged within a joint venture. Joint ventures are more often mechanisms for exchanging otherwise untradable ideas. Joint ventures do not trade inventions so much as they coordinate their development. This can be seen in the work by Potts and Behr (1987) who note that successful joint ventures demand the frequent and continuous transfer of personnel between the joint venture and the parent firm. Only the best personnel should be used in these ventures because they are best able to capture useful ideas (Devlin and Bleakley, 1988). These structures are highly indicative of a dense and frequent exchange of often subtle ideas.

Finally, in arguing against the interpretation of collusion there are the conclusions of Ouchi and Bolton. They note that the preponderance of joint ventures are conducted at a level far removed from the market application of innovation (but conducive for trading applicable ideas). Joint ventures are generally terminal agreements and the industries which practice them the most, such as telecommunications, computers, and automobiles are all quite innovative and regularly litigate against one another (Ouchi and Bolton, 1988).

5.3.2 Strategic alliances: Strategic alliances are more unbounded than joint ventures less formally structured and not as goal oriented. These seem to be the key distinctions between the two although they are often confused in the literature.

Strategic alliances are best characterized as channels which direct otherwise chaotic technological information towards firms that can make use of it. They are often made between two firms with different areas of technical expertise who both partly depend on the technology at which the other is more expert. By forming a strategic alliance they can rely on their partner to make sense of the fast

changing world of its technology and channel towards them that which is relevant to their own business. Channeling information solves management's largest problem in fast moving industries by helping to restrict the flow of information to that which is relevant. Firm decision makers therefore use strategic alliances to simplify the task of identifying relevant technologies. Strategic alliances often evolve into long term trading relationships supported by trust between the executives of the respective firms. In many cases strategic alliances may grow into formal joint ventures as specific opportunities are revealed.

Growth in the scale of technological systems and the continued application of new technologies to existing consumer products mean this phenomenon will continue to grow. The needs of firms in fast moving industries necessitates a whole portfolio of strategic alliances in order to remain technologically competitive.

Most strategic alliances are located in industries characterized by other forms of technology exchange, such as cross licensing agreements. They are particularly prevalent in telecommunications and computers where there is a very large range of relevant technologies being produced and the need to stay abreast of technological breakthroughs is most acute. This lends credence to the view that their real purpose is to identify technological opportunities.

5.3.3 Research consortia: Research consortia are a rapidly growing phenomenon often seen as the key to seizing the advantage in emerging technologies. They may be conceptualized as very large joint ventures but they tend to have more specified rules and often outlive the participation of any particular member.

Consortia fit the mold of idea trading institutions in that they are generally targeted at a rapidly advancing core technologies, or manufacturing expertise; all broadly applicable areas with large potential gains from idea

trading. Possibly the best known research consortia is the American Sematech venture which targets the manufacturing of semi-conductor chips, a technology seen as the key to controlling much of the consumer electronics, computer and telecommunications industries.

Like joint ventures, consortia are governed by rules although these tend to be constitutions rather than negotiated agreements. They also have attributes which seem designed to minimize the costs of negotiating the exchange of ideas.

Two general types of rules govern consortia. Firstly, participants are given intellectual property and licensing rights roughly commensurate with the equity and expertise that they contribute to the consortia. Secondly, a minimum contribution is set down for participation in a consortia research group, such as a minimum equity position or a minimum number of qualified personnel to be contributed. In the debate surrounding the formation of Sematech, for example, the project nearly failed over a debate concerning which prospective members would lose control over what proprietary technologies. Once minimum contributions are established, however, all participants are free to take back to their parent firms any acquired knowledge and free also to develop any patented technology.

Close examination of consortia structures and operating procedures reveals that their primary aim is to support technology exchange (transfer of ideas) in keeping with the predictions of this thesis, rather than transfer finished inventions. This is generally accomplished by allowing early access to ongoing research results rather than waiting for projects to be completed. The following quote is indicative of this approach and it refers to the American Microelectronics and Computer Consortium (MCC).

> One of Inman's earliest pronouncements at MCC was that anyone who was any shareholder in a program had

> the right to anything they were funding at anytime. Sometimes it was only any idea and we didn't know whether it was a good idea.
>
> Our job (MCC's). . . was to facilitate the early and effective transfer of information even if we weren't sure that it was ready to be called a technology. (Stotesbury, 1987, p. 64).

This quote seems quite illustrative of consortia being structures which facilitate the transfer of ideas and unfinished inventions. Consortia sponsored research is therefore well coordinated and allows for the specialization of individual researchers. In later periods of development firms will compete very vigorously to commercialize the results of the joint research. In the absence of a consortia structure many negotiated agreements would be necessary to achieve this result. Due to high transactions costs, the cross-fertilization of ideas and the non-duplication of research would not take place.

> MCC does not engage in commercial-scale volume production of any product. The rights to all intellectual property developed are vested within MCC, and not the member companies. Those firms which have funded a research project have immediate licensing rights to any products of research. The Board of Directors may, at any time, grant licenses to those properties to other member firms. It was originally intended to deliver only working prototypes to member companies, thinking that members would prefer to receive completed intellectual products. Experience has shown, however, that member companies derive great value from immediate results and can often place them into immediate use. Such an outcome is heavily dependent upon the quality of technology transfer mechanisms between MCC and its member companies. Frequent meetings are scheduled to transfer algorithms, processes, and software tools which will ultimately lead to MCC end products, or working prototypes (Ouchi and Bolton, 1987, pp. 26-27).

5.3.4 Barter: Idea trading may often be conducted through a barter mechanism. It would be expected most often when

property rights are poorly specified or lacking because in such cases legal agreements would be costly to administer and enforce.

Ideas and knowledge of a tacit nature would most likely be exchanged because more tangible ideas directed towards clearly defined results could probably be better coordinated through a joint venture arrangement. Barter may also be used to exchange trade secrets and non-technological kinds of knowledge. Barter will also be preferred in cases when market value is difficult to assess. Rather than employing engineers and market researchers to translate scientific information into an estimated market value so that senior managers can negotiate, it may be less costly in terms of organizational time to delegate the decision to engineers and allow them to barter ideas within clearly defined rules.

Barter amongst engineers can be efficiently enforced by trader reputation. This is especially true if trading relations are long term and yield strong mutual benefits. The advantages are neatly summarized by Powell:

> when repeat trading occurs, quality becomes more important than quantity. The reputation of a participant is the most visible signal of its reliability. Reputation bulks large in importance because in many network-like settings, there is little separation of formal business and personal social roles. One's standings in one arena determines one's place in the other. As a result, there is a limited need for hierarchical oversight, because the desire for continued participation successfully discourages opportunism. Monitoring is generally easier and more effective when done by peer than when done by superiors (Powell, 1987, p. 83).

In such a barter system reputations serve as hostages supporting exchange. Because contractual stipulations do not have to be formally negotiated, barter allows much subtler ideas to be exchanged. Measurement costs are

minimized by limiting exchange to those who possess the expert knowledge necessary to undertake it.

Eric von Hippel recently conducted an exhaustive study into informal idea trading (von Hippel, 1988). His finding that management is not in direct control of barter among engineers, despite the fact they are trading with their direct rivals. This clearly indicates that there are cases where the gains from idea trading outweigh the gains of protecting ideas from imitation. The von Hippel study also demonstrates that this is legitimate idea trading and not merely a case of undisciplined staff. It is a very sophisticated operation responding to economic incentives. It is limited to engineers who have knowledge of one another's abilities and reputations and depends strongly on how useful the information is as well as the possibility of earning a suitable repayment.

> Technical personnel at all firms except Quanex reported that they routinely trade proprietary know-how with other mini-mill firms and sometimes with direct rivals. So informal know-how trading appears to be a nearly universal practice in this industry. Top management is aware of it, and does not try to control it beyond providing general guidelines, such as prohibiting personnel from discussing particularly sensitive projects.
>
> All the personnel we interviewed emphasized that they were not giving know-how away but were consciously trading information whose value they recognized. An engineer at Bayou Steel told us, "How much is exchanged depends on what the other guy knows- (the trade) must be reciprocal." A manager at Caparral said, "If they don't let us in (to their plant), we won't let them in" (to ours) (von Hippel, 1988, p. 52).

Because barter systems work best when roughly equivalent values are being exchanged it would be expected that larger, more drastic ideas would not be included in the barter arrangement. Von Hippel notes that it is mostly routine inventions and ideas which are exchanged. Larger

inventions tend to involve more formal arrangements (von Hippel, 1988). The study also indicates that knowledge trading dries up when the companies are competing for a specific government contract and the deadline for submissions is drawing close. This is consistent with the theory that trade breaks down when the potential gains from monopolizing an invention outweigh those of diffusion. As contract deadlines approach the possibility of reaping a substantial monopoly return rises as does the incentive to withhold ideas from the barter system.

5.3.5 Cross and Tacit Licensing: Cross and tacit licensing agreements allow specified firms in an industry to use one another's patented inventions. As the following quote from the Wall Street Journal indicates these agreements are especially prevalent in industries characterized by forms of cooperative research such as micro-electronics.

> IBM routinely cross licenses its patent library with other companies that have libraries of patents, "We use patents principally as trading material for our own freedom of action in the marketplace," says Roger S. Mith, IBM's director of intellectual property law. He says IBM will license all of its patents for up to 5% of the sale price of a product.
>
> In a kind of intellectual property arms race, companies are trying to build libraries of patents to trade with other concerns in cross licensing agreements (1989, p. B3).

Transactions costs analysis suggests cross and tacit licensing arrangements will prevail over cooperative research as a means of idea trading as intellectual property rights become better established. If the technology is relatively easy to reverse engineer cooperative research will not be necessary to transfer all its tacit aspects. Like other idea trading arrangements, cross licensing agreements will be more prevalent when there is great technical uncertainty and a high rate of technical advance.

The advantage of cross licensing policies is that they reduce the need for continuous negotiations.

Cross-licensing and tacit cross-licensing agreements may often result simply because firms do not wish to undertake the expense of costly intellectual property litigation. Patents may serve less as a means of protection than as a means used to leverage rival firms into allowing access to their own proprietary technologies.

IBM's strategy suggests that in technologically dynamic industries patents are used less for protection than they are used as a means of supporting trade. Patent licenses constitute a hostage in that a licensing firm can revoke its licenses in the event of contractual breach. It often does not even matter how enforceable the patent rights actually are because in fast moving industries it is generally true that no party stands to gain from litigation. Patents also help to produce information that supports other kinds of exchange. For example, a portfolio of patents verifies that the firm possessing them has been successful in achieving research successes. This indicates to other firms that they will not give up too much for too little should they enter into a technology exchange agreement with this firm.

Dynamic industries such as biotechnology may, in the future, see formally mandated cross licensing agreements. These will effectively remove the issue created by blocking patents and second generation rights. Firms producing inventions based on an original invention will not negotiate for this right at all but will simply pay a pre-specified licensing fee.

Often what takes place is not formal cross-licensing but what may be best described as tacit licensing. The Silicon Valley is an example of this. Here, often firms simply choose not to litigate against one another. Cross-licensing agreements may be struck to formalize this (Businessweek, May, 1989) but there are also cases where

ideas simply become public goods. Firms acquiring the technical competence to understand one another's inventions have paid the price of entry to a sharing arrangement. Whereas neo-classical economics generally condemns common property as inefficient, this analysis implies, following Quiggen (1988) that given particular conditions of use it can be efficient to administer property through social rules and customs rather than private property rights owing to the relative costs of enforcement.

> Untraded interdependencies and context conditions are, to different degrees the unintentional outcome of a decentralized but irreversible process of environmental organization (one of whose example is the Silicon Valley) (Dosi, 1988, p. 1140).

5.4 CONCLUDING REMARKS:

This chapter began by demonstrating that most government policies and economic thinking regarding innovation have focussed on the costs of research and the potential for innovation to generate monopoly abuses. Neo-classical analyses tends therefore to focus on the need of small business to access financing and to achieve sufficient scale to conduct research and presumes that this is the motive for cooperative research.

Idea trading hypotheses suggest an alternative. It is that firms are small because this better facilitates the exploration by firms of large and unknown technical and marketing opportunities and that idea trading is a means of diffusing discoveries from this process and managing the decentralized operations of many firms. It has examined many phenomena often observed in highly innovative industries and demonstrated the power of this theory for explaining them. The next and final chapter will draw some final conclusions from this thesis and offer some thoughts regarding its application to many questions of public policy.

CHAPTER SIX
CONCLUSIONS:

6.1 OVERVIEW:

This thesis is intended to be a contribution to understanding the role of knowledge in production, the need for which arises from a growing appreciation of its importance for competitiveness. This importance is borne out by the increasing share of value accounted for by the application of skills and technology to production.

The growth of this phenomenon means that individual firms are increasingly unable to produce all the technologies relevant to their markets and must therefore devote an increasingly large share of their energies towards acquiring technologies from external sources.

In short, growing technological competition demands the trade of ideas but ideas are inherently difficult to trade. In economic terms, the exchange of ideas is subject to high transactions costs. Because of these costs, strict market mechanisms are often not enough and ideas will instead be transferred through non-standard market contracts, organizational innovations and other alternative mechanisms. Such exchange is often supported by institutions and customs which are not normally the subject of economic analysis.

To understand such exchange the new institutional economics and particularly the "economics of the contract" provide the tool of analysis. The economics of the contract analyzes the contractual stipulations governing exchange by asserting that these stipulations are designed to reduce the unique transactions costs of specific exchange relationships. While this study is based on the economics of the contract, it is not limited to strictly legal contracts but is extended to include implicit contracts, customs and other variants of the institutional setting within which exchange takes place.

The application of the economics of the contract is also broad because both markets and hierarchies are governed by contract. The need to trade or price ideas will affect both the internal contractual structure of a firm and those contracts which govern its external relations. In fact, in the study of innovation, often any economic distinction between firm and market grows fuzzy because hybrid market/hierarchical solutions will be found for specific transactional difficulties. These solutions typically involve only a partial surrender of decision making authority.

Contracts are asserted to be stipulated so as to allow the maximum gains from idea trading to be realized. The exploration of some of the transactions costs reducing properties of contractual structures has been a central thrust of this thesis. But it has also noted that specification and enforcement mechanisms of a contract cannot be understood unless these mechanisms are placed in the context of institutional arrangements. Different institutional contexts can create an entirely different contractual structure for the exchange of ideas even when the specific exchange difficulties are almost identical. In other words, this analysis always leaves a role for history, trust, reputations and "handshakes".

The analysis employed in this thesis stems from the realization that information is not costless. Information regarding product characteristics and the reliability of the trader is needed by both parties to a contract, in order to support exchange, and this information is costly to acquire. The amount of information needed to support exchange grows as product characteristics grow more complex and more difficult to measure. Therefore, as products embody increasing amounts of knowledge, the information required to coordinate their production and sale grows. As this informational requirement grows, the transactions costs of

trading ideas grows and the need to find a means of economizing on the trade of these ideas also grows. Generally, this implies that the complexity and diversity of contractual stipulations expands as attempts are made to reduce transactions costs. Strict market exchange between anonymous actors, with only price as a contractual stipulation is replaced by complex, often personal, contracts, organizational innovations, and strong contractual linkages among firms where price becomes one of many contractual stipulations. These may stipulate a number of different prices and other terms for a number of different contingencies. The ultimate purpose is to reduce transactions costs and ensure the terms of an exchange will be met by both parties. This suggests that the industrial organization of knowledge intensive industries cannot be understood if the analysis is limited to the strict market exchange conducted by firms within the industry. It also suggests that while the importance of the cost of information was first articulated by Coase over 25 or possibly even 50 years ago (Coase, 1937, 1960), the full implications of his insights are still penetrating economics.

This paper has suggested that economists have generally failed to come to grips with innovation. They have not understood the process and have not therefore advocated sound policies to support it. In part this has stemmed from too rigid an application of the taxonomies and methods of neoclassical economics. Innovation involves the movement of ideas, often at a sub-firm level and ideas have properties such as high measurement costs, publicness and cumulativeness which mean the usual assumptions of neoclassical economics do not apply.

As innovation and also the application of marketing and administrative knowledge have assumed increasing importance in the modern economy, the focus on firms has created a

general misunderstanding of the nature of production and patterns of organization. The problem has generally lain in the misconception that firms produce inventions which are made into products and then marketed, and that the relationships among these firms are approximated by models of free market exchange. This assumption led to the idea that the returns to invention are earned when a product based on that invention is monopolized. This idea has set much of the research agenda for the economics of innovation. The study of patents, for example, usually assumes a tradeoff between the benefit created by increased incentives to invent and the losses created by monopoly distortion. The study of the appropriability problem and studies exploring direct relationships between the size of a firm and innovative performance also seem to assume a one to one relationship between idea, invention and product. None of these literatures, however, seem to address the critical question of how both new ideas and new inventions are disseminated.

Studies of this standard type also do not capture the often subtle distinctions between knowledge traded in-house and out-of-house. They are unable to address the advantages to a firm of contracting out, organizing research teams, of establishing research divisions, or establishing overseas laboratories. They do not recognize that a successful idea need not be a successful invention. They do not recognize that often a successful invention is the product of many firms. They do not recognize that often the successful application of invention is more difficult than the production of invention. They fail to understand that research must not only be produced but its diffusion must be coordinated and that there is a connection between the production and coordination of research.

All these important phenomena are captured in an analysis of the transactions cost determinants of the

institutions of idea trading. This research agenda also allows recognition of the economic efficiency reasons behind organizational innovations such as research consortia. It can capture the value of "failed research" or the dynamics which lead to the clustering of organizations in areas such as the Silicon Valley where tight formal and informal trading relations bind these firms.

The challenge for any economics of innovation is to recognize that the benefits of innovation are often not earned by firms (or people) selling products or processes which embody innovative thinking, but instead through the exchange of ideas themselves. Idea trading is the mechanism by which invention is rewarded, rapid transfer of technology is achieved, and through which the coordination of research effort is allowed. This is turn creates the ability to rapidly advance technology and apply it to new products and processes.

This requires escaping the seductive tangibility of analyzing "legal firms" and instead focussing on the explicit and implicit contractual relations governing idea trading. These relations can be both internal and external to firms. In fact, when the analysis is extended to contractual relations within firms it can be seen that innovation is an economic process not simply because it responds to economic incentives such as demand and market structure but because it is the product of many mutually beneficial exchanges. When it is recognized that idea trading cuts across the taxonomy of legal firms, then advances can be made in the understanding of intellectual property rights, industrial structure and the appropriate policies to support innovation and economic development.

This analysis has focussed specifically on the development of new technologies. In fact, this type of analysis is potentially amenable to any type of knowledge based production, including that employing administrative

and marketing knowledge. The application of these principles to other aspects of knowledge transfer in production is implied but not spelled out by this thesis.

In summary, this thesis began with five questions. It is now possible to spell out the answers that have been developed.

Question One: Why do some firms joint venture and trade research results while others devote resources towards protecting these?

Answer: Firms will sometimes choose to transfer or trade technology rather than protect it because the technology may be broadly applicable enough to warrant incurring the transactions costs of idea trading. When ideas are not widely applicable a better return can be earned by protecting these against imitators.

Question Two: Is there a logic to the internal structure of a firm which is engaged in the generation of knowledge?

Answer: The internal structure of such firms emerges from a need to realize better net gains from trading ideas within the firm. Generally this involves placing knowledge relevant to different aspects of production adjacent to (in a physical or corporate sense) those types of knowledge with which it is most complementary and designing employee or contractor contracts which encourage the maximum revelation of knowledge from workers.[1]

Question Three: What is the role of the institutions governing idea trading?

Answer: Industries which are characterized by swift technological advances and employ highly sophisticated types of knowledge face very difficult transactional difficulties in exchange. Generally these are not overcome by the stipulations within a contract alone. Many identifiable institutions can be analyzed for their ability to support the exchange of different types of ideas.

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1. The generality of this term should be stressed. The revelation of knowledge need not be restricted to the revelation of new knowledge. Applying well established techniques such as accounting or mechanical skills is also the revelation of knowledge.

Question Four: Why do firms continue to research areas that they do not lead in and what is the economic utility of so called "failed research"?

Answer: Research does not need to be successful to be useful. Often it may be undertaken only to generate the knowledge necessary to understand the technology pertinent to an industry. In simple terms, it generates the competence necessary to acquire new technologies.

Question Five: What is intellectual property used for? Why do firms patent when in many cases they do not find intellectual property to be a useful means of protecting their inventions?

Answer: Intellectual property is not always used strictly for protection. In fact, protection is not generally its most important role except in special cases such as pharmaceuticals. This thesis has demonstrated that intellectual property has a diverse role supporting the exchange of ideas and signalling the quality of a research program.

6.2 IMPLICATIONS FOR PUBLIC POLICY:

The discussion of the implications of this thesis will be largely speculative and limited to policy areas, although clearly important changes in the industrial organization landscape, such as value added partnerships[2] and strategic alliances, could be explored more fully. Policy questions related to the production and dissemination of advanced knowledge are arising in intellectual property, in corporate law, in development policy and in trade issues. Often, these questions are entwined because much trade is being driven by the effects of knowledge based production on the patterns of trade and industrial organization. Nonetheless, this final chapter will ignore the more subtle interactions and apply the understanding of the institutions of idea

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2. A value added partnership refers to a network of exchange relationships between centralized producers and suppliers and distributors which can change far more quickly than a centralized firm structure would allow.

trading to the policy areas mentioned above in a straightforward fashion.

6.2.1 Intellectual Property: The traditional rationale for intellectual property stems from an appreciation of the need to provide an incentive to invent. It is argued that in the absence of intellectual property protection, inventors will not be able to prevent imitators from copying their invention and inventors will therefore not be able to earn a proper return. Successful inventors will either not earn the return necessary to support further innovation or they will not see an incentive for undertaking innovation in the first place.

Most empirical studies suggest that only a small fraction of industries find intellectual property to be a useful means of protecting their invention.[3] This has led to some puzzlement amongst economists because despite the low credence that they place upon intellectual property as a means of ensuring a return on their investment, the preponderance of industry opinion still holds that intellectual property is useful (Scherer, 1984). Empirical studies find that in most industries the majority of inventions are still patented.[4]

Theoretical and empirical studies are both uncertain on the question of when intellectual property provides net support for innovation. For example, it is often argued that patents may actually block innovation. A firm that is granted too broad a patent may use it to prevent other firms from undertaking research in that area. Firms may be

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3. Studies undertaken by Levin (1987) and Mansfield (1986) both confirm this statement. In fact, the studies are very consistent. Both show that in most industries the incentive provided by intellectual property for further innovation is very marginal, with only pharmaceuticals, industrial chemicals and sometimes machine tools reporting it provided a strong incentive.
4. F.M. Scherer finds this in "The Propensity to Patent" (1983), which addressed the question of whether inter-industry differences in the propensity to patent exist.

reluctant to invest resources into new research areas for fear that these areas will be closed off by a successful patent grant to a rival. Other studies note the possibility that successful patents signal rival firms that a successful research area exists. These firms can then simply invent around the originally patented invention. In this case patents may actually be detrimental as a means of protection (Horstmann, 1985).

This thesis explains patenting behavior by suggesting that patents are not used simply as protection. They serve a number of different roles and therefore firms may continue to patent even when they do not find intellectual property to be a good means of protection. A sound intellectual property policy should account for the different roles patents play in different industries and not simply assume that broader protection increases the incentive to invent.

Rather than protection, patents may actually facilitate knowledge transfer in some industries; a patent grant may effectively measure and delineate what has actually been invented. This can substantially reduce measurement costs and reduce the need for participants in a technology transfer agreement to negotiate over what has actually been invented. Patents may serve as a signal of quality or of credibility needed to enter idea trading alliances. In this case, the novelty criteria of patent protection signals that the firm has produced original research. Patents may also serve a hostage role in supporting the exchange of ideas. Patents may serve as an inducement or potential litigation threat needed to leverage other firms into cross-licensing agreements.[5] Empirical studies all confirm that in most

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5. The quote from a representative of IBM's intellectual property division cited in Chapter Five (Wall Street Journal, March 14, 1989) certainly suggests this. See also, the recently signed agreement between Cray Super-Computers and Hitachi of Japan outlined in the **Wall Street Journal**, July, 1989.

industries patents are only marginally effective in fulfilling their traditionally assumed role of protection. The policy question becomes what role do patents serve in a particular industry and given that role, what are the appropriate term, scope and stipulations.

In order to devise proper policy it is important to understand the role patents actually play within different research areas. For example, the scope of a patent grant in pharmaceuticals has come to encompass the whole product and most variations of the product based on the original invention. The innovating firm need not have even produced these variants to be given patent protection over them. But, in traditional pharmaceuticals the applicability of invention was very low outside the specific products to which the invention applied.[6] Protection of such breadth would not be feasible in another industry, where research is cumulative and the researching firms are therefore dependent upon one another. If, for example, a single firm had been given the rights for all subsequent improvements to the microchip it is hardly likely that the industry would have advanced as much as it has.

Protection has shown signs of broadening in the software industry. Recent court decisions have expanded the protection to include the "look and feel" of software rather than merely the specific code used to produce that result (Businessweek, April 3, 1989). This is effectively extending software protection over a whole product. Once again this is in keeping with the principles of idea trading because there is generally little need for idea trading regarding the specific application of software to a problem.

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6. Certainly, this has been true in the last thirty years with pharmaceuticals based on chemical manipulations. There was little sense of new techniques being employed or new principles of chemistry developed which were applicable to unrelated products. This does show signs of changing however, as increasing use is made of biotechnology in new pharmaceuticals.

Software often has a highly specific end use, with only a small degree of cumulativeness or advances in principles resulting from the development of a new program. Idea trading would be far more likely in the improvement of algorithms and the development of new programming languages.

Within knowledge trading industries even individual firms may gradually be coming to recognize that broader patent protection is not necessarily to their advantage. The aircraft patent pool study noted that one of the intentions of the patent pool seemed to be a reduction of the scope of the patent grant (Bittlingmayer, 1988). This does not seem consistent with the theory that the patent pool was a conspiracy to create market power, nor even with the traditional assumption that firms earn a return on invention by monopolizing products based on that invention. It is more consistent with the theory that firms were facilitating idea trading by ensuring that no firm entering the patent pool would hold out. It also ensured that patents closely correspond to the quantum of the idea. This is perfectly consistent with the theories of idea trading.

The Japanese patent system has evolved in a context of idea trading institutions. It has already been noted that Japan the scope of the patent grant is much smaller than in the US but that the institutions of idea trading are considerably more evolved (Rogers, 1987). Interestingly two industries where the Japanese did not achieve notable success against the Americans were pharmaceuticals, where patents serve their traditionally assumed role as protection devices, and aircraft where the patent pool was in place.

> protection actually afforded by each Japanese patent is often very limited in scope. The Japanese patent system provides for the filing of numerous patent applications with each particular application very narrowly directed to a particular embodiment of a development. In the US, our patent applications are often drafted to cover both the broader concepts behind the development as well as the numerous various

embodiments, all of which are submitted in one application (Oespepchuck, 1988).

This suggests that policy debates involving patents should address the needs of firms in many industries to trade ideas as well as protect invention. In cases where idea trading is the predominant motive patent protection would be more quickly granted and the scope of patent protection would correspond more closely to the novel idea rather than the applicable invention.

A proper understanding of the potential benefits of idea trading would resolve much of the current confusion in the policy debate surrounding patents. Debate that surrounds the seemingly contradictory needs to promote the diffusion of ideas and also the production of ideas. This confusion has produced much of the wrangling surrounding the appropriate scope of patent grant and the legitimacy of compulsory licensing or second generation rights to invention.

In some industries too broad a degree of patent protection will create a disincentive to disseminate ideas and result in a slowing of innovative activity. The policy remedy is generally to enshrine second generation rights or implement some kind of compulsory licensing scheme. In fact, this will only be a second best solution. The best policy solution would be to initiate patent grants which more closely correspond to the quantum of the idea. This will create the incentive for firms to trade in ideas. It will also strongly affect the contractual relations among the firms in the industry in ways which cannot be easily predicted.

Current practices do not allow the patenting of ideas. It is the invention or physical embodiment of an idea which is generally patented. In recent years, a great deal of pressure has been put on this policy as more and more abstract ideas have come to have a direct commercial value.

Recent court decisions have, for example, granted patent protection to the mathematical algorithms used in software. This has created the precedent for a large scale shift in the thrust of intellectual property towards the support of idea trading and the consequent coordination of research within specific areas. Such a shift may be beneficial in many industries because of the growing scale of the technologies which they employ. This is leading to an increasing emphasis on the need to attain a critical mass in a research area and the need to coordinate the production of research. It is sometimes advocated that government play a role in this by targeting research areas. This study suggests that the proper government role is to support the growth of idea trading institutions which will allow firms to coordinate research in response to emerging opportunities. As the scale of technologies and research areas grows the importance of idea trading will also grow and anonymous market exchange will be increasingly supplemented by institutions such as consortia and strategic alliances which policy makers will not be able to understand, except in the context of idea trading. Patents which better approximate the quantum of the idea will provide better third party measures of what is being transacted in a technology exchange. This can greatly reduce the measurement and negotiation costs incurred in such exchange and by so doing greatly expand the number of beneficial exchanges which take place and certainly reduce any incentive for inventors to hold out from a socially beneficial exchange.

A move towards a smaller scope of patent will create some problems and resolve others. It will certainly lessen the need for litigation regarding the delineation of rights in jointly developed research. It will also increase the burden on patent examiners. Certainly, patenting on the scale of the Japanese experience would do this but these

patents are much closer to utility patents and therefore each individual patent need not consume as much time.

6.2.2 Competition Policy: The implications of this thesis on competition policy are difficult to unravel. Part of the problem is that many of the devices which are used to trade or protect ideas might also be used to gain market power. An optimal competition policy would seek to effectively discriminate between devices which are used to legitimately support the trade of and protect ideas and those which are used to achieve greater market power. The analysis is further complicated by the introduction of contractual innovations, such as the joint venture or strategic alliance, which a traditional market based analysis would tend to view as a collusive device.

A preliminary summary of the evidence suggests that in the past some mistakes have been made in the enforcement of competition policy. Bittlingmayer argues convincingly that the aircraft patent pool was a significant example. Certainly, the new thrust is towards recognizing the needs of firms to pool research resources if international competitiveness is to be maintained. The US perhaps spurred by the technological challenge of the Japanese, passed in 1984, the National Cooperative Research Act which has in turn led to considerable government support of cooperative research projects. The Canadian government has recently made the support of research consortia its official policy, as well, and has allowed an exemption from stipulations of the Competition Act if a combination is formed for research purposes. But generally, the stated purpose of these policy thrusts is to help defer the cost of research. They are little different from older programs such as research tax credits which also help defer costs and seem to rest on the assumption that the returns to research are substantially uncaptured and research is therefore underinvested. This analysis suggests that the purpose should be to minimize the

transactions costs of idea trading and the best way to do this is to introduce trust and a common understanding into an exchange relationship. Ultimately, analysis of this nature suggests that homogeneous societies with highly evolved customs may be better able to support idea trading on the scale that modern production demands.

This analysis suggests then that cooperative research is not so much a cost saving phenomenon (a benefit which could be properly evaluated by capital markets), as they are a coordination device providing a push for research through the provision of a knowledge base and a pull by providing a market for ideas. Competition policy should be enforced on the basis of an analysis of the research area and the usefulness of knowledge coordination in that area.

A proper understanding of this phenomenon requires more than understanding the variety of organizations and contractual linkages used to trade ideas. It also necessitates understanding the variety of devices used to enforce the terms by which a contractual transfer of knowledge takes place. The difficulties in measurement and the considerable moral hazard that the transfer of ideas creates suggests that there will be a strong growth in "personal" long term trading arrangements, tied selling and other such devices.

An understanding also requires that the characteristics of invention within a specific area be related to the trading arrangements characterizing the research area. While no complete predictive relationship can be found to use as a policy guide this thesis has suggested some general guidelines. The proper discrimination of idea trading collusion from market power collusion will help to further promote economic welfare in a knowledge based economy.

6.2.3 Development Policy: Great attention has been paid in recent years to the growth of advanced services and the growing importance of knowledge based goods as a share of

world trade. It is surprising, in light of this, how little of this knowledge seems to have spilled over into an understanding of development.

This thesis suggests that the usual smokestack industrial characterization of economic development is not correct in more advanced economies. While resources and assembly have a shrinking share of total income, an increasing share is coming from work in advanced manufacturing and services (Merrifield, 1987).[7]

The attraction of advanced manufacturing and services does not seem to depend on traditionally assumed economic determinants of invention; factors such as transportation costs and wages. Advances in administration and information systems have made it possible to locate the assembly work which these costs affect, well away from the centers of administration, engineering and marketing which comprise the bulk of production costs. This has led to an often observed phenomenon of de-industrializing cities and movement of production facilities offshore. In fact, a summary glance at the evidence suggests that often locating an industry in a city cannot really be justified in terms of land and labour costs. Nonetheless, most advanced economies are seeing a disproportionate share of the service and administration sector growth occurring in cities. This suggests that the density of information needed to be exchanged in knowledge services is so large that often personal contacts are needed to support exchange. Dense personal contracts within a city core permit the rapid exchange of information needed to coordinate the production of advanced products. Businesses can more easily respond to changing market conditions because in a large city different

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7. Merrifield contents that the labour component of manufacturing costs is now very low and will ultimately fall to as low as 5% of total costs. This holds true despite the high wages which prevail in many manufacturing industries.

business services and suppliers are easy to find. Regional support programs which simply redirect money out of the cities will not address the structural advantages which dictate greater growth in cities and will fail therefore to address the phenomenon.

The development of nations beyond the smokestack stage of development seems to hinge then not so much on policies of tax cuts and wage cuts as it does on building informational infrastructure to support the dense, often personal exchange of information which supports the production and application of advanced technologies and knowledge. Essentially, policies which encourage linkages between business services and research capabilities break into a hitherto closed black box in which R&D and education are translated into economic success. Such policies must understand the density of the information being transmitted and address the use of organizational innovations and the reliance on enforcement devices, such as trust and reputation to support this transfer. Even the ongoing phenomenon of urban concentration may be considered an organizational innovation in analysis of this nature.

With the growing importance of specialized knowledge, economies may reach a point where static analysis of input-output relations or multiplier effects simply ceases to matter. The critical step becomes not demand management or the construction of capital stock but policies which support the use of highest order knowledge creating the maximum value from labour in production.

6.2.4 Trade Policy: The point has already been made that there has been a fundamental shift in the patterns and content of world trade. Recent developments at the GATT stress the growing importance being attached to the trade of advanced services, intellectual property protection and rules governing investment. The long term trends are of a decline in the share of trade accounted for by commodities,

a growth in intra-company trade and a trend towards the integration of economic regions, such as Europe and North America into trading blocs.

Of particular interest here is the emergence of advanced services, intellectual property, telecommunications and investment as the major areas of trade law. In fact, all four of these areas are related to the movement of knowledge needed for modern production. This is certainly in keeping with the importance that this thesis has attached to the need to coordinate the movement of knowledge in advanced economies.

The development of knowledge and coordination of production systems has taken place on a super-national scale. Statistics bear out the increasing share of production costs which are accounted for by offshore production.[8] Business analysts note the increasing internationalization of production coining terms such as multi-source production. Industry observers such as Charles MacMillan of the Prime Minister's Advisory Committee on Science and Technology note that among nations an increasingly dense and complex series of technology transfer agreements are governing the trade of advanced products.[9] Quite often with advanced and difficult to measure technologies, technologies are embodied within an organization and are transferred as it expands.

Trade problems have emerged as idea trading institutions have expanded beyond national borders. Newly internationalized firms have discovered that in different jurisdictions intellectual property rights, rules of corporate disclosure and anti-trust enforcement all differ. Rules of access to government sponsored research organizations, such as consortia, are swiftly emerging as a

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8. **OECD Observer**, December January, 1988.
9. Taken from a discussion at the Planning Forum seminar on managing R&D, held in Toronto, March 4, 1988.

major focus of the trade debate as are the rights of foreign firms to takeover companies containing technologies with a large potential commercial value.

This thesis has not really explored these issues but has instead simply noted that their resolution seems to ultimately depend on the construction of some common understanding about why these problems are emerging. Certainly, the development of a trading and investment environment which facilitates the exchange of ideas beyond national borders is where the world is headed. The real policy questions in trade are related to how these organizations will be governed and financed and what the path of adjustment will be that leads to this governance.

6.2.5 Modern University: The modern university provides an example of the applicability of the theories of idea trading. The university's role is currently changing because academic research is being seen as increasingly valuable for industry. The reasons for this are unimportant but certainly the claim is borne out by the mushrooming of university industry research ventures, discovery parks and spin-off firms from academic research.

This has triggered some debate regarding the appropriate role of the university, the rights and obligations of both private sector sponsors and academic researchers, the rights of involved parties to research facilities and intellectual property rights and a lively discussion regarding the implications of large scale private research being conducted in the traditionally "open" university environment.

The approach taken in this thesis suggests a new framework for addressing these problems. Essentially, the conflict is created by using academic researchers to produce two very different research types. Applied research conducted with industry demands very different idea trading institutions from traditional academic research.

Traditionally, academic research is unbounded and directed into questions of "academic" interest. It fits all the criteria for non-market allocation because it cannot be easily packaged for sale in the marketplace and the ultimate beneficiaries are not easily identified. Nonetheless, because it is potentially very valuable a means of payment which rewards success has developed.

Academic research is governed by rules which simultaneously encourage its maximum diffusion while also providing a quasi-market incentive for researchers. The incentive is provided by reputation and the tenure and salary system which rewards the number of publications and citations. Because payment for research is assured by salary there is no incentive to withhold research results and therefore maximum diffusion of this research is sought. The research becomes public property. No attempt is generally made to extract any payment for the use of ideas generated by academic research. (This would simply increase transactions costs which the tenure system seeks to circumvent). In fact, the Copyright Act contains provisions which allow for the use of copyrighted academic material without permission, so long as this material is cited (Note both the inducement provided to disseminate academic research and the use of citations as a proxy for output. In the absence of such a proxy this would be a very difficult measurement problem and would make the task of approximating academic output more difficult.

The challenge posed by the new structures which do not make research public property (discovery parks etc.) is therefore considerable. Strong pressures are emerging to develop rules which discriminate between these two types of research and allow professors to retain direct control over some research results. The interesting questions will be the ability of professors to use private research results for academic credentials and their responsibility towards

the university which may have provided the facilities and much of the basic knowledge needed to produce their market application. Additionally, it is uncertain whether professors who spend most of their time working on private projects will be contributing substantially to the free exchange of ideas in a university.

It is perhaps premature to say that the two systems will simply be separated. There is probably considerable interaction between the two with many strictly academic researchers contributing (with or without their explicit knowledge) to private research simply by interacting with colleagues who are conducting private research.

No solution for delineating the two systems of payment will be suggested here. This just provides a different means of conceptualizing the issue. Perhaps by better understanding the source of a policy issue its solution can be better defined.

6.3 CONCLUSIONS:

This thesis has sought to resolve some of the economic questions that relate to the role of property rights in the innovation process. In so doing, it has advocated a different approach of assessing the economic gains from knowledge and from the organization of production. This is not a standard recipe approach in which parts of capital and labour are combined by firms employing a given "technologically based" production function, rather it is one in which ideas are continuously being traded in order to produce new knowledge and thereby advance both products and production processes. Within this new approach it is the application of knowledge which produces new economic gains. Economic success is therefore determined by the efficiency of institutional structures, including property rights regimes, in supporting the trade of ideas and ensuring the

rapid application of knowledge towards meeting both individual and public demands.

This thesis has suggested only a conceptual basis from which to begin. What the theory lacks is the operationalization that modelling of specific idea transacting would provide. Such operationalization would provide a firmer understanding of the role of different organizational forms (both intra and inter-firm) in coordinating information flows and thereby encouraging technological advancement. This could lead to a more complete understanding of the transactional difficulties preventing the realization of all gains from trade in the "marketplace" for ideas. Furthermore, the codification of the techniques and insights of the new institutional economics could create an information based theory of human exchange and social decision making that would go beyond the strict market focus of most economic theory and allow the incorporation of organizations and other institutions making economics a more complete social science.

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