

Potential Competition and Contracting in Innovation

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Traditional analyses of patents commonly begin with a derived demand curve. The marginal revenue of this demand curve is then equated with some marginal cost curve, and the area between the two curves is considered as the private return to a patent.¹ The close resemblance of this solution with the monopoly pricing solution shapes the impression that patents and competition are incompatible. However, no attention in the literature has been paid to the way inventive activities are organized. This omission turns out to be crucial in affecting the logic, the conclusion, and the applicability of the traditional model in explaining real world behavior.

Consider a sample of the questions which this paper addresses: Why do patent licenses frequently include the granting of future patent rights? How are they enforced? Under what situations do we expect the practice to be more frequent? Why do patent licenses seldom specify the patent number, which seemingly is the most effective way to specify the subject matter licensed? What might explain the high turnover rate of inventors? With what kinds of industries and types of inventors do we expect the turnover rate to be higher? How does the turnover rate relate to licensing practices in the industries? What is the conceptual distinction between anticipated and unanticipated improvements? What was the rationale behind certain old patent laws? What problems of enforcement were faced? Why are certain restrictive stipulations imposed on patent licenses? Why is vertical integration so prevalent in the inventive industries? What are the distinctions among ordinary patent licenses, cross licenses, patent pools, and grant backs? Why are they formed? None of these questions can be answered by the traditional monopoly patent licensing model.

This paper develops a framework to analyse these questions. The framework consists of two main components: (1) With zero transaction cost, competition in innovation should take the form of potential competition. The implications of this concept help rationalize certain contractual arrangements in innovation. (2) Noncapturability of return to ideas will result from potential competition on anticipated improvements -- a phenomenon which arises only because certain aspects of patent rights cannot be costlessly enforced. The identification of the causes and consequences of these aspects help explain another set of observations in innovations.

The organization of the paper will be as follows: section I explains the concept of potential competition in innovation. It will be argued that prior contracting is sufficient for the viability of this form of competition. The implications of potential competition are then examined, and real world patent licenses will be shown to reveal its influences. There remains other contractual behaviors, however, which cannot be explained by the notion of potential competition alone. Section II, therefore, brings in the sequential nature of innovations. The problem it creates in the capturing of return to innovation will be discussed. It is argued that patent law remedies may be ineffective to solve this problem in many cases. As an alternative, private remedies (i.e., additional contracting) would have to be adopted. Section III explains why private remedies may be more effective and contractual arrangements representing the remedies will be discussed.

I. Prior Contracting for Innovation

The traditional model envisions the progress of an industry to start from inventors. Ideas first pop out from a random distribution; the useful ones will then be gradually adopted in the industry. In a world of zero transaction cost, however, the organization of inventive activities may follow a reversed sequence: consumer first demands cheaper and better products from manufacturers, who demand better and useful ideas from the inventors (or the research organization).² To fulfill these demands, inventors compete among themselves in supplying ideas to various manufacturers, who also compete among themselves in producing products incorporating the new ideas for the consumers. Viewed in terms of a consumer-manufacturer-inventor sequence, patent merely awards property rights to the output of an inventor; the incompatibility of patent and competition is an illusion.

The unique feature of ideas is not the monopoly aspect, but rather the public good aspect; i.e., once an idea is invented, another identical or inferior idea will be valueless. The winner-takes-all property thus motivates propositions on premature innovations.³ However, competition can take many different forms.⁴ Potential competition for one, which received much attention in issues concerning public utility,⁵ has been neglected in the area of innovations until recently. In essence, potential competition implies that the return to an innovation is not the monopoly rent traditionally described but is constrained by the cost of the next best inventor.⁶

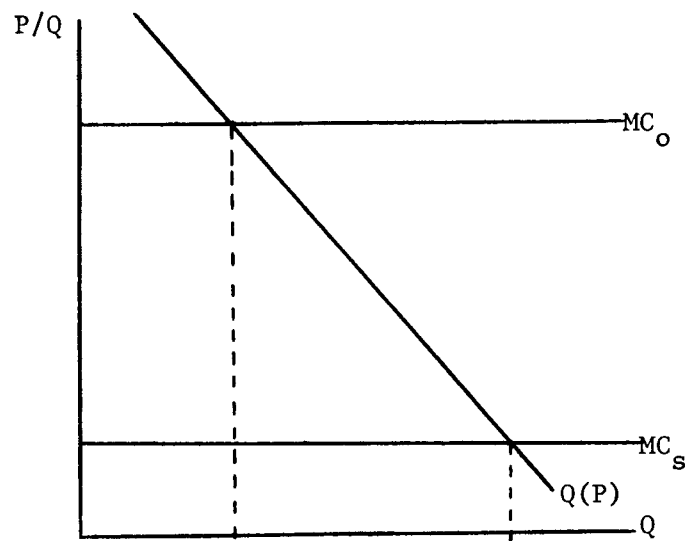
The choice of the different forms of competition is not entirely arbitrary. Under the postulate of maximization, the least costly way to compete will always be chosen.⁷ In view of the positive welfare consequences of potential competition, its applicability in innovation must be seriously considered.

The application of potential competition in innovation is straightforward. Consider a new innovation which reduces the marginal cost of producing a private good Q from MC_0 to MC_s in Figure 1(a). The derived demand curve for utilizing the idea can be constructed as dd in Figure 1(b). The vertical height of dd is simply the vertical difference between the old marginal cost (or the demand of Q depending on which one is lower) and the new marginal cost. A horizontal movement along the x-axis of Panel (b) does not mean more innovations. Rather, it implies only a more intensive use of a single innovation. Since dd is derived net of the cost of producing Q , the marginal cost of using the innovation is zero -- a characteristic of a public good. The cost of inventing the idea, however, is not zero. Including this cost in the figure implies a downward sloping average cost curve that asymptotically approaches zero. If inventors have different cost comparative advantages, a superior inventor's average cost will be everywhere lower than that of an inferior inventor as represented by ac_s and ac_i in the figure. The situation is identical to the case of "natural monopoly," which exhibits economies of scale in production. As Demsetz (1968) pointed out, competition in this case takes the form of potential competition.⁸ Even though there may be only one firm operating in an industry, the price the firm can charge is subject to potential competition of firms outside the industry. The term "competition for the market" is thus distinguished from the term "competition within the market."⁹

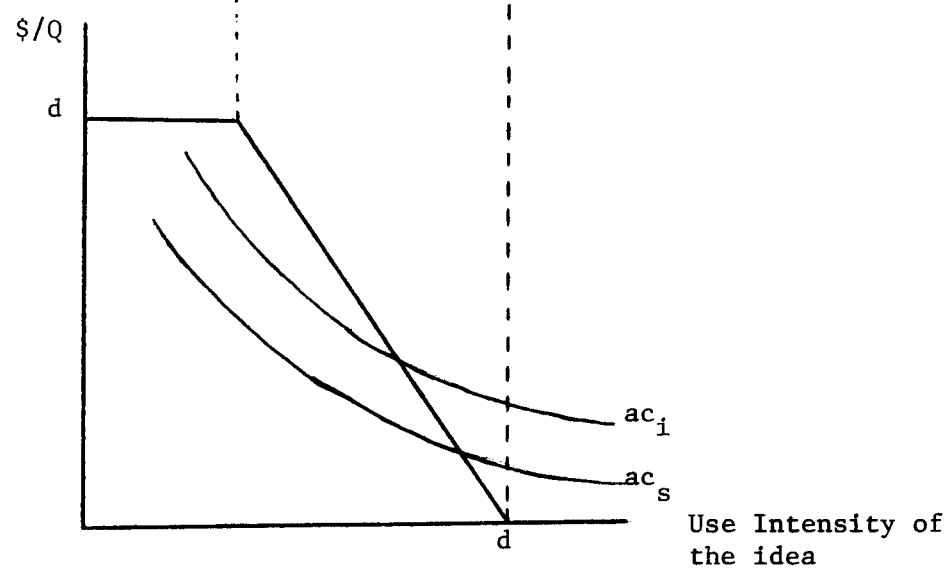
Plausible as the argument may seem, potential competition is often regarded as "too costly."¹⁰ Central to Demsetz's argument is a bidding process that involves either the sellers contracting with many consumers, or an auctioneer selecting potential competitors on behalf of the consumers.¹¹ In both cases, the bidding process occurs prior to production, and the host of contractual

Figure 1. Effective Demand for an Innovation

(a)



(b)



problems pointed out by Williamson (1975) becomes especially severe. In the case of innovation, these problems are compounded. Inventors do not go from door-to-door to solicit consumers' commitments, and no real world auctions exist yet to facilitate the bidding procedure as described by Demsetz. Potential competition in innovation appears entirely fictional.

Real world patent licenses are often drawn between inventors (or research organizations) and the manufacturers of the products which incorporate the innovations; the manufacturers then sell the products to the consumers. Unrelated to potential competition as this may seem, one might nevertheless argue that such licenses are in effect contracts between inventors and consumers with the manufacturers being the middlemen. Under wealth maximization, the manufacturers have every incentive to choose the lowest cost production technique (or the highest quality product) with the lowest royalty. A superior inventor cannot charge too high a royalty, for then he will lose his manufacturers. Even if a patent can be obtained on the innovation, no "monopoly" power can be exerted if the royalty is negotiated before the patent is obtained. In fact, it is precisely the threat of facing a high royalty that may prompt the manufacturers to make arrangements prior to the issue of the patents. It would not be rational for manufacturers to wait passively for an innovation only to be slammed with a high royalty rate. To get the lowest possible royalty rate, the manufacturers have every incentive to negotiate under the condition in which they face a wider range of alternatives (i.e., before the innovation is patented). The larger the amount the superior inventor anticipates to charge, the greater are the incentives for the manufacturers to make prior arrangements.¹² A manufacturer who is not alert enough to make such arrangements is stuck with higher royalty consistently and would necessarily lose his business in the long

run. On the other hand, a manufacturer alert enough to select the "right" inventor cannot pocket the saving in royalty since competition among successful manufacturers necessarily implies that the gains are passed on to the consumers.¹³ For this reason, manufacturers can be viewed as auctioneers hired by the consumers to search and compare competitive bids offered by potential inventors.

It will be naive to flatly reject potential competition in innovation on grounds that neither explicit inventor-consumer contracts nor explicit auction systems exist. Behind the determination of the terms in every contract (including patent licenses), there may be a bidding process among potential buyers and sellers. In fact, this is the underlying force in determining the price in every competitive market.¹⁴ Even an automobile dealer, a grocery store owner, or any other so-called seller may be analytically indistinguishable from auctioneers for the goods he is selling. An explicit auction system is not a necessary condition in potential competition.

The sufficient condition for potential competition to be viable in innovation is prior contracting. Prior contract is a promise to innovate. Its output is, by definition, unknown before it emerges, and its production may be highly uncertain. Three central questions, therefore, immediately arise:

- (1) How does prior contracting affect resource allocation in inventive activities?
- (2) What are the enforcement mechanisms for prior contracting?
- (3) To what extent has the market been using it?

The theoretical analysis of resource allocation under prior contracts may be slightly more complicated than the case described above in which innovation is lumpy, but the underlying bidding process remains. The only conceptual complication added is that the manufacturers have to compare not only the royalties, but the "quality" of the research results to be anticipated from each inventor as well.

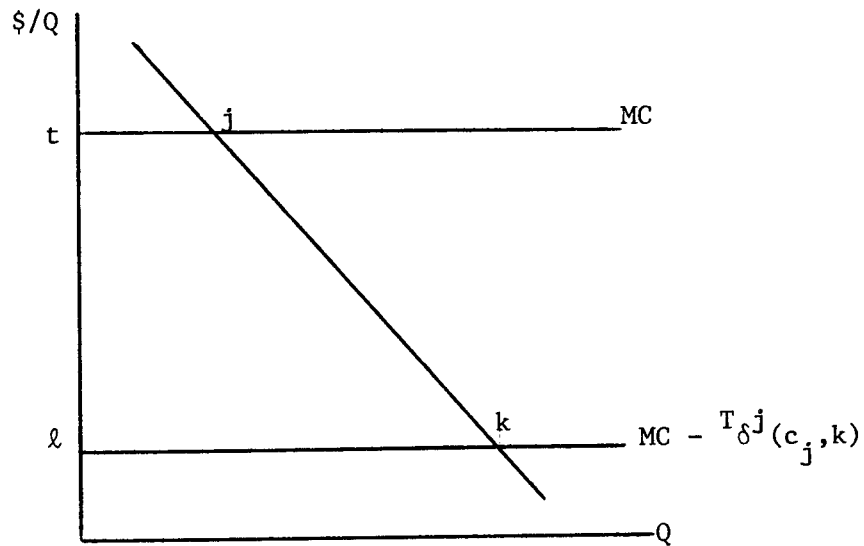
Suppose the reduction in the production cost of a product (i.e., the "quality" of the research) is a function of the research effort an inventor puts into it. This functional relationship, in general, will be affected by the state of the art, the ability of an inventor, and the type of research, etc. Algebraically, one can denote this relationship by $T_{\delta}^j(c_j, k)$; T represents the type of research; j represents inventor j ; c_j represents inventor j 's effort, and k represents the state of the art before any inventive effort c_j is expended.¹⁵ If all the c_j efforts can be accumulated without any time lags and if demand for the output incorporating the innovation is constant over time, all inventive efforts will be undertaken at the initial period. Pareto efficiency requires an inventor to expend inventive effort up to the point at which the marginal product, $\frac{T_{\delta}^j Q(p)}{r}$, equals the marginal cost which equals one in this case.¹⁶

Figure 2 graphically illustrates resource allocation in innovations. Additional inventive effort continuously pushes down the marginal production cost of Q in Panel (a). The area between two successive marginal production costs and the product demand can be plotted as a function of c in Panel (b); the present value of this amount is the marginal product of inventive effort. By construction, area $tjkl$ in Panel (a) equals $mnco$ in Panel (b); both represent the gross gain of aggregate inventive efforts. The areas also denote the optimal "quality" of the innovation as marginal cost (which is \$1) equals marginal product at point n . The net gain to the society is area mnq .

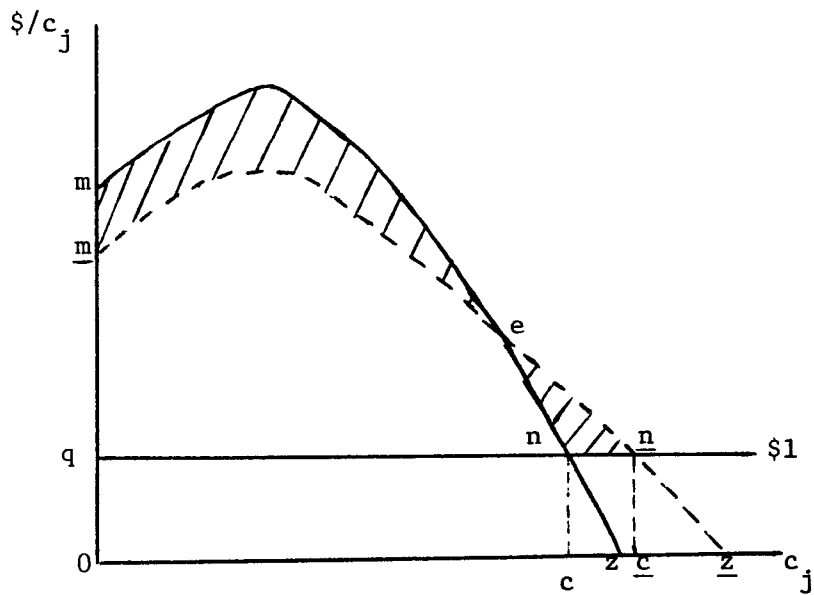
The quantity of inventive efforts, c , need not be systematically related to the number of new machines or processes. Indeed, the cumulative reduction of the marginal production cost may arise from a single high productivity machine or a group of trivial improvements on different machines. The exact content of the package is not important. All that is important is for the manufacturers

Figure 2. Resource Allocation in Innovations

(a)



(b)



to know the size of the anticipated reduction in cost and their ability to compare the cost reduction potentials among different inventors (or research organizations). Graphically, the inventive potential of another inventor can be represented by another marginal product schedule as represented by mnz in Panel (b). The total inventive potential of the second inventor is thus $mnco$. If all innovations within a package can be accumulated instantaneously, the two inventive packages become mutually exclusive. To choose the best alternative, the consumers would compare the difference in the gross gains of the two packages with the difference in the costs of the two packages. This is equivalent to comparing area mem with nen , the two cross-hatched areas in the figure. If mem is larger than nen , the first inventor will be chosen; otherwise, the second inventor will win the bid. If prior contracting for innovation packages can be effectively enforced, contents of the package will in fact be delivered but the winning inventor can charge, at most, the difference between the two areas plus his cost of inventing.¹⁷

The prespecification of the content of the package and its enforcement in prior contracting are problems, but they are not unique problems. The owner of a professional ball club faces the same problem when signing an untested athlete fresh out of college. Two individuals face the same problem when signing a marriage contract. Subscribing to magazines and paid television, taking the car to the mechanic, dining at a restaurant are all prior contracts. The difficulties in prespecifying the output and the incentive to cheat are only matters of degree; they are everywhere. Contracts on the delivery of such "unspecified" commodities are made every day. In each case, past performance may serve as an indicator of future performance in selecting the "right" seller. Nondelivery may occur, and there is strong presumption that such will take place if the innovation is a once-and-for-all venture. However, like any other activities, an inventor

once successful would tend to invent more. His incentive to repeat performance, therefore, provides the strongest enforcement mechanism of prior contracts.¹⁸

An action cannot be too costly if people are doing it. Casual observation suggests that prior contracting in innovation is quite common. Three predominant forms immediately come to mind: they are development contracts, employment contracts and patent licenses. Development contracts are used by research companies for contracting out part of their research projects. Explicit biddings are often observed. Thus, the applicability of potential competition is most intuitive.

Less obvious is the influence of potential competition in employment contracts. Typically, inventors are hired before their act of inventing, and they are paid according to their inputs (hours of research) rather than outputs (the value of their research results). Patents obtained in the course of the research are routinely turned over to the employer via assignments of patent rights.¹⁹ The setting is perfect for potential competition. Thus, regardless of the "social" contribution of an inventor, we should expect his income to merely equal the expected cost (quality adjusted) of the next best invention.

Much attention in the literature has been paid to the enforcement of employment contracts. In many situations, inventors allegedly quit the firm supporting the original research and assign the patent to another firm instead.²⁰ The incentive behind such action, however, is not so much the inventors' desire to appropriate more return for particular patents as their inability to convince existing buyers that their lifetime abilities are higher than what they believe. Outright renegeing on prior contracts will undoubtedly decrease the future reliability of an inventor. If his inventive potential remains the same as expected, he has little to gain by renegeing. But if his inventive potential turns out

higher than what was expected, and if information is asymmetrical, existing buyers may not be easily convinced to give the inventor a salary adjustment. Thus, it is the high information cost of evaluating inventors' capabilities that accounts for the high turnover rate among employed inventors. To the extent that asymmetrical information is more likely to emerge when the sample of observations is small, inventors' turnover rate ought to be higher for "young" inventors and for industries in which the state of the art is still "primitive."²¹ While the testing of these implications is not the main idea of this paper, it pays to emphasize the obvious element: in spite of high turnover rates in some industries, prior contracting remains as the predominant form in the transaction of ideas.

Perhaps the most subtle form of prior contracting exists between research companies (who acquired their patents from the employed inventors) and the manufacturers. Patent licenses typically include the right to use future patented inventions, and the rights are coextensive with the terms of the agreement. Since the term of the contract is usually quite long (many up to 17 years) and the provision regarding future patents is ubiquitous,²² it would not be surprising that a substantial proportion of patents in the United States are actually invented under some form of prior contract.

How "unspecified" commodities are transacted may be better understood by examining real world patent licenses. In general, the granting clause does not directly specify the ideas (or the patents) transacted, but merely designates the relevant area of research. The following granting clause is typical:

The licenses herein granted and agreed to be granted by Products (a firm) are under all present and future United States patents in respect of which Products now has or during the term of this agreement may acquire the right to grant such licenses, insofar as and to the

extent that such patents relate or are applicable to the equipments herein referred to and to the uses and purposes for which said licenses are expressed as granted, and said licenses shall be for the term of this agreement.²³

The "equipments referred to" in the granting clause includes "recording equipment," "reproducing equipment," and "sound record." In a different section of the contract, the definitions for each of these terms are specified. For example, in defining "recording equipment," the contract reads,

Equipments adapted and intended for the recording of sounds and/or equipment adapted and intended to maintain a timed relation between the recording of sound and the taking or projection of motion pictures.

Not all patent licenses granting future patents extend to such a broad scope. By using appropriate words and phrases in the definition, contracting parties can widen or narrow the scope of the innovations in the package. For example, in a contract between a glass manufacturer and a research company in the glass container industry in the 1920's, the scope of the improvement seems narrower. In section 8 of a license Hartford-Empire (the research company) granted to Laurens Glass Works, Inc., (the manufacturer) it states:

The word 'improvements' when used in this license and lease, shall be held to mean only (1) substitution of new parts for old parts of said leased machinery, or (2) changing old parts thereof, or (3) addition of new devices which are intended and adapted to become integral portions of such machinery, and not otherwise.²⁴

The precommitted supply of improvements is the essence of prior contracting. This commitment can be detected from the research policy of Hartford-Empire. In a memorandum of the company, the development of these improvements was emphasized:

Licensees demand this kind of engineering work. It reduces their costs, retains their support, insures the maintenance of present royalty rates for Hartford, and often increases total royalty returns.

Elsewhere in the same memorandum, the "long distant policy" was spelled out:

Hartford must be ready to supply improvements when needed, or others, more prepared, will get the business. All licensees have an inherent dislike to paying royalties, but they will pay royalties if they are assured that Hartford will apply some of these royalties to an extensive development program. They probably would prefer to have Hartford do development work for them, rather than attempt it themselves ...They therefore have a right to expect Hartford to be continually working on methods and equipment to reduce their costs.²⁵

The precommitted supply of improvements can be viewed from a different angle. Manufacturers would not contract with a fly-by-night research organization which has nothing except a few existing patents. Anticipating obsolescence caused by the future emergence of a more dominant inventor, they would wait to contract with the latter. Even if a manufacturer has mistakently chosen the wrong research organization, he has much incentive to cancel the contract once shirking is detected. The more restrictive is the initial contract, the stronger will be the incentive for such cancellation. On the other hand, the constant supply of improvements may be the most effective way to enforce a highly restrictive organizational structure that will be difficult to enforce otherwise.²⁶

Not all innovations in the world are prior contracted, of course. At least two factors deter complete prior contracting -- risk and regulation. The risks involved in prior contracting are twofold. The first is the "technological" risk of inventive efforts (i.e. uncertainty in the innovation production function); the second is the "information" risk in selecting the right inventor for the appropriate type of research. In the presence of such risks, both manufacturers and the inventors may not want to precommit themselves too much for

too long. The term and the area of research specified in a prior contract would then be adjusted to allow for such flexibility. The information risk, in particular, perhaps explains why some patents are contracted after their innovation. In selecting the right inventor in prior contracting, manufacturers probably want to see some headstart. A few patents and a crude machine may serve as the credential for an inventor. Such indicators may lower the information risk in prior contracting. Thus, on one hand, manufacturers do not want to contract with inventors too late because by doing so they will have to pay a higher royalty. On the other hand, manufacturers do not want to contract with the inventors too early because they suffer the higher risk of selecting the wrong inventor. Balancing the gain and the cost, there ought to be an optimal timing for prior contracting. One should anticipate the following phenomena: The more useful the anticipated innovation (thus a larger royalty if not prior contracted), the greater is the proportion of innovation prior contracted. The higher the information cost of selecting the right inventor, the lower is the proportion of innovation prior contracted. The more uncertain the innovation production function, the shorter is the term of the license and the narrower the area of research stipulated in prior contracting.

Regulation can be another deterrent to prior contracting. In many industries, the production of ideas is heavily subsidized. Government development contracts may require the research company to disclose all research results and assign patents back to the government.²⁷ A manufacturer would then have less incentive to prior contract since the innovation is in effect made nonexclusive.²⁸ In fact, one might argue that government subsidy can be an effective way to produce and to transact ideas if the tax and the research subsidy can be coordinated in accordance with consumer preferences.²⁹ Consumers pay for innovations

by lump sum tax. In return, they receive a cheaper product, since the gross return to innovation will be competed away by manufacturers freely utilizing the innovation results.³⁰ Regulation may also affect the licensing of ideas. Antitrust considerations may limit the content of an inventive package in both dimensions: area of research and time. A patent owner may not, as a condition of granting his patent rights, require the licensees to accept other patents.³¹ On the time dimension, a research organization may be prohibited from granting long term contracts.³² These regulatory constraints would undoubtedly distort the optimal timing and the frequency of prior contracts.

Although the added complication of risk and regulation may modify the notion of prior contracting, the main point must be re-emphasized: the market for innovation is not a market for the end product which incorporates the innovation, but rather, a market for innovating services. Contracts between innovators and manufacturers can be viewed as an ongoing brokerage relationship between a provider of innovating services and consumers of those services. In fact, the vertical contractual link of consumer-manufacturers-research-organization-inventors are interrelated. One should expect behavior at a particular level to be a function not only of the contractual obligations in that level, but the contractual obligations in the other levels as well. For example, the turnover rate among employed inventors should be smaller in industries in which manufacturers are under long term commitments to utilize the research results of the established research organization. Who would bother to set up a new research organization if he cannot find any buyers? Conversely, manufacturers would not be willing to commit themselves to a research organization if the ranking of inventors' capabilities is not yet clear. Expecting spin-offs from the parent research companies, manufacturers would be foolish

to make long term commitments in prior contracts. Complicated as the interaction may seem, potential testable implications may nevertheless be derived. One can look at the patents assigned as a percentage of the total patents in an industry, and correlate it with the percentage of future patents included in the manufacturers' patent licenses. The former is a measure of the extent of prior contracting at the inventors' level; the latter is a measure of the extent of prior contracting at the manufacturers' level. To the extent that the two variables are positively correlated, potential competition in innovation cannot be rejected.

II. The Sequential Nature of Innovations

The instantaneous accumulation of innovations is so far assumed only for expositional purposes. Relaxing this assumption is not only harmless to the analysis of prior contracts, it also yields additional insights on other aspects of contracting in innovation. In this section, we argue that the sequential nature of innovation and potential competition during its accumulation process creates certain enforcement problems in prior contracting. Although certain aspects in the old patent laws were designed to mitigate the problems, their practicability is often handicapped by the elusive nature of ideas. We suggest that various modifications of prior contracts, patent pooling arrangements, and grant-backs are alternative if not more effective remedies to such problems.

The package of innovations prior contracted may be complements or substitutes. Two separate ideas representing two machines used jointly in the same production line will be called complements; two ideas representing alternative machines that are mutually exclusive in a production line will be called substitutes. If innovations can be accumulated instantaneously, complement packages will deliver a variety of machines whereas substitute packages will deliver only one machine -- the best machine.

Such is not the case if innovations take time to accumulate. Generally, it is not a wealth maximizing strategy to deliver only the best version of a machine at the end of a long research period. Income foregone during the gestation periods may be so large that it is to both the advantages of the inventors and the manufacturers to utilize some forms of crude models while the research is still in progress. This crude model is expected to be displaced, and in fact will be displaced once additional research results are obtained.³³ An ex-post view of this sequence of events may prompt one to condemn research in

the early periods as "wasteful."³⁴ Others may consider the subsequent improvements as trivial changes to strengthen existing patent positions.³⁵ However, if one recognizes the costliness of the accumulation process in innovations, early research is merely the forerunner to the latest improvements;³⁶ there are no a priori methods to weigh early vs. subsequent components of an innovation package.³⁷

It is not the physical displacement of old machines by the new improved machine per se that creates the problem in the capturability of return in sequential innovations. If the whole innovation package has been prior contracted, the royalties initially negotiated would have taken such anticipated displacement into account. Even though the old machine is physically displaced, the innovative value of the old machine, in the sense that it serves as forerunner to the improved machine, would be included in the method of payment originally negotiated.³⁸ For example, royalty could be stipulated based on consumers' output rather than on the machine. Any improvement that reduces cost and thus increases output would automatically increase royalty when the improved version replaces the old. In the absence of enforcement problems in prior contracting, the return to early research remains capturable even though the old machines are physically displaced.

Nor is the displacement from another inventor's improved machine what causes the problem. If the improved machine of the other inventor utilized a completely different principle, it is a case of unanticipated displacement.³⁹ The old model is certainly bearing the windfall loss. But since the social ex ante return to the research incorporates the risk of obsolescence, private return equals social return ex ante, and there will be no resource misallocation. Even if the improvement is based on the crude model and a potential capturability

problem arises when the best inventor of the crude model becomes inferior inventor in the improved model,⁴⁰ no major problems can arise in a world of zero transaction cost. For example, the crude model inventor could purchase the stocks of the improved model inventor prior to the display of his crude model.⁴¹ Alternatively, the crude model inventor could prior contract with the improved model inventor thereby the exclusive right of the crude model is pre-assigned to the improvement inventor. The improvement inventor can then prior contract with different manufacturers on behalf of the crude model inventor. If such prior contracts can be enforced, there will be no capturability problem.

It is an enforcement problem in prior contracts that is created by sequential innovations. The early research results, incorporated in a crude model which if marketed, are disclosed to the public including the potential inventors. These potential inventors can then free-ride on the early information by improving the crude model.⁴² Subsequent to the introduction of the crude model, such potential inventors could solicit the manufacturers with their improved versions. Their royalties are likely to be lower than the one originally stipulated in the prior contracts, since they do not have to cover expenses on early research, which, of course, the inventor under prior contract must. Even though manufacturers have made an earlier commitment to the original inventor, they are tempted to cancel the prior contract and patronize the potential inventors instead.⁴³ Thus, return on early research becomes non-capturable.

Free-riding as a property right issue would not arise if ideas could be unambiguously described and their exclusivity effectively enforced, i.e. a "perfect" patent right, which would guarantee the original inventor of a crude

model a royalty from an anticipated improvement even though the physical form of the model is displaced. To what extent existing patent systems have provided this function is a crucial issue which must be examined.

Superficially, this function is apparently lacking. The ruling in an old patent case perhaps best describes the attitude of the court:

Every invention may in a certain sense, embrace more or less discovery, for it must always include something that is new; but by no means follows that every discovery is an invention. It may be the soul of an invention, but it cannot be the subject of the exclusive control of the patentee, or of the patent law until it inhabits a body any more than a disembodied spirit can be subjected to the control of human laws.⁴⁴

The soul and body analogy is most appropriate for the issue on hand. The ideas are the souls; the particular models by which ideas are manifested are the bodies. If the patent law only gives protection to the body, ideas will not be appropriately compensated.

Hopeless as the situation may seem, Professor Edmund Kitch has recently argued the contrary.⁴⁵ He cited many cases in which crude ideas had been given patent protection long before they were reduced to practice. He called this the "prospect" function of the patent system. My investigation into the early history of the patent laws not only supports the notion of "prospect function," it reveals the intended "scope" of a prospect. Section 2 in the Patent Act of 1793 states:

Provided always, and be it further enacted, that any person who shall have discovered an improvement in the principle of any machine, or in the process of any composition of matter, which shall have been patented, and shall have obtained a patent for such improvement, he shall not be at liberty to make, use, or vend the original discovery, nor shall the first inventor be at liberty to use the

improvement. And it is hereby enacted, and declared, that simply changing the form or the proportions of any machine, or composition of matter, in any degree, shall not be deemed a discovery.⁴⁶

Is the capturability problem solved? Perhaps no uniform answer can be given to all industries. The identification of an anticipated improvement is costly and in many cases highly subjective. More importantly, it is difficult to distinguish anticipated from unanticipated improvements.⁴⁷ If Section 2 of the 1793 Act is enforced indiscriminately, many obsolete ideas would still be receiving royalty and would be over-compensated.⁴⁸ It is perhaps this reason that this section has not been incorporated into Title 35 in the Patent Act of 1952. Although modern court decisions still carry the doctrine inherited in the section,⁴⁹ the distinction between basic and improvement patents is, as one Judge put it, "somewhat elastic and shadowy."⁵⁰ Thus, it would not surprise anyone that the capturability problem remains unsolved in many situations.

III. Private Remedies

Economic waste resulting from any divergence between private and social gain is intolerable in a framework of joint maximization. We expect private contractual arrangements to minimize the waste resulting from the divergence.⁵¹ For at least two reasons private remedies may be superior to the direct enforcement of patent rights. First, the cost of identifying anticipated v. unanticipated improvement may be lower for people within the industry than for people outside the industry. The judges, the lawyers, or the economists do not usually have the talents to evaluate research outside their professions. The most effective way to invent varies among different industries. Laboratory experiments, feedback from machine maintenance, trial and error of crude models, seminars, lunchtime conversation and pipe-puffing in an isolated office all have relative values that can be more accurately evaluated by the members of industry. Thus, private research organizations in an industry can more efficiently tailor the degree of property right protection through contractual arrangements on their own. For example, if patent law protection in an industry is "excessive," patent rights can be abolished by the mutual granting of nonexclusive rights among members of the industry to use the patents at no charge. In fact, the automobile patent pool in 1915 may have this idea as the underlying purpose.⁵² If patent law protection is ineffective, other contractual arrangements can in principle be adopted to strengthen protection in ideas.

The second support for private remedies is the lower enforcement cost of contract law as compared to patent law. Patent law protection relies heavily on the interpretation of patent claims which are often elusive.⁵³ Private contracting, on the other hand, has the freedom to adopt alternative enforcement mechanisms that are directly observable, resulting in easier detection

of contract violations.⁵⁴ In essence, this is a contract to enforce a contract. The notion was implicit in most of the works on contracting.⁵⁵ Recent works by Klein, Crawford, Alchian (1978), Klein and Leffler (1979), Mayer and Thaler (1979), research in progress by Barzel, Hashimoto and Yu all explicitly adopt the notion that contractual stipulations can be prespecified to enforce post-contractual behavior.⁵⁶

Clearly, there is a place for contracting whenever there is a problem. We wish to examine the different forms of contracting. Recall the nature of the problem: licensees have the incentive to cancel their prior contracts with the original inventor once the inferior inventors can improve on the crude model of the original inventor. Private actions to alleviate the problem can, therefore, come in two ways: A direct way is to impose penalty (or reward) on the licensees if they break (or comply with) the terms of the contracts -- i.e. modify the prior contracts to prevent the licensees from patronizing the inferior inventors. An indirect way, probably a more effective way, is to contract with the inferior inventors, securing a promise from the latter that they will refrain from competing with the original inventor. Or, in other words, instead of asking the licensees to be honest, the superior inventor could indirectly reduce the temptation to the licensees by contracting with the inferior inventors. This, I believe, is the reason behind certain patent pooling arrangements.⁵⁷ Both remedies will be elaborated in the rest of this section.

a. The Modification of Prior Contracts

If innovations accumulate instantaneously, the licensees of a prior contract have no reason to cancel the contract until unanticipated improvements emerge. Thus, no contractual stipulations are required to bind the licensees. Such is not the case if anticipated improvements emerge over time. Licensees must make an all-or-nothing decision to bind themselves to the original inventor's improvements. Again, the glass container industry serves as an example. The prior

contract was for a period of eight years. For the right to use the glass feeder and its improvements, licensees had to pay a nonrefundable lump sum fee of \$2,500, plus an annual minimum royalty of \$1,500 regardless of contract cancellation. Section 17 of the license to Laurens Glass Works, Inc. specified the right and penalty of revocation:

(Subject to certain unrelated conditions), no termination or revocation whatsoever of this license and lease under any Section hereof...affect or in any way discharge the liability of the Licensee hereunder, to pay and continue to pay to the Licensor, the minimum royalty, _____, for and during the term of this license and lease..., nor shall⁵⁸ any royalties paid by said Licensee be returned.

One might suspect that the guarantee payment would encourage shirking on the delivery of improvements. However, as explained in previous sections, repetitive performance (on other devices if not on the same device) provides the incentive for the established research organization to fulfill its promises.⁵⁹ In addition, a royalty based on output could bolster such incentive. In the case of Hartford-Empire, the royalty was based on the weight of glass.

The agreement to refrain from patronizing the inferior inventors need not be explicit. The penalty (or reward) may take various different forms. Two possibilities are suggested: first, assuming that an inferior device produces inferior output, an agreement to refrain from the use of the inferior device could be stated in terms of some quality control of the products. Furthermore, to show good faith, the licensees might willingly agree to deposit earnest money, subject to rebate once the contractual terms are fulfilled. A system similar to this was adopted in Standard Sanitary Mfs. Co. v. United States, 226 U.S. 20 (1912). To what extent the technology in the enameling process

corresponds to the reasons provided here cannot be ascertained without more investigations.⁶⁰

Second, both the licensor and the licensees could agree to develop features specific to their relationship.⁶¹ Licensees bearing some specific investment would find it more costly to switch to other inventors. In the computer industry, for example, some companies were allegedly "locked in" by IBM.⁶² This makes some sense considering that much software developed is specific to certain machines.⁶³ If a company has invested in a set of software, patronizing the inferior inventors would at the margin be more costly. Since "locked in" carries a bad connotation, perhaps this arrangement could be viewed as simply an all-or-nothing proposition to prevent premature contract cancellation.

In the modern world, licensing between inventors and manufacturers is often replaced by vertical integration. Wilson (1975) indicated that the money returns to licensing are only about 4% of total returns to R & D in a given year.⁶⁴ In light of the contractual problems discussed here and the theory provided by Klein, Crawford, and Alchian, vertical integration in inventive industries may be explained.

b. Contract With Inferior Inventors

Presumably, an ideal contract between the superior and the inferior inventors is one in which the inferior inventors agree to refrain completely from any inventive activities on the improvements. However, the inferior inventors in one project could very well be the superior inventors in other projects. Therefore, to ask the inferior inventors to give up their profession as inventors is infeasible. An agreement stipulating the inventive activities of the inferior inventors is equally unlikely, since the contract would be both difficult to write and difficult to enforce. Thus, if a contract among inventors is to be viable, its enforcement must rely on stipulations regarding the

end products of the inventive effort rather than the effort itself.⁶⁵ A promise by the inferior inventor to refrain from competing with the superior inventor must be stated in terms of relinquishing his rights to license an innovation in the area held by the superior inventor.

Potential competition between the superior and the inferior inventors can be bilateral or unilateral. The former situation arises when A is inferior in B's project, and simultaneously B is inferior in A's project. The latter situation arises when A is inferior in B's project, but B's work is totally unrelated to A's. Depending on which situation prevails, the relinquishment of patent rights can be achieved in two different ways: (1) If potential competition is bilateral, the inferior inventor will grant an exclusive license to the superior inventor within the field in which the latter possesses comparative advantage; in return, the superior inventor will grant exclusive licenses to the inferior inventors within their fields of specialty--an arrangement that is commonly known as cross license.⁶⁶ (2) If potential competition is unilateral, all patents within a mutually defined area of inventions will be assigned to the superior inventor. The accumulation of these patents is commonly known as a patent pool.⁶⁷ Cross-licensing or pooling, the exchange of patent rights, is the heart of the arrangement.

Real world arrangements, however, are often complicated by additional price and quantity restrictions. Such complications arise because a contracting party in the real world often takes on dual roles as an inventor and as a user of the other party's innovations due to vertical integration in the inventive industries. Conceptually, each role would result in a different contract. The inventor's contract should involve nothing more than the exchange of patent rights; the manufacturer's contract, however, could be as complicated as any patent licenses ordinarily observed. If an autopsy of a cross-license is

performed, one would certainly classify the various price and quantity restrictions into the manufacturer's contract, since they are not germane to the inventor's contract. The question of why patents are exchanged, therefore, should not be confused with the question of why the return to innovation is extracted in a particular way.⁶⁸

Depending on the type of potential competition and the roles of the contracting parties, different patterns in the exchange of patent rights can emerge. For example, suppose two vertically integrated firms, A and B, started out testing their own inventive methods. Over time, A's invention proves to be superior to B's. Our theory predicts that B will grant A an exclusive license on the research the latter is doing. However, being a manufacturer himself, B will be interested in using the superior method invented by A. This can be accomplished by A granting B a nonexclusive license on A's innovation. In other words, the cross license in this case will be exclusive one way, but nonexclusive the other way.⁶⁹

Exchange of patent rights sometimes appears in subtle ways in ordinary licenses as well. If the licensees (manufacturers) do not have any extensive research facilities, they are clearly the inferior inventors in the area in which they have been licensed. A frequent practice, then, is for the superior inventor to license back or assign whatever improvement patents it may obtain in the future. It is often argued that this clause would lower the licensee's incentive to invent and, therefore, should be prohibited.⁷⁰ Advocates of this argument, however, often tend to overlook the compensating incentive on the part of the licensor to invent. If the licensor is the superior and the licensee the inferior inventor, aggregate inventive activity has to increase, giving rise to some net social benefit.⁷¹

Conclusion

Patent is not a monopoly. Within a framework of zero transaction cost, competition among manufacturers and inventors results in prior contracts in which the costs of the inferior inventors set upper bounds on the return to the patented innovations. With repetitive performance, inventors under prior contracts do not deliberately renege by nondelivery, and efficient allocation of resources in inventive activities results. A problem, however, arises when innovations emerge sequentially over time. To the extent that the patent protects only a physical form of the idea rather than the idea itself, inferior inventors can free-ride on improving the superior inventor's crude models, prompting the manufacturers to either cancel or revise the prior contracts they have with the original inventor. Consequently, returns to early research will be noncapturable. A "perfect" patent system presumably can eliminate the problem by having the improvement inventor compensate the original inventor. Although to some extent some evidence indicates that certain provisions in the patent laws have precisely this effect, perfect enforcement of the law may be very costly, and the capturability problem remains in many industries.

Real world contractual arrangements are rationalized as a means to solve the capturability problems under potential competition. There are basically two kinds of contracts: one is between inventors and manufacturers; the other is among inventors themselves. For the first class of contract, future patent grants are always included, and the term of the contract is usually quite long. This corresponds to the notion of prior contracting. Most ideas apparently are invented under a contract rather than something that pops out of the thin air. Although patents that are not prior contracted exist, they arise because of risk and regulations. Stipulations in a typical contract also illustrate the remedies

to the capturability problem as well as the enforcement mechanism in prior contracting. Right to revocation, quality control, method of royalty payment, rebates, penalties, the development of nonpatentable specific accessories, and vertical integration are all binding restrictions mutually agreed by the manufacturers and the inventors in a prior contract. They help enforce an all-or-nothing proposition which prevents premature contract cancellation caused by inferior inventors free-riding on the information disclosed in a contract.

The second class of contract includes cross licenses and pooling of patents. These contracts are viewed as indirect means to solve the capturability problem. It has been argued that exchange of exclusive patent rights is a guarantee from inferior inventors that they will not act as nuisances to the superior inventors. Furthermore, depending on the degree of vertical integration in an industry and the nature of technological information involved, the exchange of patent rights may take various different forms. Assignments, exclusive patent rights in exchange for nonexclusive patent rights, grant-backs, etc, are a few of the variations.

Casual empiricism is often unreliable. In this respect, I do not claim the confirmation or the refutation of any theory. This paper merely suggests an alternative framework to analyze innovation related problems--a framework which does conform in some way to real world practices. This is only the beginning; its prospects remain to be explored. Three will be explicitly stated. First, the series of questions asked in the introduction and answered in the text require additional statistical testing. This problem is handicapped by a lack of a large enough set of data and measures to adjust for "noises" in testing the theory. Second, the "crude model" referred to in the paper is only one type of early information. Trade secrets, technological knowhow, basic research all have properties similar to those of the crude model. The degree of risk and the

property rights protection given by the law may differ, but the underlying capturability problem and its solution may be very similar in nature. Third, the analysis may also be applied in the field of academics. University research policy, the frequency of co-authorship across different disciplines, customs on acknowledgement in scientific journals, all may be analyzed in some way by the framework described.

Footnotes

¹Either explicitly or implicitly, this approach has been used in numerous articles. The explicit ones are: Arrow, Kenneth J. "Economic Welfare and the Allocation of Resources for Invention," NBER. The Rate and Direction of Inventive Activity, (Princeton: Princeton University Press, 1962); McGee, John S. "Patent Exploitation: Some Economic and Legal Problems," Journal of Law and Economics 9 (October 1966): 135-62; Nordhaus, William D., Invention, Growth, and Welfare, (Cambridge: MIT Press, 1969); Morton I. Kamien and Nancy L. Schwartz, "Market Structure, Elasticity of Demand and Incentive to Invent," Journal of Law and Economics 13 (April 1970): 241-52; Sheng Cheng Hu, "On the Incentive to Invent: A Clarificatory Note." Journal of Law and Economics 16 (April 1973): 169-78; Douglas Needham, "Market Structure and Firms' R & D Behavior." Journal of Industrial Economics 23 (June 1975): 241-55; Bowman, Ward S., Jr. Patent and Antitrust Law, (Chicago: University of Chicago Press, 1973); idem, "The Incentive to Invent in Competitive as Contrasted to Monopolistic Industries," Journal of Law and Economics 20 (April 1977): 227-78.

²The idea here is a combination from two sources: Ronald Coase, "The Nature of the Firm," Economica 4 (November 1937): 386-405, and Jacob Schmooker, Invention and Economic Growth (Cambridge: Harvard University Press, 1966).

³Yoram Barzel, "Optimal Timing of Innovations," Review of Economics and Statistics 50 (August 1968): 348-55; Kamien, M.I. and N.L. Schwartz, "Timing of Innovations Under Rivalry," Econometrica 40 (January 1972): 43-60.

⁴For example, Earl Thompson adopted a perfect price discrimination model under a Cournot behavior assumption, see "The Perfectly Competitive Production of Collective Goods," The Review of Economics and Statistics 50 (February 1968): 1-12. Others have discussed competition in another dimension, see Scherer, F.M. "Research and Development Resource Allocation under Rivalry," Quarterly Journal

of Economics 81 (August 1967): 359-94. Baldwin, W.L. and B.L. Childs, "The Fast Second Rivalry in Research and Development," Southern Economic Journal 30 (July 1969): 18-24.

⁵Demsetz, Harold. "Why Regulate Utilities?" The Journal of Law and Economics 11 (April 1968): 55-66.

⁶Cheung, Steven N.S. and others. "Contractual Arrangements and the Capturability of Returns in Innovations: Report of a Pilot Investigation," (Mimeo., University of Washington, Institute for Economic Research, 1976).

⁷The notion of alternative forms of competition can be found in Alchian and Allen, Exchange and Production: Theory in Use, (Belmont, California: Wadsworth Publishing Co., 1969); that joint maximization is the criterion on the choice of different modes of competition is implicit in Steven Cheung, "A Theory of Price Control," Journal of Law and Economics 17 (April 1974): 53-72. The idea is basically derived from Ronald Coase, "The Problem of Social Cost," Journal of Law and Economics 3 (October 1960): 1-44. The choice of different forms of competition is analogous to the choice on initial allocation of rights. The analysis of the latter is in Richard A. Posner, Economic Analysis of Law, (Boston: Little, Brown & Co., 1977), 2nd ed., Part II.

⁸Harold Demsetz, "Why Regulate Utilities?", op. cit.

⁹The terms were used in a footnote in a later article by Harold Demsetz, "The Private Production of Public Goods," Journal of Law and Economics 19 (October 1972): 293-306.

¹⁰O.E. Williamson, "Franchise Bidding for Natural Monopolies--in General and With Respect to CATV," The Bell Journal of Economics 7 (Spring 1976): 73-104; V.P. Goldberg, "Regulation and Administered Contracts," The Bell Journal of Economics 7 (Autumn 1976): 426-8, idem., "Competitive Bidding and the Production of Precontract Information," The Bell Journal of Economics 8 (Spring

1977): 250-61.

¹¹See the discussion by Earl Thompson, "Competition and Cooperation in the Private Marketing of Collective Goods," UCLA discussion paper.

¹²Thus one might argue that the traditional $MR = MC$ solution is "unstable".

¹³This is similar in spirit to but different in content from the Schumpeterian view; see Joseph Schumpeter, "The Process of Creative Destruction," in Capitalism, Socialism and Democracy, 3rd ed. (New York: Harper Brothers, 1947)

¹⁴See the determination of price in a competitive market in Chapter 5 and 6 of Alchian and Allen, Exchange and Production: Theory in Use, 1st ed., (Belmont, CA: Wadsworth Publishing Co., Inc., 1969).

¹⁵Cooperation is implicitly assumed away in this formulation. This does not imply a loss of generality as we can always lump a group of cooperative inventors into a single entity. Also assumed away is the rate and volume tradeoff in the innovation production function. See F.M. Scherer, "Research and Development Resource Allocation Under Rivalry," op. cit.; W.L. Baldwin and G.L. Childs, "The Fast Second and Rivalry in Research and Development," op. cit. Alternative formulation of the innovation production function can be found in William D. Nordhaus, Invention, Growth, and Welfare, op. cit., chap. 2.

¹⁶ $T_{\delta_1^j}$ is the marginal reduction in production cost with respect to inventive effort; $Q(p)$ is the demand for the final output; it is constant by assumption; r is the rate of interest. The condition can be easily derived from maximizing $\frac{1}{r} \int_{MC}^{MC} Q(p) dp - c_j$.

¹⁷If \underline{m}_{em} equals \underline{n}_{en} , consumers will be indifferent between the two inventors, and the winning inventor can receive nothing more than his research cost. The limiting case in which all inventors are identical happens when \underline{m}_{ez} overlaps with \underline{m}_{ez} ; the inventor in this case receives only the research cost.

¹⁸This will be discussed in more detail in section III of this paper. It will suffice to point out here that there can conceptually be enforcement mechanisms. See Ben Klein and Keith Leffler, "The Role of Price in Guaranteeing Quality," Journal of Political Economy, forthcoming.

¹⁹See Frederik N. Neumeyer, The Employed Inventor in the United States: R & D Policies, Law and Practice (Cambridge, Massachusetts: MIT Press, 1971) chap. 2; Masanori Hashimoto, "The Employed Inventor" mimeo, University of Washington, 1977. Ben T. Yu, "The Economics of Patent Pool: the Capturing of Return to Basic Research," Doctoral Dissertation, University of Washington (1978), chap. 4.

²⁰ibid. The experience in the electronic industries is most notorious. See John E. Tilton, International Diffusion of Technology: The Case of Semiconductors, (Washington, D.C.: The Brookings Institution, 1971).

²¹Of course, in actual testing of these propositions, other considerations must be taken into account. For example, industrial espionage, inferior inventors stealing ideas from superior inventors, legal rights structures between employer and employee, all these may affect employed inventors' turnover rate. Some discussions of these issues can be found in Neumeyer, op. cit., chap. 2.

²²The observation is based on a preliminary investigation on licensing practices for the National Science Foundation. See Steven Cheung and others, op. cit. See also samples of contracts in U.S. Congress, House, Committee on Patents, Pooling of Patents, Hearing, 74th Congress on H.R. 4523, 1936; Exhibits in the Hearing before the Temporary National Economic Committee, Part 2.

²³Recording license agreement between Electrical Research Products, Inc. and Hal Roach Studios, Inc., Pooling of Patents, ibid.

²⁴Hearing before the Temporary National Economic Committee, Part 2, Exhibit 120. See also license from Hartford-Empire to Florida Glass Mfg. Co. (1935), T.N.E.C., Part 2, Exhibit 118.

²⁵T.N.E.C., Exhibit 125, p. 771. The argument was neglected during the hearing as well as in the analyses of subsequent writers. See Bishop, Robert L., "The Glass Container Industry," in The Structure of American Industry, ed. Walter Adams (New York: Macmillan, 1950); Brown, James A., Jr., Antitrust and Competition in the Glass Container Industry, Ph.D. Dissertation, Duke University, 1966. Much attention has been paid instead to another section of the memo in which "predatory" purposes in securing patents were alleged, p. 776.

²⁶The Antitrust court in the U.S. is filled with impressive cases in which a Colossus imposes highly restrictive covenants on its licensees: the dominance of IBM, the restrictive arrangement between Standard Sanitary and the manufacturers and jobbers, the integrated nature of the ethyl gasoline market. In light of the textbook theories on cheating in cartels and the erosion of monopoly profit via entry, such arrangements are highly impressive if not puzzling. While in some of these cases the restrictive structure could be enforced via some old patent rights acquired, without constant improvement, patent rights on one or two obsolete ideas will soon lose its power. Thus, it is probable that such highly restrictive organizational structures are enforced by constant hard work of the Colossus rather than by pure luck. For example, in the case of IBM some evidence of improvements and services provided by IBM can be found; see George Schussel, "IBM vs. Remrand," 74 Datamation 10 (May and June 1965), Richard A. McLaughlin, "Monopoly is not a Game," 19 Datamation 75 (September 1973): 73-77. To what extent these improvements were prior contracted is not known. For other restrictive structures, see Standard Sanitary Mfg. Co. v. United States, 226 U.S. 20 (1912), Ethyl Gasoline Corp. v. United States, 309 U.S. 436 (1940).

²⁷See Neumeyer, op. cit., chap. 5.

²⁸The incentive will not be completely absent if the cost of utilizing the research results is positive. If it is costly to imitate a new product, shortrun

monopoly rent may still exist. Manufacturers may still safeguard themselves by some prior arrangement with the research companies.

²⁹See an excellent discussion of private vs. government financing of innovation in Kenneth Arrow, "Economic Welfare and the Allocation of Resources for Invention," op. cit.

³⁰If the utilization of inventive results varies according to managerial capability, i.e. not only does the marginal cost of production decline, but the slope of the marginal cost changes as well, part of the return to innovation will be capitalized in a firm's asset. In that case, lump sum taxes would be levied on the manufacturers as well.

³¹A general discussion of this subject matter can be found in Raymond C. Nordhaus, Patent - Antitrust Law, 2nd ed. (Chicago: Jural Publishing Co., 1972), p. 309-328. The fact that the plaintiffs in some of these package patent cases were manufacturers (rather than government) apparently conflicts with the view presented here. For example, see Hazeltine Research v. Zenith Radio Corp., 388 F.2d 25 (C.A. 7, 1967). However, if one considers potential competition over time, a complication to be introduced in the next section, such observations may still be consistent with the general framework.

³²For example, IBM was prohibited in 1956 from leasing its tabulating or electronic data processing machine for a period longer than one year; licenses on present and future patents must be granted to whoever requests them, royalty must be "reasonable" as determined by the court; infringement suits can be instituted only under limited circumstances. See United States v. IBM, 1956 CCH Trade Cas. par. 68,245 (S.D.N.Y. 1956) amended, Civil No. 72-344 (S.D.N.Y. 1963, 1970); see also an account of the early history of the computer industry in John T. Soma, The Computer Industry, (Lexington: D.C. Heath and Co., 1976), chap. 2.

³³It is important to distinguish the sources of sequential emergence. The type of emergence referred to in this section arises because it is too costly to squeeze in too much invention in one period. On the other hand, there is emergence that is solely due to risk and unexpected changes in economic environments. As an illustration, different designs of gasoline-driven automobiles could be considered as a substitute package. To the extent that electric cars do not rely on the principles of gasoline propelled vehicles, innovations related to such areas will not be included as part of the substitute package. Without any unexpected changes in the economic environments, only one method of propelling a car will be selected although there may be some initial testing of both methods. The electric car was rejected in the early 1900's as an inferior method. It was only when the price of gasoline skyrocketed unexpectedly that research into electric cars was resumed. The substitute package referred to in the text does not include such unexpected emergence.

³⁴For example, in the thermal cracking of petroleum, early research on the Burton process which was allegedly displaced by better methods such as Tube and Tank, Holmes-Manley, etc. may not be considered as wasteful. It is not clear, however, to what extent the Burton process has provided the set-up for the subsequent research; this research could be the unexpected type of emergence referred to in footnote 33. Note also that the pooling arrangement in that industry is clustered around 1921 to 1923, a period during which the superiority of the Burton process vs. other processes was still unclear. For a detailed account of the case see John McGee, "Patent Exploitation," op. cit., Roger Beck, "Patents, Property Rights, and Social Welfare: Search for a Restricted Optimum," Southern Economic Journal 43 (October 1976): 1050-54. See also the comment by Daniel Landau, Southern Economic Journal 45 (July 1978): 285-88.

³⁵See Floyd L. Vaughan, The United States Patent System (Norman: University of Oklahoma Press, 1956); see also the discussion in F.M. Scherer, Industrial Market Structure and Economic Performance, (Chicago: Rand McNally & Co., 1971), pp. 391-2.

³⁶Joseph Schumpeter touched on this briefly, "A new type of machine is in general but a link in a chain of improvements and may presently become obsolete." op. cit., p. 98. However, his reason appeared to rely on uncertainty rather than on the costliness of accumulation as argued here. It is only when uncertainty is introduced that Schumpeter's argument on "ex ante conservation of capital" makes sense. The crude model will not be wastefully scrapped if the durability of the model is built anticipating the emergence of the improvements. It is only when the improvement emerges much earlier than expected, and thus the crude model was made too durable, that we might observe the market to "stifle improvement in order to conserve existing capital values."

³⁷F.M. Scherer called the view that weights early innovations more heavily "Usherian," ala A.P. Usher, A History of Mechanical Inventions, rev. ed., (Cambridge, MA: Harvard University Press, 1954). He called the view that weights later research more heavily "Schumpeterian," ala Joseph Schumpeter, The Theory of Economic Development, (Cambridge, MA: Harvard University Press, 1934). See Scherer's "Invention and Innovation in the Watt-Boulton Steam-Engine Venture," Technology and Culture 6 (Spring 1965): 165-6.

³⁸It is socially efficient for this type of anticipated displaced machine to continue receiving royalty. In the absence of economic obsolescence, inventive effort successively reduces marginal production cost per period. These research efforts are cumulative, and the gain from each unit of effort is counted until infinity. Even though the crude model is displaced, its idea is still

incorporated in the improved machines. Thus, on efficiency grounds, perpetual patent rights ought to be granted; see John McGee, op. cit.; if one adopts the more vigorous model developed by Nordhaus, under zero cost of licensing, patent life again should be infinity; see Nordhaus, op. cit.. This proposition is not to be interpreted as requiring compensation to obsolete ideas. An idea will only be obsolete when it is displaced due to some unanticipated change in the economic conditions. See the discussion on economic obsolescence in Alchian and Allen, op. cit., p. 310.

³⁹Generally speaking, an improved machine which utilizes a different principle cannot be anticipated at the same time. If a machine utilizes a different principle and its performance is better than the crude model, the early research effort would be diverted to a crude version based on that principle instead.

⁴⁰Stated differently, one person may be better at formulating "basic" ideas, whereas another person may be better at extending it once he has an initial push. Without proper recognition, the argument goes, the basic inventor would not bother to give the improvement inventor the initial push.

⁴¹See Jack Hirshleifer, "The Private and Social Value of Information and Reward to Inventive Activity," American Economic Review 61 (September 1971): 561-74. The argument also demonstrates why speculative purchase of stocks may not always be inefficient.

⁴²With or without patent protection, such information can be easily deduced once the crude model is marketed. As Kenneth Arrow says, "The very use of the information in any productive way is bound to reveal it, at least in part". "Economic Welfare and the Allocation of Resource for Invention," op. cit..

⁴³Even though the original inventor may be superior in the improvement, and thus able to retain all his licensees, he can only do so by agreeing to revise the original prior contract and lower the royalty rate.

⁴⁴Morton v. N.Y. Eye Infirmary, 5 Blatch 116, 1862; 2 Fisher 320. The case was discussed in Alf K. Berle and L. Sprague de Camp, Inventions, Patents, and Their Management (Princeton, New Jersey: D. Van Nostrand Co., Inc., 1959) pp. 90-92. See also Alf K. Berle and L. Sprague de Camp, op. cit., chap. 5; Charles Rivise and A.D. Caesar, Patentability and Validity, (Charlottesville, VA: The Michie Co. Law Publishers, 1936), p. 52; Ben T. Yu, "The Economics of Patent Pools", op. cit., chap. 5.

⁴⁵See Edmund W. Kitch, "The Nature and the Function of the Patent System," Journal of Law and Economics 20 (April 1978): 265-90. See also the discussion on similar issues in Cheung (1977), op. cit., and Ben T. Yu, op. cit.

⁴⁶Feb. 21, 1973, c. 11, 1 Stat 318.

⁴⁷Only extreme skeptics would doubt that railroad was an "unanticipated improvement" in transportation over stagecoaches, and that different models of pocket calculators were "unanticipated improvements" in the calculator industry. There are, however, many cases within a gray area in which people outside the industry (economists, lawyers, judges) have difficulty in classifying them either way.

⁴⁸It would not matter what the scope of a prospect is in a world of zero transaction cost. Given costly contracting, however, the initial allocation of rights is indeed important; see Harold Demsetz, "Towards a Theory of Property Rights," 57 The American Economic Review 347 (1967). See also Richard A. Posner, op. cit.

⁴⁹It is still a well-known rule in the courts that merely patenting the improvement cannot avoid the infringement of a basic patent; neither can the owner of a basic patent utilize the patented improvement. See the list of cases in United States Code Annotated, Title 35, chap. 28, section 271, note 78.

⁵⁰Northwest Engineering Corporation v. Keystone Driller Co., 70 F.2d. 13.

⁵¹Ronald Coase, "The Problem of Social Cost," Journal of Law and Economics, op. cit., Cheung, "A Theory of Price Control," op. cit.; Barzel, "An Alternative Approach to the Analysis of Taxation," 84 Journal of Political Economy 1177 (1976).

⁵²The pool was formed as a result of chaotic patent litigations in the industry. It was almost fashionable for patent holders to sue each other at the time. This was not a period when drastic improvements had been made in the industry, however. As a matter of fact, even when the Selden Patent was still dominant, no improvements were provided by the association that owned the patent. Furthermore, contrary to the common practice, the association did not grant any future patent rights to the licensees. Licensing arrangements prior to 1912 can be found in Ralph C. Epstein, The Automobile Industry, (1928), Appendix C, pp. 361-374. The pooling arrangement itself can be found in T.N.E.C., op. cit., Part 2, exhibits 93 to 98. See also R.W. Beach, "Patent Cross-Licensing Agreements and Methods of Their Administration," Journal of the Patent Office Society 19 (August 1937): 578-95; U.S. Congress, T.N.E.C. hearing, op. cit., Part II (1939); John B. Rae, American Automobile Manufacturers: The First 40 Years, chap. 5.

⁵³Ellis strongly emphasized the drafting of claims. His discussion of central vs. peripheral definition of an invention and the importance in the passage of the Patent Act in 1870 illustrates the great extent to which enforcement of patents relied on patent claims. Ridsdale Ellis, Patent Claims, (New York: Baker, Voorhis and Co., Inc., 1949), pp. 4-5. Similar emphasis was placed by Berle and de Camp, op. cit., chap. 4 and 5. See also the arbitrariness of claim interpretation in Wright Co. v. Herring-Curtiss Co. et al, 204 F 596.

⁵⁴This may no longer be true once Antitrust laws are considered.

⁵⁵For example, the metering argument on IBM cards relied on the assumed low cost of counting cards. See Bowman, "Tying Arrangements and the Leverage

Problem," Yale Law Journal 67 (November 1957): 19-36. For works on property rights, see Harold Demsetz, "The Exchange and Enforcement of Property Rights," Journal of Law and Economics 7 (October 1964): 11-26; Steven Cheung, "The Structure of a Contract and the Theory of a Non-exclusive Resource," Journal of Law and Economics 13 (April 1970): 49-70. For works on the theory of firms, see O.E. Williamson, Market and Hierarchies, (New York: The Free Press, 1975); H. Jensen and W. Meckling, "Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure," Journal of Financial Economics 3 (October 1976): 305-60.

⁵⁶Klein, et al, op. cit.; Klein and Leffler, op. cit.; Mayer and Thaler, "Sticky Wages and Implicit Contracts: A Transactional Approach." Economic Inquiry 17 (October 1979): 559-74. Hashimoto and Yu, "Specific Capital, Employment Contracts and Wage Rigidity," University of Washington, August 1979, Dis. Paper No. 79-23.

⁵⁷Kitch has also mentioned the possibility of private contracting. However, he sees private contracting as a complement rather than an alternative to patent protection. "The Nature and Function of the Patent System," op. cit., p. 277 and p. 285.

⁵⁸Similar clauses can also be found in the licenses Hartford-Empire granted to Northwestern Glass Co. (1933), to Florida Glass Mfg. Co. (1935). The latter was on the Miller Feeder rather than the Hartford Single Feeder. See T.N.E.C. Exhibits 118, 119, 120, Part II.

⁵⁹Hartford-Empire is known to have engaged in many different types of research besides glass feeding techniques. See T.N.E.C. op. cit., Exhibit 125.

⁶⁰The innovation in the case was an automatic dredger for enameling bath wares. The biggest advantage of the innovation was to provide an even layer of enamels on bath wares and thus make the wares more durable. Uneven enamel bath

wares are difficult to detect and easily crack. Standard Sanitary's licensees charged \$5 per day for each furnace, but 80% of these payments were to be returned if the licensees complied with the restrictions in the contract. Among many restrictions stipulated in the license, there was one that prohibited the marketing of "seconds", i.e. inferior bathtubs. We speculate that prohibiting the marketing of "seconds" reduces the incentive to use inferior (or uneven) enameling devices. See the technology reported in William Z. Ripley, Trusts, Pools and Corporations (Boston: Ginn and Co., 1916), pp. 606-34. Existing literature has different viewpoints regarding the manufacturing of "seconds"; see John S. McGee, "Patent Exploitation," op. cit.; Laurence I. Wood, Patent and Antitrust Law, (Chicago: Commerce Clearing House, 1942), p. 121; George L. Priest, "Cartels and Patent License Arrangements," Journal of Law and Economics 20 (April 1978): 334-40. In other licensing arrangements, a penalty rather than a rebate is charged for violating certain restrictions in the contracts, e.g., E. Bement and Sons v. National Harrow Co., 186 U.S. 70 (1902).

⁶¹The argument here is a derivative of the one in Klein and Leffler, op. cit.

⁶²Richard A. McLaughlin, "Monopoly is not a Game," op. cit., p. 75.

⁶³ibid; an interesting account of the computer industry is provided in Gerald W. Brock, The U.S. Computer Industry, (Cambridge, MA: Ballinger Publishing Co., 1975), p. 11-21, pp. 49-51; see also Soma, The Computer Industry, op. cit., pp. 28-30, William Sharpe, The Economics of Computers, (New York: Columbia University Press, 1969), p. 234.

⁶⁴Robert W. Wilson, "The Sale of Technology through Licensing," unpublished Ph.D. dissertation, Yale University, May 1975.

⁶⁵If it is too costly to enforce input, output has to be enforced. See A. Alchian and H. Demsetz, "Production, Information and Economic Organization," American Economic Review 62 (September 1972): 777-95.

⁶⁶An example of this case can be found in the arrangement between AT&T and General Electric in the 1920's. AT&T was the superior inventor in communication systems; General Electric was the superior inventor in electric appliances. Although their researches were highly related, each was the inferior inventor in the other's field of research. A consent decree in 1932, however, changed the cross-license from exclusive to nonexclusive. See Laurence I. Wood, Patents and Antitrust Law, (Chicago: Commerce Clearing House, 1942), pp. 128-37. Other examples can be found in Hartford-Empire Co. v. United States, 323 U.S. 386 (1945); Standard Oil Co. (Indiana) v. United States, 283 U.S. 163 (1931).

⁶⁷Examples are numerous. Notable ones are Standard Sanitary Mfg. vs. U.S., cited in the text; United Shoe Machinery Co. vs. United States, 258 U.S. 463 (1922); Ethyl Gasoline Corp. v. United States, 309 U.S. 436 (1940).

⁶⁸The difficult question of the various price and quantity restrictions in patent licenses has not been examined in this paper. Some of these restrictions have been rationalized in the paper by Priest, op. cit., but the link between the exchange of rights aspect and the licensing aspect has not been made clear. Without any solid theory on this link, it seems odd that the court has traditionally taken a more stringent stand on interpreting restriction in patent combinations. See the observations reported in Cheung, "Antitrust and Patent Combinations: Some Economic Implications of Section One of the Sherman Act." Mimeo. University of Washington.

⁶⁹This is my view on certain aspects of the patent pool in the glass container industry in the 1920's. Hartford-Empire Co. v. United States, op. cit.. Before 1912, glass container manufacturing technique had been limited to what was known as the Owens suction method. Between 1912 and 1924, considerable research was done by Hartford on a method known as the gob-fed. For certain types of glassware, gob-fed was certainly superior to suction. The cross license between Hartford

and Owen in 1924 exhibited the exchange of patent rights described in the text.

⁷⁰See for example United States v. Aluminum Company of America, 91 F, Supp. 333 (S.D.N.Y. 1950). The court argued that "smaller companies will likely be discouraged from pursuing, with fullest vigor, technological investigation in the possibilities of the future." See also Hartford-Empire Co. v. United States, 323 U.S. 386 (1945).

⁷¹In the Hartford-Empire case, the grant-back provision was condemned without consideration of the possibility that it increased net inventive activity. Even in cases in which grant-back provisions have been upheld, it is unclear whether the courts had this argument in mind. In Transparent-Wrap Machine Corporation v. Stokes & Smith Co., 329 U.S. 637 (1947), the court endorsed the possibility that the progress of science may be retarded under grant-back arrangements, but ruled, however, that "whatever force that argument may have in other situations, it is not persuasive here." See also other cases reported in Raymond C. Nordhaus, Patent-Antitrust Law, 2nd. ed. (Chicago, IL: Jural Publishing Co., 1972), pp. 226-38.

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