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NOTE DE RECHERCHE

Reappraising the Efficiency of Probabilistic Patents and Prescriptions for Patent Policy Reform

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Abstract

A growing patent policy literature now acknowledges that, because a patent may be invalidated or the scope of its claims reduced during post-issuance litigation, a patent is more aptly regarded as an uncertain or "probabilistic" property right. Uncertain, or so called "probabilistic patents" (PPs) affect social welfare by fostering competition among patentees and unlicensed competitors which also reduces incentives to invest in research and development (R&D). With respect to the potential pro-competitive effects of PPs, in their influential article, Ian Ayres and Paul Klemperer, advocate institutions of patent enforcement that maintain some degree of uncertainty in patent rights. With PPs, the authors argue, patentee profits, and thus incentives to invest in R&D, need not be diminished, if patent term can be extended in order to compensate for the modest entry of infringing competitors that drive down the price of a patented product.

In this paper I contest this basic claim of efficiency improvement, as well as the prescriptions for extending patent term. I show that increasing uncertainty of patent rights so as to induce limited infringement can be the *least efficient* means of rewarding patentees. A regime PPs prevents the patentee from raising most profits from buyers that have a highest willingness to pay for the invention. Moreover, as Mark Lemley and Carl Shapiro have recently argued, uncertainty in patent rights, when combined with high litigation costs, can induce a patentee and a licensee to engage in collusive licensing agreements that allow a invalid patent to remain unchallenged.

Conflicting conclusions regarding the prescriptions for uncertainty in patent protection originate in 1) underlying assumptions about the nature of competition within a market for a patented invention and; 2) the use of incomplete measures of efficiency of the patent system. With respect to the first, patentees and infringers do not necessarily collude as oligopolists, such that increased uncertainty in patent rights will favor competitive entry without considerably reducing patentee profits. Second, efficiency of the patent system must be defined with respect to patentee profits per dollar of deadweight loss, as opposed to total deadweight loss. Moreover, when concepts of dynamic efficiency (*i.e.*, the speed at which new inventions are developed, as well as demand for them over time) are duly considered, the gains from a regime of less certain patent rights may not outweigh the attendant losses.

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I. INTRODUCTION

For much of the history of the modern day patent system, the statutory definition of a patent – a right to exclude others from making, selling or using the invention without a license[1] – has caused a patent to be regarded as a stable property right. A patent confers to the patentee, specific rights to enjoin competitors from copying the invention, as well as to control the distribution and use of the invention through licensing agreements. Viewing a patent in this way has undoubtedly been useful for appreciating a number of issues such as the need to balance monopoly social costs (deadweight loss) against welfare benefits attributable to the new inventions, whether alternative regimes[2] of patent enforcement could be more efficient and, whether stronger patent protection provides greater

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[1] 35 U.S.C. § 271 (2005)

[2] A number of alternative means of rewarding inventors, such as cash rewards and government buyouts of inventions have been suggested. *See e.g.*, Steven Shavell & Tanguy Ypersele, *Rewards Versus Intellectual Property Rights,* 44 J. L. & ECON. 525 (2001) (proposing that government cash rewards would be appropriate in situations where R&D costs are high, that is, there is a large difference between marginal and average costs); Micheal Kremer, *Patent Buy-Outs: A Mechanism for Encouraging Innovation*, 113 Q. J. ECON. 1137 (1998) (suggesting a system in which the government conducts an auction to determine the appropriate price it should pay the inventor for the invention); F. Scott Kieff, *The Case for Registering Patents and the Economics of Present Patent-Obtaining Rules*, 45 B. C. L. REV. 55 (2003) (proposing a registration system with only "soft" examination procedures and a reduced presumption of validity for issued patents would be socially beneficial because it would require patentees to more carefully scrutinize prior art and apply for patent claims, in order to avoid post-issuance challenges for validity or infringement).

social benefits[3] from innovation, or if they create obstacles[4] for build-upon inventors.

Today, however, a growing body of empirical evidence[5] suggests why that a patent is more aptly regarded as an uncertain or "probabilistic" property right. A patent may be invalidated in post-issuance litigation or the scope of its claims reduced as a result of the Patent Office or the courts re-interpreting the claims, (for a number of reasons such as undisclosed prior art that undermines the

[3]A number of economists have examined the relationship between the patent system and growth of the economy. *See* F. Scott Kieff, *Property Rights and Property Rules for Commercializing Inventions,* 85 MINN. L. REV. 697 (2001), n. 4-5 (providing a review of economic research of the past 60 years on the relationship between patents and economic growth). However, even though such research is often invoked as a basis for the argument that stronger patent protection fosters economic growth, micro-level economic analysis on the relationship between patents and R&D suggests that patents facilitate development and commercialization of R&D inventions rather than provide stimuli for undertaking costly and risky R&D. *See*, Robert P. Merges, *Uncertainty and the Standard of Patentability*, 7 BERKELEY TECH. L.J. 1, 26 (1992) (illustrating using a Bayesian analysis of the inventor's decision to undertake R&D, patents increase the expected returns to commercialization of an invention, which in turn causes the inventor to revise her decision rule about whether a risky R&D project should be undertaken). Other investigators have argued that the patent system in itself does not provide incentives for R&D that are important in relation to other considerations such as being first to market. *See*, Edwin Mansfield, *Patents and Innovation: An Empirical Study*, 32 MGMT. SCI. 173, 176 (1986) (reporting that in many industries patents play an insignificant role in protecting economic rents); Jenny Lanjouw, Ariel Pakes and Jonathan Putnam, *How to Count Patents and Value Intellectual Property*, 46 J. IND. ECON. 405, 415 (1998) (reporting that evidence from patent renewal data indicate that only very few patents create large rewards and incentives for R&D, and in particular, that the declining value of a patent can be inferred from failure to pay renewal fees). Finally, while macroeconomic studies have demonstrated the relationship between the patent system and economic growth, and microeconomic approaches suggest why patents may not be essential in some industries, these apparently disparate findings may be reconciled by the fact that the patent system provides technological benefits, the value of which are in large part captured not by inventors, but by consumers. *See*, William D. Nordhaus, *Schumpeterian Profits in the American Economy: Theory and Measurement*, *Cowles Foundation Discussion Paper* No. 1457 (2004), (indicating that innovators on average, are able to capture "about 2.2%" of the total social surplus from innovation). While this figure is based on the aggregate US non-farm business sector, the author indicates that in some industries, the proportion may be higher.

[4]By requiring developers to seek licenses to create new inventions that build on existing patented inventions, the patent system increases the transactions costs for improvers and build-upon inventors. Legal scholars and commentators have warned that such patents can reduce incentives for innovation when they create "thickets" of patent rights which must be resolved prior to undertaking R&D. *See*, Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard-Setting*, 1 INNOVATION POL'Y & ECON.119, 120 (2000) (stating that, "with cumulative innovation and multiple blocking patents, ... patents can have the perverse effect of stifling, not encouraging innovation"); Micheal A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCI. 698, 698-701 (1998) (explaining how "reach-though licence agreements" for gene fragments can encumber R&D in biomedical research). *But see also*, William A. Haseltine, *The Case for Gene Patents*, 103 TECHNOLOGY REV. 59, (2000) (arguing that inventors should be nevertheless be entitled to patents for inventions relating to gene sequences because they are "artifacts made by the hand of man" and only rendered patentable when they are combined with some medical utility and that such patents provide valuable incentives for investment in R&D).

[5]*See* Mark Lemley & Carl Shapiro, *Probabilistic Patents,* 19 J. ECON. PERSP 75, 80 (2005)[hereinafter L&S] (describing patents as "lottery tickets"); Carl Shapiro, *Antitrust Limits to Patent Settlements*, 34 RAND J. ECON. 391, 395 (2003) (describing patents as "partial property rights" with less than "ironclad" property protection).

novelty or non-obviousness of a claimed invention),[6] judicial discretion, that redefines the legal metes and bounds of the claims[7] in addtion to other reasons such an insufficient disclosure of the invention that fails to meet best mode requirements.[8] And, while a relatively small proportion of patents are litigated,[9] for those that are, patentees and their competitors may have private information (such as invalidating prior art) that causes a patent license fee to be discounted or otherwise adjusted in relation to the likelihood that a patent is found to be invalid.[10] Such discounting need not, however, reflect the value of the invention. Rather, rather as a result of the

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[6]The scope of a patent claim may be reduced if, for example, one or more of its claims does not meet the novelty requirement which requires that the invention was not available to be purchased or used at the time of application and that it has not been described in any publication one year prior to the filing date. 35 U.S.C § 102b (2005). Moreover, the Federal Circuit has ruled that the issue of claim construction – interpreting the legal metes and bounds of a patent claim – is a question of law to be decided solely by the judge. *See* Markman v. Westview Instruments Inc., 52 F.3d 967, 976 (Fed. Cir. 1995).

[7]Examples of judicially-created institutions of patent enforcement that redefine the effective scope of a patent claim are the doctrine of equivalents and double patenting. Under the doctrine of equivalents, infringement may be found even if the accused product lies outside the literal language of the patent claims. In this regard, the intent of finding infringement through the doctrine of equivalents is to prevent patentees from losing protection in cases where an accused product "performs substantially the same function in substantially the same way to achieve the same result". *See* Graver Tank v. Linde Products , 339 U.S. 605, 608-609, (1950). Conversely, infringement may be excused for accused products that lie within the literal scope of the patent claim if it is “sufficiently different” from the accuser’s patented device. *See* Texas Instruments, Inc. v. U.S. Int’l Trade Comm’n, 846 F.2d 1369, 1371 (Fed. Cir. 1988). Finally, judges prevent a second patent owned by the same patentee from being enforced when the second patent is deemed to be obvious in light of a first patent, such that it is intended to merely extend the duration of patent protection for the same invention. *In re* Goodman*,* 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993). As an example, Eli Lilly’s fluoxetine patent protection for its antidepressant Prozac, was successfully terminated when a generic manufacturer Barr Laboratories successfully argued that the second patent which was being enforced was obvious in light of a first patent obtained by Lilly. In each of these three examples, judicial discretion can result in patent protection being unexpectedly extended or terminated, causing the patentee to manage such uncertain property rights using “probabilistic” decision heuristics.

[8] 35 U.S.C. § 112 (2005) states that patent’s specification shall contain a written description of the invention, and of the manner and process of making and using it, in addition to setting forth the “best mode” contemplated by the inventor of carrying out the invention. The purpose of the latter requirement is to discourage inventors from applying for patents while at the same time concealing from the public the best embodiments of the inventions they have conceived. *See* MARTIN J. ADELMAN, RANDALL R. RADER, JOHN R.THOMAS & HAROLD D. WEGNER, CASES AND MATERIALS ON PATENT LAW, 614 (1998).

[9]*See* Jean O. Lanjouw and Mark Schankerman, *Characteristics of Patent Litigation: A Window on Competition*, 31 RAND J. ECON. 129, 131 (2001) (reporting that approximately one percent of all patents are litigated, but for inventions such as valuable pharmaceuticals, the figure may be as high as 25%); Mark Lemley, *Rational Ignorance at the Patent Office*, 95 NW. U. L. REV. 1495, 1501 (2001) (reporting that of the approximately 1,600 patent lawsuits filed each year, only 100 make it to trial and accordingly “less than two-tenths of one percent of all issued patents actually go to court”).

[10]In this regard, one of the disadvantages of a settlement is that it may permit an invalid patent to continue to go unchallenged, if as part of the settlement terms the licensee obtains a side payment or is acquired by the licensor. With the threat of invalidation looming, a patentee may offer a license at a lower fee in order to dissuade the patentee from challenging the patent and revealing its invalidity. For a general explication of the costs and benefits of settlements, see R.D. Cooter & D. Rubinfeld, *Economic Analysis of Legal Disputes and Their Resolution* 27 J. ECON. LITERATURE 1067 (1989).

patentee and licensee having a vested interest in concluding and maintaining licensing agreements that prevent competition among licensees, a favorable license fee may be granted in order to prevent the validity of the patent from being adjudicated. Because such agreements are incentive compatible for patentee and a sole licensee, they can maintain entry barriers that reduce the level of competition in a market, thereby reducing consumer welfare. Such concerns about the anti-competitive effects resulting from strategic behaviour of patentees and licensees have driven a growing interest in the conceptualization of the economic, and social dimensions of so-called "probabilistic patents."

For example, Mark Lemley and Carl Shapiro's (L&S) recent positive analysis,[11] argues that patents are more aptly regarded as providing opportunities to "try and exclude others [from the market] by asserting its patent in courts."[12] Particularly, when litigation costs are high, and invalidating the patent would result in increased competition among suppliers, such opportunities provide incentives for a patentee and a sole licensee to settle with favorable licensing terms, which may even include reverse payments made from the patentee to the licensee, in order to prevent the patent from being challenged. When such "licensing" terms create entry barriers for other competitors, they ensure supra-competitive profits for licensees. For this reason, in L&S's view, the main social loss resulting from probabilistic patents is the fact that they support collusive as opposed to competitive behaviour.

In contrast, where the validity of the patent is known with greater certainty, the patentee and licensee bargain to a (higher) license fee that more closely reflects the true market value of the invention, as opposed to its mere value as strategic entry barrier. L&S argue that patent policies should therefore strive to eliminate such anti-competitive situations by reducing the likelihood that such dubious patents are issued in the first place, or by making it easier to invalidate such patents once they have issued.

Paradoxically, Ian Ayres and Paul Klemperer's normative analysis of a regime of probabilistic patents[13] argues just the opposite – that the probabilistic patents are efficiency-enhancing. According to Ayres and Klemperer (A&K), uncertain patent rights can have the unforeseen benefit of inducing small amounts of competitive entry ("limited infringement") which drives down the price of the patented invention to levels below the full monopoly price. Contrary to L&S, A&K portray competitors taking a calculated risk in supplying the market, whereby expected profits are weighed against the expected penalties for infringement.[14] With each competitor following such a decision heuristic, an oligopolistic industry equilibrium occurs in which consumer welfare is improved relative to the monopoly equilibrium. What is more, total patentee profits remain relatively unchanged, as a result of the combined effects of reductions in deadweight loss and

[11] L&S, *supra* note 5.

[12] L&S, *id.*, at 75.

[13] Ian Ayres and Paul Klemper, *Limiting Patentees' Market Power Without Reducing Innovation Incentives: The Perverse Benefits of Uncertainty and Non-injunctive Remedies*, 97 MICH. L. REV. 985 (1999) [hereinafter A&K].

[14] According to A&K, if potential infringers enter to the point where they expect to earn zero profits, then in expected terms the infringers will be paying all of their profits to the patentees. *See id.* at 994.

proposed extensions of patent term.[15] The authors accordingly argue that law makers ought not attempt to minimize all sources of uncertainty in patent rights, because, the standpoint of efficiency, uncertainty can induce desirable levels of market competition.[16] Probabilistic patents, according to A&K, are therefore desirable because they induce slight increases in the level of competition which result in net efficiency gains via reductions in deadweight loss.[17]

Of course, A&K do not argue that lawmakers should deliberately randomly enforce patents in order to encourage competitive entry. The upshot of their analysis is that enforcing patents according to a liability standard (as opposed to a property rule) as well other enforcement innovations such as extending the geographic scope of patent protection, can be more efficient than current institutions of patent enforcement that strive to create stable property rights and provide injunctive relief. These propositions originate in the core principle that forcing patentees to contend with Type I uncertainty (*i.e.*, a risk that a valid patent will go unenforced), is more efficient than forcing them to contend with Type II uncertainty (*i.e.*, a risk that an improvidently-issued patent will be enforced).[18] Thus, according to A&K, the received logic of providing more certain patent rights to inventors, is inefficient, relative to the alternative of failing to enforce a valid patent. A&K contend that what the patentee may lose through infringement (*i.e.*, as a result of not enforcing injunctions) could be approximately made up by selling more of a patented invention at a lower (*i.e.*, more competitive) price, and appropriately extending patent duration.

Increasing Type I uncertainty is not, moreover, not limited to expanding judicial discretion in a manner that favors creating opportunities for competitors to escape liability for infringement. As A&K indicate, one means of creating beliefs among potential infringers about increased Type I uncertainty, is to through increased deference to the Patent Office's initial decision to grant a patent. In the limit, a registration system (*i.e.*, no examination of the patent) could be used as a means of

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[15]Deadweight loss, can be understood as an efficiency loss borne by both consumers (buyers) and producers (sellers) in the market as a result of reduced quantities of the good being purchased at higher prices. In sum, when a seller faces a downwards-sloping demand curve, increasing the price of a good effects a less-than-proportional increase in profits. Accordingly small reductions in price can therefore increase consumer welfare more than it reduces patentee profits, as a result of reductions in deadweight loss. *See* infra Part I

[16]Although a patent does not provide any affirmative monopoly right to the patentee, economic models of patent enforcement most often portray a patentee as a monopolist, because a patent allows its holder to prevent others from making, selling or using the invention without a license. 35 U.S.C. **§** 271 (2005**)**. In practice, however, we know that the market power conferred by a patent is not singular and very much depends on the availability of non-infringing substitutes. *See infra* Part III.A.

[17]Although the aim of A&K's paper is to illustrate the potential efficiency gains from uncertain patent rights, they do no advocate that patents be enforced randomly. Rather, they aim to illustrate that certain institutions of patent enforcement, such as injunctive relief, which prevents competitors from entering the market, may be less efficient than enforcing patents with a liability rule. With a liability rule, the authors argue, potential competitors, like in the case of a fictitious probabilistic patent, enter and supply the market with the expectation that they will be liable for infringement with some probability of less than one, given that the validity of the patent is determined after the infringement has occurred.

[18]*See* A&K, *supra note* 13 at 1024 (stating that, "underinclusive standards are likely to be more efficient than either rules or overinclusive standards. 'Standards' (which can only be discovered ex post) are preferable to 'rules' (which can be predicted ex ante) because standards create both the uncertainty and ex post determination necessary to cause limited infringement. And underinclusive standards are more likely to create more Type I uncertainty (which we favor) than Type II uncertainty (which we disfavor)").

ensuring that the there is a inevitable supply of improvidently issued patents. Put differently, in order to create beliefs about there are opportunities for profitably infringing a valid patent, the patent office would have to reduce the likelihood of not granting a valid patent. Giving greater deference to the PTO's decision to grant a patent is one means of reducing Type I *error*, (*i.e.*, the likelihood that a patent for an invention meriting protection is not granted) which in turn, increases Type I *uncertainty*[19] about the validity of a given patent. PP's therefore argue in favor of less diligent patent examination, in order to persuade competitors to infringe the patent while it is in force, thereby driving down the price of the patented invention closer to the competitive level.

In many regards, these opposing prescriptions and implications of probabilistic patents illustrate confusion over concepts of efficiency and economic welfare. The patent system, while intended to foster innovation, creates several social losses if patents are improvidently issued and go unchallenged. These include 1) opportunistic licensing agreements between patentees and certain licensees which bar competitive entry; 2) needless design-around activities by potential competitors; 3) obstacles to downstream innovation (because downstream inventors may be reluctant to take licenses for upstream inventions) and of course; 4) supra-competitive pricing which deprives some consumers of the new invention, while at the same time depriving the patentee of revenues from such product sales.[20]

It is this last form of social loss that is referred to by economists as deadweight loss. A&K argue that, if the price of an invention is set just slightly below its full monopoly level, consumers would gain more (as a result of lower prices) than would patentees lose in terms of licensing revenues. The reason? At slightly lower prices, increased volume of sales offsets most of the losses due to lower price. From the standpoint of reducing deadweight loss, reducing prices improves the market (allocative) efficiency because it makes at least one party (consumers) better off without harming another (patentee) by the same amount. This result is the impetus for A&K's contention that uncertainty in patent rights have the unforeseen virtue of improving efficiency, and that lawmakers need not undermine institutions of patent enforcement that inevitably create uncertain patent rights. These might include, for example, institutions that introduce increased judicial discretion, such as the doctrine of equivalents.[21]

In this paper, I deconstruct each of the models proposed by A&K and L&S, as a means of resolving such paradoxes and re-examining the professed logic of policies advocating uncertainty and delay in patent enforcement. Even without considering some of the typical criticisms or limitations of the probabilistic patents model such as the presence of near substitutes, I argue that at its most fundamental level, law and economics scholars concerned with the monopoly social costs of patent enforcement, have misconstrued the efficiency criterion that should be applied to determine

[19] Type I error refers to not granting a patent for an invention that merits patent protection. Type I uncertainty, in contrast refers to the likelihood that a valid patent is not enforced. *See* A&K, *supra note* 13, at 1026, n.108 (stating that, "...by giving deference to the PTO's initial decision [to deny a patent], our current system reduces an important source of and important source of Type I uncertainty – both on additional patents that would be issued, and on the patents that would have in any case issued but for which issuance is now a weaker signal of validity. In the extreme case, the patent office would simply become a registry that time-stamped patent claims to create a record of subsequent adjudication of validity.").

[20] Jay P. Kesan, *Carrots and Sticks To Create A Better Patent System*, 17 Berkeley Tech. L. J. 763, 767 (2002).

[21] *See supra* note 7.

if reducing uncertainty in patent rights is desirable.

To date, most efficiency analyses of probabilistic patents, being primarily concerned with monopoly power, overlook the fact that efficient patent systems strive to reward inventors by creating the greatest transfer of wealth from users to inventors. Deadweight loss, which is a measure of the social losses incurred by consumers (and producers) as a result of some consumers choosing not to purchase the invention, is an indirect measure of this transfer and is largely dependent other criteria such as the consumer's willingness to pay for an invention. Because of these interdependencies, reducing deadweight loss through increased competition in the market for the patented invention is not synonymous with increasing the efficiency of creating rewards for inventors. Indeed, from the standpoint of efficiency, it will be most desirable to permit patentees to price discriminate – that is, allow the patentee to charge the highest prices to consumers who have the highest willingness to pay for the invention.

Accordingly, I argue that prescriptions for reducing deadweight loss by maintaining probabilistic patents for the patented invention will be misplaced because they curtail patentee's market power where it is most efficiently exploited. I show that it will be *most efficient* to maintain the patentee's right to assert her property rights during the earliest years of the patent term when she faces a most inelastic demand curve – precisely the opposite prescription of A&K who argue that under a regime of probabilistic patents, terms should be extended as compensation for limiting the patentee's right to enforce her property rights or obtain injunctive relief.

The prevailing market structure and competitor behavior remain critical determinants of whether probabilistic patents will promote efficiency-enhancing competition or obstruct it. To be sure, consider that according to L&S' analysis, patentees and rivals are assumed to be few enough in number in number to be are able to maintain collusive agreements to not enter the market or challenge the patent.[22] However, because the presence of a larger number of competitors can preclude such reverse payment licensing agreements, and because they may be illegal,[23] it is essential to consider the ways in which rivals may compete against, rather than collude with, each other.

[22]*See* L&S, *supra* note 5, at 92.

[23]*See id*. (describing the case of Hytrin, in which drug maker Abott, the patentee, paid a potential competitor Geneva, $4.5 million to challenge the Hytrin patent and refrain from entering the market.) L&S contend that the there is no well-established rule for determining whether such agreements are illegal as courts have apparently ruled that such reverse payments are illegal under some circumstances but not others. In the case of an agreement between Hoechst Marion Roussel and Andrx the Sixth Circuit court ruled that such an agreement was *per se* illegal (*In re* Cardizem Antitrust Litigation, 3322 F. 3rd 896, Sixth Circuit, 2003). However, as L&S note, in an other case involving the antibiotic Ciprofloxin, the District Court found that such agreements were not *per se* illegal. (*In re* Ciprofloxacin Hydrochloride Antitrust Litigation, 261 F. Supp. 2nd 188, E.D.N.Y. 2003). Whether licensing agreements and reverse payments are illegal depends in part on whether the patentee has listed its patents in the FDA Orange Book in order to prevent generics manufacturers from entering the market. When a patent is listed in the Orange Book, it delays the entry of generics by at least 30 months or until the issue of patent infringement has been resolved. A declaratory judgement may not be sought. The Federal Trade Commission has therefore sought to minimize abuses of the Hatch-Waxman Act which sought to strike an appropriate balance to between patent term extension and prompt entry by generics suppliers at the end of a patent term. In many cases patentees and generics suppliers will negotiate a settlement regarding a patent filed in the Orange Book, and such settlements may include reverse payments. In this regard, a reverse payment may be viewed in some cases as not being illegal *per se*, because the Hatch-Waxman Act had originally intended to provide greater incentives for pharmaceutical firms to recoup their investments in R&D, given that much of the statutory patent life is begins well before the product is commercialized.

These include, for example, the assumption rivals entering the market undersell the patentee,[24] that patentees or other incumbents deter entry through predatory pricing,[25] or that new entrants (*i.e.*, infringers) have lower cost structures than the patentee because they have not had to invest in R&D.[26] I show that under these more plausible scenarios, it remains unlikely that increasing uncertainty in patent rights would in fact maintain sufficient incentives for innovation.[27]

Finally, as a second prong to an efficiency analysis, we must consider the impact of uncertainty on dynamic efficiency, that is, the extent to which the patent system stimulates the creation and supply of new inventions over time, as opposed to the extent to which it minimizes deadweight loss in a given period. Here, it is essential to consider how probabilistic patents affect the selection of R&D projects. Weaker and more uncertain patent rights suggest that larger, more expensive R&D projects, would be compromised, because the returns on a probabilistic patent must be discounted for their expected value. However, in reality, large scale R&D, is more likely to provide inventions that are sufficiently radical that they sustain important profit margins for the patentee, which, when discounted for uncertainty, are more likely to remain feasible than less radical R&D projects. However, because such projects typically require larger capital investments, they can only be undertaken by large firms operating in large markets.[28] In the limit, probabilistic patents, or a regime that strives to increase the uncertainty in patent protection can have the unintended consequence of *reducing* the number of competing inventors in a market (compared to a perfectly competitive market), as a result of only large, integrated R&D firms being able to undertake large R&D projects.

This paper is organized as follows. In Part II, I deconstruct A&K's hypothetical model of probabilistic patents, which the authors present with the intention of illustrating how uncertainty in patent enforcement may have unforeseen virtue of reducing the deadweight loss while at the same time maintaining patentee profits unchanged. A key assumption of A&K's mathematical model is that patentees and incumbents operate collusively, as Cournot oligopolists, similar to members of a cartel. In Part III, I argue why Counot competition is the least likely of other possible competitive behaviours such as underselling and discuss the limited circumstances under which Cournot behaviour may be possible. Part IV proposes a more meaningful measure of patent policy

[24] *See infra* Part III.A

[25] *See infra* Part III.A(3)

[26] *See infra* Part III.A(2)

[27] *See infra* Part III

[28] *See* Joseph A. DiMasi, *New Drug Innovation and Pharmaceutical Industry Structure: Trends in the Output of Pharmaceutical Firms*, 34 DRUG INFORMATION JOURNAL 1169, 1175 (2000) (stating that "seven of the top 10 firms and 18 of the top 20 firms ranked by pharmaceutical market share are among the top 10 and top 20 developers of NCEs, respectively"). DiMasi's analysis suggests that the largest firms (as measured by sales) are the most productive firms in terms of the development of new drugs. According to the author, industry concentration over the past 40 years (the period during drug companies started investing significantly in R&D to create FDA-approved medications) has remained relatively stable as a result of merger and acquisition activity (which raise concentration) and partnerships and alliances (which tend to reduce industry concentration) being important organizational forms that enable specialization in R&D functions. New drugs are therefore unlikely to be created and commercialized by small, independent firms, as a result of the large specialized investments required to bring a new drug to market.

efficiency in light of the realities of competition in markets for patented inventions, while Part V discusses the effect of uncertainty in patent rights on incentives for investment in R&D. Conclusions appear in the final Part.

II. DECONCONSTRUCTING PROBABILISTIC PATENTS

In order to illustrate their central thesis – that small degrees of uncertainty in patent rights can increase the efficiency of the patent system – A&K use an analytical model of competition between a patentee and an infringer, under a regime of uncertain patent rights called "probabilistic patents" (PPs). Their algebraic model demonstrates how limited entry by competitors drives down the price of the patented invention without, however, eliminating all patentee profits. Although the basic intuition underlying limited infringement is that the supply of competitors is regulated by the expected liability for infringement, the intuition underlying the efficiency gain – the reduction in deadweight loss – rests on a number of complementary assumptions. These assumptions facilitate the mathematical analysis of a regime of probabilistic patents. When examined more closely, they also help understand the limited circumstances under which uncertainty and delay can effectively reduce deadweight loss. In the sections that follow, I outline A&K's model and explain the significance of its underlying assumptions.

A. *Probabilistic Patents Defined: A&K's Analytical Model*

To illustrate how a small degree of uncertainty in patent validity can improve the efficiency of the patent system, A&K use a simple numerical example computed using an algebraic model depicting competition between a patentee and single infringer.[29] The model illustrates that where competitors believe that there is a 5% probability that the patent will be held invalid, they enter and supply less than one fifth[30] of the market, leaving patentee profits relatively unchanged. The intuition behind small degrees of uncertainty in patent validity is therefore seen by the fact that although the resulting increased competition reduces prices by almost 10%,[31] patentee profits are reduced by less than one percent.[32] Furthermore, if the shortfall in monopoly level profits can be

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[29] *See A&K*, *supra note* 13 at 995-998.

[30] Using A&K's the supply function for the infringer (entrant), and a probability of enforcement w=0.95, the infringer's supply is given by $Qe = \dfrac{(2-2w)100}{(2-w)}$.

[31] *See* A&K, *supra* note 13 at 998, Table 1. Price is reduced from p=50 to p=45.2, when the patent is enforced with a 95% probability.

[32] An important caveat applies to these results and those shown in Table 1 of A&K's paper: the changes in patentee profits, and deadweight loss apply to single period changes and not to the total profits earned over the course of several years of patent enforcement. They thus abstract from several time-varying factors such as the obsolescence and the decreased value of profits earned in later periods.

maintained by extending the patent term, A&K argue that such a regime will be efficiency enhancing and should have no effect on incentives to innovate.

According to A&K, these results are possible because of the downwards sloping nature of the demand curve for patented inventions. Along a downwards-sloping demand curve, the offsetting effects of price and quantity on patentee profits attributed to lower prices, can be explained in terms of two effects which they refer to as the "Stationarity" and "Ramsey" intuitions.

1. *The Stationarity Intuition*

The stationarity intuition explains why small reductions in the monopoly price for a new invention cause only small or no reductions in profits: at lower prices, the patentee sells larger quantities of the invention, which offset the losses from a lower per unit margin. Thus, along what mathematician's call a stationary point, the patentee's profit function is relatively flat, since what the patentee loses in profits as a result of lower prices, is approximately made up by increased sales.

These relationships between price and quantity sold are illustrated in Figure 1. Reducing price from the monopoly level of P_M to P, for example creates a net welfare change corresponding to the Area [(A+D)-(D+B)] = Area B- Area A. Along a stationary point of the profit function, where the demand function is relatively elastic, Area A will be approximately equal to Area B, creating a negligible net change in patentee profits.

Larger reductions in price, brought about by increased entry, may however, prevent a patentee from remaining along a stationary point of the profit function. In order to offset such losses A&K propose extending patent duration beyond the normal twenty-year term. Thus, when combined with extended patent duration, interim infringement resulting from uncertain patent enforcement improves the efficiency of the patent system by restoring the benefits of competition, without unduly reducing patentee incentives for investment in R&D. A&K argue, the efficiency gain resulting from extended patent duration is analogous to raising tax revenues by applying a lower tax on a larger number of goods – what they refer to as the "Ramsey intuition."

2. *The Ramsey Intuition*

In a pioneering paper on optimal taxation strategies,[33] economist Frank Ramsey, asserted that a tax applied to the largest number of goods is efficient because it minimizes the ability of buyers to avoid paying the tax by purchasing untaxed substitutes. A&K contend that the same intuition can be applied to the problem of raising profits, where the reduction in patentee profits due to monopoly pricing is analogous to the reduction in tax revenues that occurs as a result of buyers choosing untaxed substitutes. In both cases the deadweight loss, the reduction in taxes or patentee profits resulting from a reduced volume of sales, can be minimized if a smaller tax (price increase)

[33] *See* Frank P. Ramsey, *A Contribution to the Theory of Taxation*. 37 ECON. J. 47 (1927). For a review of more recent explications and applications of the intertemporal Ramsey pricing see, Robert Cooter, *Optimal Tax Schedules and Rates: Mirrless and Ramsey*, 68 AM. ECON. REV. 756 (1978); Frank Mathewson & Ralph Winter, *Tying as a Response to Demand Uncertainty*, 28 RAND J. ECON. 566 (1977) (proposing why a monopolist may, under conditions of uncertain demand, have incentives to implement Ramsey pricing across several products (tying) instead of charging a monopoly price for patented products and competitive prices for unpatented products).

can be applied to a larger number of goods (greater number of periods of patent enforcement).

Thus, as A&K contend, if each year in which the patented invention is sold is viewed as a separate good,[34] the Ramsey intuition suggests that extending patent duration can reduce deadweight loss by preventing buyers from averting the supra-competitive (but lower than monopoly) price under a regime of PP's. Thus, under a scenario of PPs, where patent duration has been extended in order to compensate for a lower probability of enforcement (*i.e.,* a more uncertain patent right), the patented invention is sold at below the monopoly price for an extended period of time, thereby sparing buyers from incurring a social loss by "waiting until the patent expires."

To see the efficiency gain, we can compare this outcome to the current regime of patent enforcement where shorter duration of patent enforcement creates a larger amount of deadweight loss as a result of some buyers refusing to purchase the invention higher prices. As shown in Figure 1, reducing price from the initial level of P_M to P for example reduces deadweight loss in the amount corresponding to Area C, since at the lower price P, a larger quantity (Q') is purchased.

Insert Fig. 1 about here

B. *Limits of the Stationarity and Ramsey Intuitions*

While the stationarity and Ramsey intuitions suggest that implementing uncertainty and delay in patent enforcement can reduce deadweight loss without significantly reducing expected patentee profits, the *rate* of efficiency improvement (*i.e.*, the marginal reduction in deadweight loss) depends upon the probability of enforcement. Small amounts of uncertainty (*e.g.*, a probability of enforcement of 95%) produce proportionately large reductions in deadweight loss, because a relatively high probability of enforcement induces only small amounts of entry. This enables the patentee to remain along a stationary point of the profit function.[35]

But where a high degree of uncertainty in patent rights creates an inevitable shortfall in patentee profits, A&K contend that the patent term can be appropriately extended.[36] While this scheme does increase total profits earned during patent term, the marginal contribution of each additional year of patent protection decreases as patent term is extended, as a result of two independent factors. First, profits received in later periods are worth less to the patentee because they must be discounted for the time value of money. Second, during the later periods of patent enforcement, the patent right is likely to be worth less because the demand for the invention will have been reduced as a result of buyers preferring newer and improved substitutes.

[34]*See* A&K, *supra* note 13, at 992 (1999) (stating that, "If we view each year (or product) as a separate product, then the most efficient way -- *à la Ramsey* – to produce a certain tax revenue (patentee profit) would be to impose some tax on *every* [emphasis added] product...an idealized patent regime violates the Ramsey intuition by taxing just the first twenty years and imposing no 'tax' on the subsequent years").

[35]*See* A&K, *supra* note 13, at 990 (1999) (insisting that the patentee always reaches a stationary point on the profit function because the patentee always sets price at a level where marginal profit is zero, that is, where the increase in profit due to a price increase is just offset by the reduction in profit due to reduced demand at the higher price).

[36]*See id.,*at 1001-3 (1999) (indicating that with a 90% probability of enforcement and a 7% discount rate, patent term would have to be increased just 3.4% over its initial length, even though it reduces deadweight loss by almost ten times as much.

In order to account for both of these time-varying devaluations of patentee profits, A&K discount patentee revenues in each period. A larger discount factor requires the patent term to be further extended in order to maintain total patentee profits at the monopoly level. However, even though extending patent duration can be shown to be mathematically equivalent to profits earned under a patent monopoly, the compounding effects of time applied to lower probabilities of enforcement and profits earned at a later period eventually lead to insurmountable reductions in patentee profits. Consider for example, that according to A&K's model, for a probability of enforcement of 70% and assuming a single annual discount factor of 7%, patent duration would have to be extended from 20 years to 45 years in order to maintain profits at the same level.[37] At a slightly lower probability of enforcement (66%), however, it becomes nearly impossible maintain patentee profits at their monopoly level by simply extending the patent term, as a result of higher levels of infringement significantly reducing patentee profits in each period and later period profits being more heavily discounted. The constraints to extending patent duration are, moreover, likely to be exacerbated when one furthermore considers that the demand in later periods when the invention faces obsolescence.

In sum, the largest ratio of change in deadweight loss in relation to patentee profits occurs at relatively high levels of patent enforcement, where the price of the invention is sold at prices near the monopoly level, and where the effects of discounting are negligible. For larger reductions in price, sustained by lower probabilities of enforcement, the combined effects of discounting for obsolescence and the time value of money prevent patentee profits from being maintained at their monopoly level. Moreover, these results rest are contingent upon several other key assumptions about the competitive behavior of patentees and infringers, discussed in the next subsection.

C. *Core Assumptions Underlying A&K's Model of PPs*

Two important assumptions of a regime of PPs are that competitors operate according to what economists refer to as a Cournot oligopoly, and that the demand elasticity of the invention does not change significantly over time. As explained below, both of these assumptions are evident from the structure of A&K's mathematical model, yet are unlikely to be present in markets for patented inventions.

1. *Cournot Competition*

Since the output level for both patentee and infringer are solved as a system of simultaneous equations (*i.e.*, in A&K's model, one seller's supply is equation is substituted into the other's), they operate according to what economists refer to as Cournot[38] duopolists, coordinating their respective

[37] *See* A&K, *supra* note 13, at 1005, Table 2.

[38] Cournot competition refers to a model of oligopolistic competition. The key underlying assumption in most analytical models of Cournot competition is that each competitor knows how the other competitor will supply the market in relation to price changes, and that each supplier, duly accounts for the supply functions of her rival. Analytical models of oligopolistic competition most often assume Cournot behaviour because such assumptions enable one to compute equilibrium levels of industry supply and price using relatively simple algebraic solutions. For a review of Cournot models of competition and solution their associated mathematical models, see JACK HIRSHLEIFER, PRICE THEORY AND APPLICATIONS (3d ed. 1984); JEAN TIROLE, THE THEORY OF

supply decisions so as to maximize joint profits. Put differently, they operate as members of a cartel, maximizing joint profits by restricting their respective output levels so as to avoid flooding the market. Prices are thus maintained at optimal levels by coordinating output levels, given that lower prices have a positive effect increasing sales volume, but also a negative effect in that they reduce the profit margin on each unit sold.

As A&K indicate, under a regime of probabilistic patents, prior to entering, the infringer observes the probability of enforcement as well as the demand for the new invention to as to conclude an agreement with the patentee to produce an amount that maximizes the joint profits of the two rivals. In the mathematical model, this is given by each rival's reaction function.[39] Under Cournot competition rivals agree to not deviate from their reaction functions, even though each supplier could in practice, increase profits by slightly underselling his rival. As a result, A&K's model of PP's implies that both parties act as though they simultaneously supply the market (*i.e.*, without observing if the other has attempted to undersell) with an identical product and that each unit of which is sold in each period at a uniform price.[40] Price and output levels are maintained through the duration of the patent term, since both the probability of enforcement for the patent term and the demand for the new invention are known and never changes.[41] The Cournot assumption thus portrays patentee and infringers as being able to make credible binding commitments about the relative level of output they supply in each period, for the duration of the patent term.

2. *Elasticity of Demand Does Not Change Over Time*

In addition to Cournot competition, A&K's model assumes that the elasticity of demand for the patented invention remains unchanged for the duration of the patent term. A constant elasticity of demand[42] implies that the marginal willingness to pay for an invention remains unchanged over

INDUSTRIAL ORGANIZATION, 1988. *See also, infra* note 40.

[39] *See* A&K, *supra* note 13, at 997 (noting that the probability of enforcement *w* is "common knowledge... The order of play is: (1) the patent is awarded; (2) the patentee and the competitive fringe simultaneously choose output levels; and (3) the court flips a coin and announces if the patent is to be "enforced"). The commitment to maximize joint profits is in effect, implied by the assumption that "each competitor chooses a quantity to produce that maximizes its profits, given an equilibrium expectation about the output of other producers." In the Cournot game, this expectation is that competitors maintain their output levels fixed (or that there is but a single period in which such decisions are made), inducing each rival to agree to restrict output so as to maximize joint profits.

[40] The assumptions of the Cournot duopoly are well-known. See for example, DAVID M. KREPS, A COURSE IN MICROECONOMICS THEORY 326 (1990) (stating that "each firm will act in a way to keep fixed the quantity that it sells").

[41] In A&K's analytical model of Cournot competition, this can be seen by the fact that the demand function depends on the probability of enforcement *w*. Equilibrium output *levels* for the patentee and incumbents are computed for different probabilities of enforcement, meaning that the marginal propensity for each to supply the market at different prices and probabilities of enforcement remains constant. *See* A&K, *supra* note 13, at 997 (indicating that entrant supply function *Qe,* remains constant and a function of *w,* and the patentee's output).

[42] By "constant elasticity" I mean that demand elasticity remains unchanged at a given price from one period to the next, as opposed to remaining constant *along* a given demand curve. In fact, along a linear demand curve the elasticity of demand varies with the price. This is because, at higher prices, some of the most price sensitive buyers are absent from the market. In the limit, along a linear demand curve, at the "choke price" – the maximum price at

the life of the patented invention, in spite of the availability of newer, improved substitutes.[43]

Even so, A&K's model does not entirely overlook the development of substitutes or improved versions of the patented invention or substitutes. In order to account for the reduction in sales due to technological obsolescence, A&K discount later period patentee revenues. Solving the Cournot equilibrium using this additional discount factor indicates how many additional years of patent protection are needed in order to maintain patentee profits at their monopoly level. These adjustments to patent duration are not, however, equivalent to assuming that the elasticity of demand for a new invention increases over time as a result of the reduced willingness of buyers to choose the patented invention in favor of other substitutes. Increasing elasticity of demand – a condition not analyzed in A&K's static model – thus affects the significance of the Ramsey and stationarity intuitions in explaining how much uncertainty can improve efficiency of the patent system.

In the case of stationarity, increasing elasticity of demand causes the patentee to reach a stationary point on the profit function corresponding to a lower price, because along a more elastic demand curve, a given increase in price effects a larger reduction in profits. More specifically, as demand for the invention becomes more elastic over time, the patentee is required to make greater concessions in price in later periods in order to avoid losing market share. Thus, under an assumption of time-varying change in demand elasticity, the stationarity principle is not violated but rather incorrectly attributed to improving the efficiency of the patent system.[44] To see why, recall that the patentee always reaches a stationary point on a profit function because, in order to maximize profits, she continues to supply the market up to the point where marginal profits are zero. As the demand curve facing the patentee becomes more elastic however, it becomes less representative of the initial demand and profit conditions. The profit maximizing price will still be described in terms of a stationary point, but it will be on along a *new* profit function.

In particular, as a greater number of improved substitutes becomes available towards the end of the economic life of the patent, the demand curve becomes relatively more elastic, with the result that any subsequent reductions price are less likely to effect an increase in revenues of the same magnitude as when the invention was not obsolete. Thus, even though it remains true that the stationarity intuition holds for a *given* profit function, when an invention faces obsolescence, setting price at a level corresponding to a stationary point may always ensure that profits remain unchanged.

Similarly, when applied to the Ramsey intuition, the time-varying increase in demand elasticity argues for prescriptions of patent term which are just the opposite of those indicated by A&K. As the demand becomes relatively more elastic (due to, for example, the availability of

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which the product is purchased by at least one consumer – the own price elasticity of demand approaches infinity. Conversely, at the lowest price, along a linear demand, own-price elasticity of demand approaches zero, since increasing price in this neighbourhood causes price sensitive buyers to refrain from buying the good. The "elastic portion of the demand curve" therefore refers to the upper portion of the demand curve (*i.e.*, higher price levels) where demand elasticity is greater than one. For a review of the relationship between own-price elasticity of demand and price see JACK HIRSHLEIFER, *supra* note 38.

[43] However, A&K do in fact acknowledge that the presence of substitutes will lead to erosion of patentee profits or patentee profits being overstated. *See* A&K, note 13, at 1016(stating that the benefits of probabilistic patents may be overstated if structural factors independently induce patent holders to charge less than the static monopoly price).

[44] *See* also *infra* Part IV.B

improvements or substitutes), the ratio of deadweight loss to patentee profits increases.[45] Under these circumstances, as A&K concede,[46] it will be most efficient for the patentee to charge the highest price during the earliest periods of patent enforcement in which demand is least elastic so as to minimize the deadweight loss.

To summarize, the assumptions of both constant elasticity of demand and Cournot competition portray competition in the market for patented inventions as a single-period game in which rivals are able to both determine and commit to supplying their respective share of the market, so as to maximize joint (industry) profits. In reality, however, competition in markets for patented inventions departs in many different ways than a single-period Cournot duopoly. Rivals undersell their competitors, new technologies replace existing ones and not all firms have equal access to resources and markets. A few of these economic models, which incorporate more plausible assumptions about how rivals respond to competitive threats, and how the demand for a new invention evolves over time, are presented in the next section.

III COMPETITION IN MARKETS WITH NEW INVENTIONS

The professed efficiency improvement of A&K's regime of PPs over the current regime of patent enforcement assumes patentees set price at the full monopoly level and that the patentee is able to maintain a cartel with infringers. In fact, however, new inventions are rarely sold under such competitive conditions, owing to the presence of substitutes. Moreover, recognizing that the economic life for a new invention will be shorter than the statutory life of a patent, if competitors are expected to introduce non-infringing substitutes, patentees strive to earn most of their profits while the demand for the invention is relatively strong.

Even in the absence of such competitive R&D, rivals can still be expected to pose a threat to patentee profits if they act independently as opposed to colluding as Cournot duopolists. For example, if rivals undersell the patentee, they acquire the patentee's share of profits but return, in expected terms, less than the patentee's lost profits, so long as the probability of enforcement of the patent is less than one. Cognizant of such outcomes, patentees can be expected to protect market share through price cuts, but only to find that competitors respond similarly. Over time, the price of the invention can be eroded to levels where the patentee no longer remains along a stationary point along the initial profit function. Economists have developed several formal models of competition to describe the outcomes of such competitive behavior, which can be understood as plausible alternatives to Cournot competition. Finally, as L&S argue, under limited circumstances, uncertainty in patent rights can result in some degree of oligopolistic coordination (*e.g.*, à la Cournot) in which patentees may offer very favorable licensing terms to licensees, so as to prevent a patent of dubious validity from being invalidated.

[45] This is seen in Figure 1 by the fact that, along a relatively less elastic (i.e., less steep demand curve) the ratio of deadweight loss (area C) to patentee profits (area A) increases.

[46] *See* A&K, *supra* note 13 (stating that, "it is preferable to tax inelastically rather than elastically-demanded goods).

A. *Competition in Markets for Patented Inventions: Alternatives to the Cournot Oligopoly*

Just as the Cournot model of PPs describes the case of collusion between a patentee and infringer, other formal models of competition can be applied to described the outcome of PPs when rivals engage in price-matching, entry deterrence and product differentiation strategies. Though these behaviourial assumptions can be considerably more difficult to model than Cournot competition, they have the advantage of incorporating more plausible behaviours between and infringers under a regime that permits interim infringement. The following sections present economic models of Bertrand, kinked demand, limit pricing (entry deterrence) and monopolistic competition. More importantly they also show why under a regime of PPs, patentee profits would not be maintained at their monopoly levels.

1. *Bertrand Competition*

In contrast to the case of Cournot competition, where rivals are assumed to maintain prices fixed so as to maximize joint profits, Bertrand competition assumes that rivals attempt to maximize profits by increasing market share through price competition. With each rival selling a homogenous product, customers quickly switch to the least cost seller.[47] Each rival must therefore closely monitor and quickly readjust price so as to prevent loss of market share to lower-priced competitors. The reciprocal actions of competitors to maintain the lowest price eventually erodes profits to the competitive (zero economic profits) level. The case of Pfizer's sales of tetracycline (a patented drug), cited by A&K, illustrates this result. Describing the rapid decline in the price of tetracycline occurring as a result of the entry by competitors who doubted the patent could be enforced, A&K report that:

> From 1956 through the mid-1960's, the Pfizer Company and its four licensees sold the antibiotic tetracyline to druggists at a wholesale price of $30.60 per bottle of 100 capsules. Total sales at wholesale drug stores exceed $1 billion during this period. Production costs ranged between $1.60 and $3.80 per bottle and when doubts about the validity of Pfizer's patent began to mount, several unlicensed firms began producing and selling tetracycline at approximately $2.50 per bottle wholesale.[48]

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[47]The Bertrand *equilibrium* is defined with the assumption that each rival hold conjectures that the other will not change the price it is quoting (*see* KREPS, *supra* note 40, at 330). Based on these conjectures, one is able to define the equilibrium sharing of demand as a function of the prices set by each rival: the least cost rival serves the entire market because all other rivals maintain prices fixed. However, since price is easily and quickly adjusted, we need to consider how this hypothetical equilibrium would change after several periods in which rivals holding similar conjectures respond to their loss in market share. A reasonable assumption is that they subsequently reduce their own prices in an attempt to regain market share. Thus, while the Bertrand conjecture refers to the belief that a rival maintains prices fixed, the *equilibrium* behaviour observed over several periods is a gradual erosion of price to the level of marginal cost, with any sharing of the total market demand between patentee and infringers being possible. For the sake of brevity, I allude to this multiperiod erosion of price as "Bertrand competition" and reiterate that the Bertrand conjecture is essential to this process.

[48]*See* A&K, *supra* note 13, at 1018 (citing F.M. SCHERER, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE 450 (1980).

Uncertainty about the validity of the Pfizer patent is analogous to reducing the probability of enforcement (w) in A&K's model. It is thus perhaps ironic that A&K contend that on one hand that "uncertain ex post enforcement will give rise only to limited amounts of infringement that need not substantially reduce the expected profitability of the patent"[49] while at the same time providing empirical evidence to the contrary.

The Pfizer example shows that the price of the patented invention, need not, as in the Cournot model, be determined through an equlibration of supply and demand. The price of tetracycline dropped to $2.50 not because both Pfizer and the unlicensed firms collusively agreed to increase production, but rather because the unlicensed firm was willing to risk oversupplying the market in order to maximize its market share.

While it is clear that customers would benefit from Bertrand competition, because they would be paying less for the patented invention, such outcomes are not necessarily efficient since erosion of supra-competitive prices also eliminates incentives for investment in research and development (R&D). Even where profit margins are not entirely eroded, total patentee profits would in the least, be highly volatile since market shares are extremely sensitive to small variations in price, since each seller sells a homogeneous product. Prospective inventors would reason, as the case of tetracycline illustrates, that returns to R&D would be highly uncertain, seeing that infringers, having made no investments in R&D, would have a cost advantage under Bertrand price competition.

The enabling disclosure of a patent[50] which is intended to permit the public to replicate the invention without undue experimentation, moreover suggests why Bertrand price competition may occur under a regime of interim infringement: with little or no experimentation, such competitors could enter and exit without having to recover the fixed costs patentees have invested. In essence, entrants have less to lose by engaging in a price war. Even so, the decision to enter the market ultimately rests on beliefs about how entrants expect competitors will react to reductions in price. As discussed in the next section, patentees and infringers foreseeing a price war may refrain from instantaneously readjusting price levels so as to avoid the erosion of profits.

2. *Kinked Demand*

The threat of Bertrand competition may explain why patentees and infringers absorb differences in costs or maintain supply or prices unchanged in response to variations in demand. According to the theory of kinked demand,[51] each oligopolist believes that its rival will match reductions in the current price, but not increases. The analytical model embracing these assumptions

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[49] *Id.*, at 1021.

[50] In order to be valid, a patent must disclose the means of practicing (e.g., making, selling, using) the invention in sufficient detail that a person of ordinary skill in the art is able to obtain the claimed result without undue experimentation. 35 U.S.C. § 112. *See also supra* note 8.

[51] *See* Paul M. Sweezy, *Demand Under Conditions of Oligopoly,* 47 J. POL. ECON. 568 (1939), one of the founding papers of the theory of kinked demand. *See* also F.M. SCHERER, *supra* note 48, at 145; George J. Stigler, *The Kinky Oligopoly Demand Curve and Rigid Prices,* 55 J. POL. ECON. 432 (1947) (criticizing this theory of price rigidity and an empirical analysis of oligopoly pricing behavior in several industries).

portrays each rival as facing a kinked demand curve consisting of a steeper lower and a flatter upper segment, as illustrated in Figure 2A. The lower segment indicates the quantity sold when rivals maintain price fixed, as in the case of Cournot competition. The upper, more elastic segment of the demand curve represents the case where rivals are assumed to match reductions in price, but not increases. The kink in the demand curve of Figure 2A occurs at the maximum price *P,* the price at which the seller (patentee) believes rivals will match reductions but not increases, in order to maintain market share. For prices above *P*, the patentee's demand curve is relatively more elastic than the case in which it faces no price-matching rivals, because it expects to lose market share to rivals who maintain prices at *P*, following a price increase.

Insert Fig. 2 about here

For prices below the kink, the demand will be similar in elasticity to the demand curve facing all other rivals, since the patentee does not expect to make inroads in to the lower-priced rival's market share. The relative elasticity of the demand curve at any point thus depends on the responsiveness of rivals to reductions in price – the more responsive are the rivals (*i.e.*, the more they cut price in order to maintain market share) the more elastic[52] will be the demand above the kink. Under these circumstances, the patentee may be forced to maintain price at the level *P* in order to maintain market share, in spite of differences in costs or variations in demand.

In order to understand the range over which the patentee maintains price at *P*, consider the marginal revenue curve illustrated in Figure 2A. Although it is defined for prices both above and below the kink price, it has a discontinuity[53]at the output level corresponding to the kink in the demand curve. This is shown as a vertical section (segment CE, in Figure 2A) between the upper and lower segments of the marginal revenue curve, whose length is proportional to the sharpness of the kink. Because the patentee and infringer maximize profits by supplying the market with a quantity where the marginal revenue is equated with the marginal cost, it is evident a number of cost structures may correspond to an intersection of the marginal cost curve and the vertical segment of marginal revenue curve. The length of the vertical discontinuity in the marginal revenue curve thus defines the range of variation in production cost for which price *P* and output level *X* is optimal.[54]

This range is illustrated in Figure 2A, where fixed costs of R&D appear as the vertical distance (CF) between the patentee's ($AC_{Patentee}$) and entrant's ($AC_{Entrant}$) average cost functions. At output level X, the entrant earns a higher profit since the profit on the last unit produced, shown in Figure 2A by the distance P-P_F, is larger than the margin for the patentee, which is given by the distance P-P_C. Thus, where R&D costs create significant differences between the average costs of the patentee and entrant, there are significant disparities in the amount of profits earned by each

[52]It is important to note that along a linear demand curve, the elasticity increases with price. In discussing how elasticity changes as a result of the pricing strategies of rivals or the availability of substitutes, we are therefore referring to the *relative* elasticity of demand.

[53]The discontinuity is due to the fact that the derivative of the demand function with respect to quantity is undefined at the kink.

[54]As shown in Figure 2A it will be optimal for each rival to supply quantity *X*, because it at this level of output that which marginal revenue is just offset by marginal costs.

rival.[55] The relationship holds even when the patentee and infringer have different marginal costs, so long as both cost curves intersect the marginal revenue curve along the vertical discontinuity CE.

The differences in cost also indicates another competitive advantage: the least cost producer (*i.e.*, the infringer) is able to continue profitably supplying the market at lower prices when the introduction of newer, improved substitutes drives down price of the patented invention. As shown in Figure 2A, below price P_C, but above P_F the entrant could still profitably supply the market, while the patentee fails to recover fixed costs of R&D for any price below P_C.

While these differences in profits do not account for expected damages that would reduce infringer profits, they nevertheless illustrate how very plausible assumptions of differences in costs can lead to a quite different distribution of market shares than what is implied by the Cournot model of competition. In particular, larger R&D costs create a larger cost advantage for the competitive fringe. Moreover, because, this scenario of competition can be easily anticipated by inventors, it reduces incentives for investment in R&D. Such considerations remain absent from A&K's analysis, since both the patentee and infringer are assumed to have symmetric (zero) cost functions.[56]

In addition to differences in costs, variations in the demand for a new invention lead to differences in the level of profits earned by patentees and infringers. As shown in Figure 2B, following an increase in demand from an initial level of D_1 to D_2, the patentee maintains price at P, since the marginal cost curve intersects the marginal revenue curve (MR_2) along its vertical discontinuity. Price is maintained at the level P in spite of higher costs of production, because increasing price would cause the patentee to lose market share to other rivals who maintain price at this level. The quantity supplied thus increases from its initial level of Y to Z, with the patentee earning a lower profit on each additional unit supplied.

The resulting "sticky" prices illustrated in the model of kinked demand imply that net patentee profits would be lower and subject to more variation than what is suggested by the A&K's model of Cournot competition. Stated alternatively, the threat of losing market share forces the patentee to compete with producers who escape the costs of R&D and meet variations in demand by making additional investments in production capacity. A patentee operating in such an environment has somewhat less market power than in the case of Cournot competition, but somewhat more market power than in the case of Bertrand price competition. The deadweight loss from this arrangement is therefore expected to lie somewhere in between the extremes of perfect competition and monopoly.

In order to understand how differences in demand elasticity (resulting form kinked demand or other factors) alone can change the quantitative significance of the reduction in deadweight loss resulting from competitive entry, it is helpful to compare the effect of a a 10% reduction in price on patentee profits when patentees are monopolists to the case they face competition from cheaper non-infringing substitutes – that is at lower prices where the demand curve is relatively more elastic. Using the inverse demand function of in A&K's model, $p = 100 - q$, and assuming the patentee sets price at the full monopoly price of $p=50$ (*i.e.,* along the elastic portion of the demand curve), reducing the probability of enforcement to 95% reduces the market price by approximately 10% and patentee profits by less than one percent. The loss in patentee profits is, of course, relatively small

[55] A&K's mathematical model abstracts from any such differences, because of course, it assumes that there are no costs of production, and more importantly, that the patentee and entrant face identical costs of production.

[56] *See* A&K, *supra* note 13, at 995 (stating that marginal costs are assumed to be equal to zero).

compared to the 20% reduction in deadweight loss. Along this stationary point most of what the patentee loses in profits due to a lower price is offset by increased sales at lower prices.

At lower prices, however, where the demand is less elastic,[57] the same magnitude of reduction in price effects more than a five-fold loss in patentee profit compared to the case where the patentee is presumed to set price at the full monopoly level. Using the example presented in Table 1 of A&K's paper, if non-infringing substitutes were to prevent the patentee from setting price above p=30, a 10% reduction in price brought about by increased uncertainty in patent enforcement would reduce profits from an initial level of 84% to roughly 79% of the monopoly profits.[58] This five-percentage point reduction in profits, moreover, assumes that the patentee continues to operate at lower prices along the same demand curve.

However, as we have argued above, if rivals adopt a policy of matching reductions in price, the reduction in profit would be yet still more pronounced, since the patentee's demand curve at lower prices is even more inelastic below the kink. Thus, if a non-infringing substitute prevented the patentee from setting price above p=30 (the highest price the patentee expects to charge without losing customers), interim infringement under these circumstances would result in an even larger reduction in profit which prevents the patentee from remaining along a stationary point of the profit function.[59] This would not be efficient, because the reduced profits would reduce incentives for investment in R&D.

Finally, while the theory of kinked demand explains why patentees and entrants would maintain prices unchanged in spite of demand or supply shocks, deliberately reducing prices can be a means of deterring entry by competitors, thereby increasing profits in subsequent periods.

3. *Limit Pricing (Entry Deterrence)*

Given that the sale of a patented invention is not a single period occurrence, but one that continues until the invention becomes obsolete, deliberately maintaining prices at unprofitably low levels may be one means of forestalling competition by infringers. This strategy, known as "dynamic limit pricing"[60] increases total patentee profits if the losses incurred in earlier periods are outweighed by the gains made in later periods in which the patentee is a monopolist.

The benefits of predatory pricing can be understood by considering how economic models

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[57] Reductions in demand elasticity can be seen by the slope of the demand curve, where a less steep curve corresponds to a more elastic curve. However, along a linear demand curve, demand elasticity also diminishes with reductions in price, since $\eta = \frac{P_X}{X}\frac{dX}{dP_X}$.

[58] A&K *supra note* 13 at 998, Table 1.

[59] Another factor that may prevent the patentee from setting price at the full monopoly level is pre-emptive innovation. If an improved, non-infringing substitute becomes available, the patentee will not be able to maintain prices at a level corresponding to a stationary point. Instead, she will likely have to set price at a level that is competitive in order to maintain market share – a price below the kink. At such prices, further reductions in price prevent patentee from remaining along a stationary point of the profit function.

[60] *See* Joe Bain, *A Note on Pricing in Monopoly and Oligopoly*, 39 AM. ECON. REV. 448 (1949) (arguing that monopolists may initially not charge the full monopoly price in so as to deter entry of competitors and exploit monopoly power in later periods).

of limit pricing define profits: the incumbent maximizes the present value of expected profits of each period, given the constraint that higher prices increase profits but also the likelihood of entry. Under a regime of PPs, the patentee's choice of the pre-entry or "limit" price, is thus the solution to an optimal control problem[61] in which the price in each period is chosen both as a function of its direct effect on increasing profits (higher unit prices increase total revenues) and its indirect effect in deterring entry (lower prices reduce later-period competition). While the patentee may be able to deter entry by initially selling at lower prices, it only pays to deter entry for a limited time, since later period profits must be discounted for the both the time value of money in and the reduction in demand in later periods due to obsolescence.

Because of their multi-period formulation, limit pricing models capture many of the problems patentees encounter in marketing new inventions such as stimulating growth in demand during the early years and managing the decay of product demand in later periods of its economic life. An often cited criticism of this view is that it assumes that lower prices create unambiguous signals for potential rivals. Lower prices can in fact be perceived by the infringer both as a threat to engage in a price war (à la Bertrand), or as evidence of an entry deterrence strategy. In the latter case, the potential entrant reasons that the patentee would only be willing to forgo some an initial level of profits so as to be able to recover a larger amount in later periods, as a result of having successfully thwarted the entry of other competitors. [62]

In order to assess the credibility of the patentee's deterrence efforts, the entrants may therefore look to secondary considerations such as the patentee's production capacity. Large and more well-established firms that are able to exploit economies of scale in key post-issuance activities such as production and distribution, send more credible signals of deterrence because they indicate that a firm is committed to remaining in the market in spite of increased competition. Similarly, large multi-product firms will also be perceived as being able to deter entry because temporary losses in one market may be offset by large profits on others.[63]

The costs of entry deterrence under a regime of PPs, may be regarded as costs of contending with uncertainty and delay in patent enforcement. This is one scenario where it is assumed infringers do not collude as Cournot duopolists, but instead compete directly with the patentee by reducing price or through other non-price strategies. The expected profits under PPs will thus be inversely proportional to the probability of entry but would also depend on the costs of deterring

[61] *See e.g.,* Morton L. Kamien and Nancy L. Schwartz, *Limit Pricing and Uncertain Entry*, 39 ECONOMETRICA 441(1971); Darius Gaskins *Jr. Dynamic Limit Pricing: Optimal Pricing Under the Threat of Entry*, 3 J. ECON. THEORY 306 (1971).

[62] *See e.g.*, Paul Milgrom and John Roberts, *Limit Pricing and Entry Deterrence Under Incomplete Information*. 50 ECONOMETRICA 443 (1982) (proposing that the entrant can determine whether the incumbent sets a low pre-entry price because he intends to maintain a low price in later periods or he does so merely to deter the entry, by determining the Bayesian equilibrium solution of a game theory formulation of this problem.). Using this equilibrium solution concept, separating and pooling equilibria for the incumbent's choice of price are defined. In the pooling equilibrium, the incumbent's strategy is to not reveal whether the pre-entry price will be maintained in later periods by setting price independently of costs. In the separating equilibrium, the entrant sets price according to his cost of production, in order to signal his intention of maintaining low prices in subsequent periods.

[63] Economists refer to short run reductions in price made with the intention of driving competing firms out of the market as "predatory pricing." *See* Paul Joskow and Alvin Klevorick, *A Framework for Analyzing Predatory Pricing*. 89 YALE L. J. 213 (1979).

entry during the early periods. While it is clear that deterrence strategies would reduce deadweight loss (as a result of lower prices) one cannot categorically state whether the total deadweight loss under such an arrangement would be greater or less than the Cournot outcome, without imposing additional assumptions about the extent of reduction in price that is required to keep a potential rival from entering the market.

4. *Monopolistic Competition*

In light of the difficulties of maintaining profits through price strategies discussed above, patentees and entrants may resort to non-price strategies in order to reduce the degree of competition among rivals. Differentiating products for example, allows each rival to maintain some degree of market power by serving smaller niche markets. Because the prices and outputs under this type of competition lie somewhere between the extremes of perfect competition and monopoly, economists refer to firms practicing such strategies as being monopolistically competitive.[64] Even though monopolistic competition can reduce deadweight loss by enabling sellers to price discriminate,[65] it also creates efficiency losses in the form of added costs of differentiation.

Monopolistic competition between patentees and infringers would enable each seller to cater to subgroups of buyers within the market for the patented invention, thereby allowing each seller to face a smaller number of competitors. If the differentiated product is more valuable to the buyer because it fulfills specific needs, each buyer would be willing to pay a price in excess of the undifferentiated product under perfect competition. The higher price obtained for such goods need not, however, result in proportionately higher larger profits. This is so because with a larger number of differentiated producer, each producer bears higher average costs of production since it produces smaller batches. Such efficiency losses may, moreover, be exacerbated if rivals engage in overly wasteful methods of differentiation (*e.g.,* excessive advertising) in the hope of increasing market share.[66]

With a reduced demand, the patentee supplies a reduced quantity of a differentiated version of the patented invention at a higher price P_{MC}, seen in Figure 3 as the tangency between the average cost (AC) curve and the demand curve D_2. Thus, even though the long-run monopolistically competitive equilibrium price (P_{MC}) is higher than the perfectly competitive price (P_C), the patentee who serves his own smaller niche market earns no profits.

Insert Fig. 3 about here.

The price, output and profit levels of the monopolistically competitive patentee are also

[64]*See* EDWARD CHAMBERLIN, THE THEORY OF MONOPOLISTIC COMPETITION (1956); Steven Salop, *Monopolistic Competition with Outside Goods*, 10 BELL J. ECON. 141 (1979).

[65]Recall that perfect price discrimination eliminates deadweight loss because each buyer pays exactly what he is willing to pay, and no buyers are excluded from the market.

[66]Breakfast cereals are an often-cited example of this phenomenon. The sheer variety of brands, sizes and products that are insignificantly different often confuses consumers (creates added search costs) without any considerable benefits. Here it could be argued that the cost savings from having fewer products (inventory management, reduced advertising) could outweigh the profits earned through brand management.

illustrated in Figure 3. Prior to entry by infringers, the patentee earns profits in the amount of area ABCD along a demand curve D_1, since the monopolist entrant maximizes profit by selling quantity Q_M of the undifferentiated product at price P_M. Although entrants could hypothetically earn the same level of profits, from these profits must be subtracted the expected damages that they would pay to the patentee under a regime of PPs. The remaining expected profits are therefore what induce entry of new, monopolistically competitive (*i.e.*, suppliers of differentiated goods) entrants. However, as the number of entrants increases, the market share for each is reduced causing each to supply a smaller quantity (Q_{MC}) to the market. This is shown in Figure 3 as a leftward shift of the patentee's demand from D_1 to D_2.

The relative efficiency of product differentiation strategies therefore will depend both on the reduction in deadweight loss and the efficiency losses due to smaller scale production. Where differentiation creates in a more valuable invention for buyers, deadweight loss can be reduced as a result of rivals in each market being able to charge a higher price without leaving some customers in the market unserved. In the limit, deadweight loss may be completely eliminated if each seller develops differentiated products that allows the market to be entirely served by different sellers – a case of perfect price discrimination.

Where buyers view the differentiated products as substitutes, the demand for each good will be more sensitive to variations in price, resulting in a higher proportion of deadweight loss for a given increase in price.[67] In this case, differentiation is wasteful since suppliers will incur higher costs of production (because they do not produce at the minimum efficient scale) while failing to deliver added value to consumers. Interim infringement under a regime of PPs could thus reduce efficiency of the patent system if buyers do not value to the differences the products resulting from product differentiation strategies.

5. *Summary of Alternatives to Cournot Competition*

The behavior of rivals and equilibrium outcomes under each of the models of competition reviewed above are summarized in Table 1. As in the case of Cournot competition, the equilibrium price and output levels relating to these alternative models of competition lie somewhere between the extremes perfect competition and monopoly. Ranking the relative efficiency of these equilibria is, however, beyond the scope of this analysis, since it would require incorporating additional assumptions about the time-varying nature of demand, the costs of entry and the behavior of rivals. Moreover, even when such assumptions are properly accounted for, one must also consider that changes in the probability of enforcement can reduce deadweight loss and incentives for investment by different amounts under each model of competition. In presenting these alternative models, my intention is merely to illustrate that the Cournot equilibrium employed in A&K's analysis is but one of possible outcomes of under a regime that permits competition between patentees and infringers. Cournot competition moreover incorporates some of the least plausible assumptions about how rivals in the market for a patented invention are likely to behave.

Notwithstanding these criticisms, it is important to recognize that the competitive equilibria discussed above are not directly comparable to the Cournot equilibrium assumed by A&K, because they do not account for the damages that reduce the expected profits of infringers. While greater

[67] This is easily seen as a demand curve that is relatively more elastic (*i.e.,* relatively flatter) than the one drawn in Figure 3.

liability for infringement can be presumed to reduce the likelihood of infringement, it is important to recognize that the liability for infringement may not always correspond to the infringer's actual market supply.[68] In particular, current jurisprudence suggests that infringers would only be liable for that portion of the demand that would have been served by the patentee in the absence competition.[69] Thus, under Bertrand competition for example, entrants may very well reason that it is profitable to enter and infringe because underselling the patentee allows one to capture the entire market while being liable for infringement for only part of the total market – and with some probability less than one. In the case of entry deterrence (limit pricing), reduced liability for infringement increases the expected profits of entry. Incumbents can therefore be expected to be willing to make greater concessions in price, compared to the case where they are liable for infringement in the amount of their total supply to the market. It is also important to recognize that, while I have discussed each model of competition individually, nothing prevents competitors from adopting a variant behavior that incorporates the essential features of two or more of these stylized models of competition.

Finally, in addition to the assumption of Cournot competition, it must be remembered that A&K's analysis rests upon the assumption that the patentee always sets price at a level that corresponds to a stationary point on the profit function. A number of independent factors, such as the availability of substitutes from infringing rivals who don't behave as Cournot oligopolists and the obsolscence of the patented invention may prevent the patentee from setting price at the full monopoly level. Under these circumstances, the improvement in efficiency from increased competition will be largely overstated because the patentee profits are assumed to remain unchanged. Even so, as I argue in the next subsection, models incorporating assumptions of Cournot behaviour need not be categorically rejected, as under some circumstances, there can be incentives for patentee and entrant to coordinate their behaviour.

[68]The important point to appreciate here is that if the patentee is a monopolist, she supplies a reduced quantity to the market (compared to the case of perfect competition) because the demand curve is downwards sloping. However, if the entrant supplies the market at a lower price, one could argue that the patentee is not entitled to damages on this expanded market share, but only that portion which would correspond to what she would have sold as a monopolist.

[69]*See* Rite-Hite Corp. v. Kelley Corp., 56 F.3d 1538, 1545-1547 (Fed. Cir. 1995). But more recently, Judge Frank Easterbrook has suggested that if infringement caused by several competitors erodes price to a level below what it would have been had the patent not been infringed, the liability of each infringer shall be based on the monopoly price and computed using its share of total industry sales. *In re* Mahurkar Double Lumen Hemodialysis Catheter Patent Litig., 831 F. Supp. 1354, 1392 (N.D. Ill 1993).

Table 1
Likely Outcomes of Infringement: Alternatives to Cournot Competition

Model of Competitive Behavior	**Characteristic Behavior of Rivals**	**Characteristic Equilibrium Outcome**
Bertrand	Rivals attempt to steal market share by underselling.	Price eroded to marginal cost; market share depends on capacity constraints.
Kinked Demand	Reductions in price are matched by rivals but not increases.	Stability in prices in spite of differences in costs, variations in demand.
Limit Pricing (Entry Deterrence)	Profits over several periods maximized by setting price low in early periods so as to deter entry.	Deterrence cost reduces total profits derived from innovation. Low prices can create ambiguous signals for infringers.
Monopolistic Competition	Differentiate products so as to maintain market power in smaller markets.	Efficiency loss due higher production costs incurred in the production of a larger number of specialized products.

B. *Plausible Scenarios for Cournot Competition*

Lemley & Shapiro maintain that in some cases invalid patents remain unchallenged because patentees and potential infringers have interests in colluding in order to maintain a patent that provides supra-normal levels of profits.[70] However, a necessary condition for this result is that the entry of competitors be some how regulated in a manner that prevents profits from being competitively eroded through Bertrand or other forms of competition. A&K make a similar assumption regarding the behaviour of incumbents in that they assume that patentees and infringers behave as Cournot oligopolists. Why is Cournot behaviour plausible under some situations and not others? Two basic entry barriers support coordinated behaviour (of which Cournot competition is an example) in a market where there is a patent of dubious validity.

First, high litigation costs can induce patentees to opportunistically assert invalid patents against potential entrants, because they prevent a competitor from challenging a patent unless the payoffs from doing so are high enough. Second, because a patent is presumed valid, if it is not challenged by potential entrants (who have a vested interest in maintaining it) it, it may be interpreted by other entrants as being difficult or impossible to invalidate, biasing their subjective assessment of whether they should challenge the patent.

[70]L&S *supra* note 5 at 93 (noting that patentees occasionally conclude licensing agreements with rivals who are "*allegedly*" infringing, and that "such settlements involve payments in excess of litigation costs, by incumbent patent holders to potential entrants").

1. *High Litigation Costs*

The USA, unlike many other Commonwealth countries, employs a "pay-your-own-way" system which provides few opportunities for even winning parties to a patent dispute to be reimbursed for legal costs. Although some states have enacted loser-pay rules, fee shifting is generally the exception rather than the rule. The provision for fee-shifting provided under 35 U.S.C. § 285 for invalid or unenforceable patents is intended to apply to "exceptional"[71] cases which, legal scholars have argued, rarely creates an effective disincentive to opportunistic and strategic patenting -- seeking numerous patents for the sake of thwarting competitor innovation. Under existing rules for example, there is no provision for fee-shifting for patent claims that are invalidated on the basis of prior art that could have been discovered by the patentee through a more diligent search. [72] A challenger therefore bears the costs of an improvidently issued patent, and what is more, once the patent is invalidated, other competitors may enter costlessly and compete with the challenger who must recover litigation costs. In this manner, if the probability that the patent is valid and the cost of litigation are high enough, they can outweigh the expected benefits of challenging an invalid patent.

In order for it to be worthwhile for a competitor to challenge the patent, the benefits (*i.e..,* the savings in license fees) must outweigh the expected costs of a patent challenge. Assuming the competitor is risk neutral and behaves as through she maximizes expected benefits, a competitor challenges a dubious patent when her expected profits (net of litigation costs whether she wins or loses) exceed the losses in profits from allowing the patent to remain unchallenged.
In symbols, we can express this as:

$$-L < \delta(L - CT_w) + (1-\delta)(CT_l) \qquad (1)$$

Where L is the benefit to the challenger (i.e., accused infringer) of invalidating the patent. The left hand term -*L* , corresponds to a reduction in profits when a license fee L must be paid for a dubious patent;

δ is the probability that the infringer will win his case, where $0<\delta<1$;
CT_W is the court cost to the infringer if she wins the case;
CT_L is the court cost to the infringer if she loses the case.

Rearranging equation (1) gives:

[71] *See*, Knorr-Bremse Systeme Fuer Nutfahrzeuge GmgH v. Dana Corp. 372 F Supp 2d 833 (2005 Ed. Va) , where it is stated that, Congress, in choosing to limit district court authority to award attorney's fees to "exceptional" cases, has made clear that this should occur only in rare or extraordinary cases, and courts elucidating this statutory language have generally found that "exceptional" cases are those of rare and extraordinary cases that are blighted and marked by party's bad faith or inequitable conduct. The purpose of 35 USC §285 is to give court power to throw burden of unnecessary and vexatious litigation on shoulders of those responsible for it : Colgate-Palmolive Co. v. Carter Products, Inc. 230 F2d 855, cert. den 352 US 843, reh. den. 352 US 913 (1956).

[72] *See*, Jay P. Kesan, *supra* note 20, at 787 (noting that the requirements in section 285 of establishing an exceptional case remains a formidable barrier that has been difficult to establish).

$$L < \frac{\delta}{1+\delta} CT_W - \frac{(1-\delta)}{1+\delta} CT_L \qquad (2)$$

Equation (2) demonstrates that the higher the court costs (to win an invalidation suit), the larger will be the minimum license fee that triggers a patent challenge.[73] Also, the higher is the probability of winning a court challenge, the more the more important will be the costs of winning the suit relative to the license fee in determining whether to initiate a patent challenge. Fee shifting, by reducing the likelihood that a patent is improvidently issued, therefore limits the opportunities for patentees and a licensee to behave as Cournot duopolists, while high litigation costs (as a result of the absence of fee shifting) supports Cournot behaviour.

2. *High Presumption of Validity*

While fee shifting increases the likelihood that invalid patents will be challenged, some patents remain unchallenged regardless of litigation costs. The problem, in the eyes of the challenger is not that the prior art has not been diligently examined, but that the challenger believes that it has been, and as a result, that there are no substantial opportunities for the patent to be invalidated. The longer a valuable patent goes unchallenged, the less likely a non-expert will initiate an attempt to invalidate a patent, because she presumes others must have found it to be impossible to do so. Social losses in the form of reduced competition and wasteful design around efforts therefore occur when invalid patents remain unchallenged and new competitors that are dissuaded from entering the market.

Admitedly, not all competitors erroneously presume that unchallenged patents are valid. Challenging valuable patents in itself, can be a viable business strategy if there is potential to recover high litigation costs. Numerous patent challenges, for profitable drugs such as Zyprexa, Lipitor, and Plavix whose annual combined sales exceed $13 billion have been successfully initiated in recent years by competitors or generics manufacturers.[74] An important limitation of the presumption of validity argument is, therefore, that it assumes that the competitors are relatively ignorant with respect to the underlying technology of the patented invention and that their beliefs about the difficulty of invalidating a patent are reinforced the longer the patent goes unchallenged. These may only be reasonable assumptions in cases where information about competitor R&D is not well disseminated in the public domain through scientific journals and patents disclosures themselves. As this is in effect more infrequent, it leaves us to ask whether competitors deliberately refrain from invalidating a patent with the intention of other competitors reciprocating.

Finally, at the core of such arguments for coordinated efforts among competitors is the assumption that parties are able to maintain binding commitments over time. With few competitors, such commitments may be possible, as the benefits of such small numbers bargaining need not be

[73] Although a patent challenge is understood in this example as presenting a defence of invalidity, charges to a patent infringement suit may be equally defended on the basis that the accused activities lie outside the scope of the claims. An important difference, however, is that in the latter case, the patent remains in place, and may continue to be regarded as an entry barrier as long as it is regarded as valid by other competitors.

[74] *See* Matthew Harper, *Drug Patent Peril* (Jan. 26, 2005), (reporting patent challenges for top selling drugs Lipitor, Zyprexa and Plavix) <http://www.forbes.com/technology/2005/01/26/cx_mh_0126patents.html>, accessed 14 March 2006.

distributed to a large number of competitors. With many, however, since each competitor's share of the benefits of coordinated behavior diminishes, there are greater incentives for defection from collusive agreements that may be viable under small numbers bargaining.

IV. MEASUREMENT OF PATENT POLICY EFFICIENCY

As argued in the previous sections, patentee profits ultimately depend on market conditions such as the nature of competition and the availability of substitutes. However, as A&K argue, to the extent that obsolescence and the nature of competition do not significantly reduce patentee profits, probabilistic patents (when combined with extended patent term) are intended to increase the efficiency of the patent system by creating a more competitive market structure that reduces deadweight loss. The logical extension of this line of thinking is that efficiency-improving patent policies should strive to increase competition in the market for the patented invention, and that efficiency is correlated with the degree of competition in the market. What this view assumes is that market (*i.e.,* allocative) efficiency is synonymous with patent policy efficiency – the more competitive a market is, the more efficient is patent policy that increases competition. Since the benefits of a new invention, whether measured in terms of patentee or consumer benefits are assumed to remain constant over time, A&K's prescriptions are solely concerned with market efficiency.

Minimizing deadweight loss is not, however, synonymous with improving the efficiency of the patent system if the invention is expected to become rapidly become obsolete, regardless of the market structure in which it is sold. In the sections that follow, I argue that a proper measure of patent policy efficiency accounts not only for the deadweight loss, but also the willingness of consumers to pay for such inventions. Considering both the time-varying value of the invention and deadweight loss allows us to appreciate why PPs and extended patent term are, in fact, relatively *inefficient* patent policies, for inventions that quickly become obsolete.

In Section A, I introduce a measure of efficiency that illustrates the relationship between both price and the elasticity of demand, so as to define the criteria for determining whether a one patent policy is likely to be more efficient over another. In Section B, I assess the efficiency of A&K's alternative regime of uncertain patent rights and current regimes of patent enforcement, under the assumption that the demand for a new invention follows well-established, time-varying changes in the demand for a new invention.

A. *Developing Efficiency Measures of Patent Enforcement*

Introducing a patented invention to the market creates two types of welfare effects which are relevant to efficiency analysis. First, as A&K contend, the patented invention is often sold at a price that exceeds its marginal cost of production, thereby creating deadweight loss. Second, because patented inventions replace existing inventions, they often provide new and additional benefits compared to existing substitutes. A new drug, for example, can reduce the need for costly surgery but may also improve the health of the patient beyond what would be possible through surgery alone. A proper measurement of welfare change must therefore account for not only the cost savings resulting from the substitution of the drug for surgery, but also the patient's improvement in quality of life and earning capacity. While the first, "substitution" effect may be measured simply by comparing the relative cost of surgery to drug therapy, the value of the second, "income" effect may remain unaccounted for if the improved health of the patient cannot be measured in terms of indices of market value, such as wages.

The combined substitution and income effects can, however, more easily be seen in the case of a process invention, as a reduction in average costs of production of the good to which the process invention is applied. This is because the process invention may not only replace other inputs (a substitution effect), but also increase the yield of the process (an income effect) so as to reduce unit costs of production. Accordingly, the total savings resulting from substitution and income effects may be viewed as an upperbound on the license fee (*i.e.*, patentee profit) for a patented invention since a licensee never pays a license fee in excess of the amount by which the process invention reduces cost of production. Stated alternatively, the highest feasible price for a patented invention must leave the purchaser (a licensee, in the case of a process invention) no worse off than the case where existing substitutes are used.[75]

Given that the licence fee represents the value of the benefit the invention provides, and that deadweight loss is the efficiency loss due to monopoly pricing, a measure of patent policy efficiency is the ratio of deadweight loss to patentee profits (license fees). Efficient policies will have a low ratio, while inefficient policies will be characterized by a high ratio. A high ratio also indicates that a given price increase will contribute relatively little to increasing patentee profits in relation to the resulting deadweight loss.

Insert Fig. 4 about here.

This measurement of efficiency is analogous to A&K's ratio of deadweight loss to patentee profits except that in this case, deadweight loss is measured along the demand curve for a product made using the patented process invention[76], instead of along the demand curve for the invention itself, in order to capture both substitution and income effects. As shown in Figure 4, for example, prior to introducing the patented invention, costs of production for the good in question are C_0. At this long-run equilibrium price, producers using the patented invention earn zero profits since along

demand curve D_1, the competitive price P_M equals C_0. Implementing the new cost-saving patented process invention, however, reduces production cost to C_1, resulting in profits in the amount of the cost savings. A patentee exercising full monopoly power appropriates all producer profits by charging a license fee (L) corresponding to area C_0EAC_1, such that producer costs, output prices and quantities remain at their pre-invention equilibrium level.

Because applying the patented process invention reduces average production costs to C_1, yet the price of good remains above the marginal cost of production, enforcing a patent (*i.e.* charging

[75] In important qualification of this principle is that patentees may indeed command a license fee that exceeds the reduction in production costs, if the value of the good to which the process invention is applied is superior to existing substitutes. In this case, and depending on the relative bargaining power of patentee and licensee, a patentee may even appropriate some of the surplus attributable to an improvement of the product over existing substitutes. The present analysis abstracts from this case, because it assumes that the process invention produces a product that is no better than existing products.

[76] As an example, we may think of a new type of tire made by using a patented process technology that reduces the cost of production, yet produces a product that is just as durable as conventionally made tires.

a license fee) creates a deadweight loss in the amount of area *EAN*. Thus, contrary to A&K's assumption that the price of an invention is determined by the patentee's cost function,[77] the maximum license fee that can be charged is determined by the pre-invention equilibrium price, C_0. While these constraints are later acknowledged by A&K in terms of "independent forces that restrain patent holders from setting monopoly prices,"[78] the quantitative model they use to illustrate the relative rate of change in deadweight loss to patentee profits, assumes that the patentee charges the full monopoly price.

Given that area *EAN* represents the periodic deadweight loss, the direct social cost of patent enforcement corresponds to resent value of deadweight loss incurred for each year of patent enforcement. Upon expiry of the patent, the price of the good that uses the process invention drops to the competitive level, C_1, eliminating both deadweight loss and patentee profits. This is because all producers adopt the cost-saving patented process without having to pay license fees, as illustrated in Figure 4 as a new demand curve D_2. Net social welfare benefits due to patent enforcement can be thus computed as the present value of the increase in consumer surplus from the 21st year until the invention is obsolete, minus the costs of deadweight loss and R&D.

As A&K emphasize, the question patent policy aims to resolve is rather, whether the deadweight loss resulting from patent enforcement is small in comparison to the resulting patentee profits.[79] A geometric representation of efficiency is given by the relative size of deadweight loss to patentee profits shown respectively, in Figure 4, as areas EAN and C_0EAC_1, which may also be expressed algebraically, in terms of price and quantity. The deadweight loss (D), given by area *EAN*, is equal to $\frac{1}{2}\Delta P\Delta Q$. Similarly, area C_0EAC_1 corresponding to patentee license fees (profits) may be expressed as $L=\Delta P(Q_{C1}-\Delta Q)$, which is also the loss in consumer surplus resulting from patent enforcement. Finally, defining the change in quantity as $\Delta Q=Q_{C1}-Q_M$, the efficiency measure D/L is given as:

$$\frac{D}{L}=\frac{\Delta Q}{2(Q_c-\Delta Q)} \tag{3}$$

As Richard Posner[80] has shown, it is moreover possible to express this ratio in terms of the percentage increase in price that occurs as a result of monopolization. Letting, $p=\Delta P/P$, the percentage increase in price, and given that the elasticity of demand is expressed by $\eta=(\delta Q/\delta P)*(P/Q)$, the ratio of deadweight loss to license fees may be expressed as:

$$\frac{D}{L}=\frac{p}{2\left[\frac{1}{\eta}-p\right]} \tag{4}$$

[77] The assumption is that the patentee selects an output level (and thus a price as determined by the inverse demand function $p = 100 - q$) at which marginal costs are just offset by marginal revenues.

[78] *See* A&K, *supra* note 13, at 1013.

[79] *See id.,* at 988 (stating that, "Patent policy has to resolve two issues: (1) how much of a reward should be granted to induce sufficient innovation; and (2) how this desired reward [can] be produced for the innovator with least social inefficiency. This paper takes on the second question.").

[80] *See* Richard Posner, *The Social Costs of Monopoly and Regulation*, 83 J. POL. ECON. 807, 812 (1975).

With the ratio of deadweight loss to license fees expressed as a function of demand elasticity (η) and increase in price due to patent enforcement *p*, one may understand how market power (price increases) and changes in demand elasticity affect patent policy efficiency. Differentiating equation (4) with respect to the elasticity of demand, η gives:

$$\frac{\partial(D/L)}{\partial\eta} = \frac{2p}{(2-2p\eta)^2} \tag{5}$$

While differentiating with respect to the price increase, *p* gives:

$$\frac{\partial(D/L)}{\partial p} = \frac{2\eta}{(2-2p\eta)^2} \tag{6}$$

Equations (5) and (6) indicate that both increases in demand elasticity and price affect the efficiency at which rewards are created for patentees. Equation (5) indicates that the more elastic is the demand, the larger will be the deadweight loss for a given increase in price over marginal cost. Similarly, the ratio of deadweight loss to patentee profits also increases as patentees collect higher license fees.[81] These relationships also imply that exercising full monopoly power when the demand for a new invention is least elastic is most efficient,[82] since a large price increase along a relatively inelastic demand curve produces the least amount of deadweight loss per dollar of patentee profits.[83] This prescription is, moreover, consonant with Louis Kaplow's ratio criterion[84] alluded to by A&K, which calls for patentee entitlement to be expanded so long as they cause profits to increase at a greater rate than deadweight loss.[85]

Finally, since the efficiency of the patent enforcement is contingent upon the elasticity of demand, it becomes important to reassess the relative efficiency of PPs under the assumption that demand elasticity changes over time.

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[81]To see this in the geometric representation of deadweight loss in Figure 4, consider that increasing price extends the height of the deadweight loss triangle EAN.

[82]By inspection one notes that, $\frac{\partial^2(D/L)}{\partial p\,\partial\eta} \geq 0$ thus increases in price (*p*) will have the least effect on increasing the ratio of deadweight loss to patentee profits when the demand elasticity is low.

[83]The geometric representation of this relationship also seen in Figure 4 as the ratio of area deadweight loss (area EAN) increasing in relation to patentee profits (area C_0EAC_1) as the slope of the demand curve decreases.

[84]*See* Louis Kaplow, *The Patent-Antitrust Intersection*: *A Reappraisal,* 97 HARV. L. REV. 1813, 1831 (1984).

[85]Kaplow asserts that for a given practice, the higher the ratio of *incremental* change of patentee reward to monopoly loss (deadweight loss), the more socially desirable it is. *See id*. at 1831 (stating that the, "higher the ratio, the more desirable the practice."). Our analysis of the ratio of deadweight loss to loss in consumer surplus is consonant with the Kaplow criterion because it asserts that a *lower* ratio of deadweight loss to patentee profits (D/L) (*i.e.,* the *inverse* of the Kaplow ratio) will result in a more efficient patent system.

B. *Dynamic Analysis of PPs: Applying the Product Life Cycle Hypothesis*

1. *The Product Life Cycle*

It is well known that the demand for patented inventions changes over the life of patent enforcement as a result of the development of improved versions of the patented invention or new substitutes. In coining the phrase "creative destruction,"[86] economist Joseph Schumpeter asserted that the parallel development of improvements and non-infringing substitutes by competitors eventually renders the existing inventions obsolete. Similarly, in advancing the Product Life Cycle Hypothesis[87] economists maintain that rate of sales over the life of the invention follows an S-shaped curve, comprising entry, growth, maturity and decline stages. As shown in Figure 5, during the later stages of its life cycle, a product's demand becomes more elastic. Thus, where the economic life of an invention is less than the statutory life of the patent, patentees face a limited window of opportunity to recover R&D costs and earn profits. Patentees maximize profits by adjusting price in each period, so as to minimize the losses in market share due to obsolescence.

During the entry stage for example, when the invention is not well-known to buyers, a seller may deliberately set prices below the profit-maximizing level in order to induce buyers to switch to the patented invention. As the invention becomes accepted among buyers and enters the growth phase however, sales volume increases rapidly, while demand remains relatively inelastic. Large increases in price create relatively small amounts of deadweight loss in relation to patentee profits because buyers are more willing to pay a premium for a new product that confers net benefits over existing products.

Insert Fig. 5 about here.

In the case of a process invention, the highest price a patentee can charge for an invention will be a license fee that maintains the price of the product at its pre-invention equilibrium level (shown in Figure 4 as C_0).[88] This is so because in the case of a process invention that produces an identical product at lower cost, there will be no advantage to paying a license fee that requires the licensee to set price for the new product using the invention, above existing substitutes. However, as so long as the invention is not adopted by the majority of producers (particularly those not paying

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[86] *See* JOSEPH A. SCHUMPETER, CAPITALISM. SOCIALISM AND DEMOCRACY 83 (3RD ed. 1950)

[87] *See* James Utterback and William J. Abernathy, *A Dynamic Model of Process and Product Innovation*, 3 OMEGA 639 (1975). *See* also Jay Forrester, *Advertising: A Problem in Industrial Dynamics,* in MARKETING MANAGEMENT AND ADMINISTRATIVE ACTION (S.H. Britts and H.W. Boyd Jr, Eds, 1968) (describing the product life cycle as being composed of four separate phases); Klaus Brockhoff, *A Test for the Product Life Cycle*, 35 ECONOMETRICA 472 (1967) (developing methods of empirical estimation to determine whether the characteristic shape of the product life cycle curve is empirically substantiated).

[88] *See* Frederick M. Scherer, *Nordhaus' Theory of Optimal Patent Life: A Geometric Reinterpretation*, 62 AM. ECON. REV. 422, 423 (1972) (noting that, "[e]ven though a patent confers some monopoly power, it does not permit the patent holder to charge a price above the cost...associated with the (now inferior) competitive process. Because of this, and if demand is not very elastic in the neighborhood of the competitive price, the optimal post-invention price and quantity will be identical to the preinvention equilibrium.")

license fees), so as to reduce equilibrium price of the good to which the process is applied to, purchasing a license for the process invention, even at its maximum price, will confer a net benefit to the licensee if it results in a net cost of production savings. Because of this, the patentee will be able to increase the license fee (*i.e.*, the price of the invention) without losing significant market share. Demand is, therefore, relatively inelastic during the growth phase because using the patented invention confers net profits to the licensee. In Figure 4, such profits appear as the reduction in cost beyond the pre-invention equilibrium level of $C_{0.}$

The growth phase also represents the stage of the product life cycle during which sales of the invention increases by the largest amount. If the demand for the patented product exceeds available supplies, the invention will be rationed to buyers willing to pay the highest price, resulting in a relatively inelastic demand curve. Thus, both the condition that the invention provides net benefits to its users and the increasing demand, are conducive to creating and maintaining a relatively inelastic demand for the invention. In practice, however, because a process invention has near zero marginal costs, the price it commands will be largely dependent upon the benefits it provides (*i.e.*, cost reduction) over existing substitutes.

What are the implications of these time-varying changes for efficiency of patent policy? Reducing the price of the invention during the period when the demand is least elastic would be least efficient because lower license fees reduce the amount of profits that can be earned during this period in which the ratio of deadweight loss to patentee profits is relatively low. Under a regime of increased uncertainty over patent rights, profits foregone during the early years of patent enforcement (when demand is relatively inelastic) would therefore have be recovered during the remaining maturity and decline phases in which demand is relatively more elastic. However, if competitors have also successfully designed around the invention or created non-infringing substitutes, it will only compound the patentee's difficulty in raising profits in a market where the invention is on the verge of obsolescence. For example, as the price of the downstream product using the patented invention drops to C_1, the invention offers relatively no advantage (economic profit) to the licensee, and will hence command only a relatively small license fee. When the price of the downstream invention drops to C_1, it will be impossible for the patentee to increase the price of her cost-reducing invention, because the price for the downstream product that uses the invention affords no means of sustaining a license fee. Under these circumstances, the demand for the patented invention becomes relatively more elastic because the invention is worthless in terms of its ability to reduce production costs more than other available substitutes.

Such implications are not overlooked by A&K. In a footnote, they acknowledge that "if the demand becomes more elastic, then raising most of the revenues in the first few years may be efficient."[89] The mathematical model they use to illustrate the efficiency gains from PPs, however, assumes that the demand elasticity remains constant over time. In order to account for the impact of increasing demand elasticity, they assume only that the reduced *quantities* of the patented invention are sold in later periods, but that the demand elasticity remains unchanged.

While both assumptions capture the time-varying patterns of declining-demand, only the assumption of increased demand elasticity is relevant to efficiency. One cannot therefore dispute the conclusions of A&K's analysis, but rather take issue with whether it adequately captures the dynamics of the demand for patented inventions. In particular, because new inventions may become obsolete well before the statutory expiry of the patent, it will not be efficient to combine limited

[89] *See* A&K, *supra* note 13, at n. 12.

infringement with extended patent duration. Allowing the patentee to charge the full monopoly price during the early years of patent enforcement can be socially efficient because patentee profits are earned from buyers who are most willing to pay for the invention. Moreover, as discussed in the next subsection, time-varying changes in demand elasticity call into question the correctness and relevance of the Ramsey intuition in explaining the efficiency of the patent system.

2. *Why a PP Regime of Interim Infringement Violates the Ramsey Intuition*

In asserting the efficiency improvement resulting from limited infringement, A&K argue that patent enforcement is analogous to applying a tax, in that higher prices for the patented invention increase the social costs of deadweight loss.[90] Drawing upon on two central tenets of the Ramsey intuition which assert that it will be efficient to (1)" tax as many goods as possible"; and (2) "tax goods with inelastic demands more severely than goods with elastic demand,"[91] A&K maintain that interim infringement and extended patent duration will be efficient because, "it is better to spread the patentee's market power over multiple years."[92]

With demand becoming more elastic over time as a result of the development of substitutes, reducing the patentee's market power and extending patent duration violates the second principle of the Ramsey intuition. Allowing the patentee to charge the highest price during the period in which the demand is least elastic is efficient because it minimizes the total *ratio* of deadweight loss to patentee profits over the life of patent enforcement.[93] Interim infringement, however, works just against the second principle of the Ramsey intuition, in that it reduces the patentee's ability to raise price during the period (*e.g.*, growth phase) in which a price increase would create the largest increase in patentee profits and the smallest deadweight loss.

Undoubtedly, as A&K contend, "consumers would be better off living under oligopolistic pricing for a longer period rather than monopoly pricing for a shorter period."[94] However, this statement confounds the objective of increasing consumer surplus with that of increasing the efficiency of the patent system. Lower prices would clearly benefit consumers, but as A&K state, the core issue PPs address is how the desired reward for the inventor can be produced with "the least social inefficiency."[95] Where demand elasticity increases over time, it will be most efficient for patentees to earn most profits during the earliest periods of the patent term, when the ratio of deadweight loss to patentee profits is lowest.

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[90] *See* A&K , *supra* note 13, at 991.

[91] *See id.* at 991.

[92] *See id.* at 992.

[93] The ratio of deadweight loss to patentee profits can be reduced by reducing deadweight loss or by increasing patentee profits. If it is profits that are increased, it is important to note that higher profits are socially desirable to the extent that they make larger investments in R&D possible. Such larger investments in R&D, can support the creation of new, more valuable inventions that enhance social welfare through technical change. *See infra* Section V.B.

[94] *See* A&K, *supra* note 13, at 991.

[95] *See id*. at 988.

In this regard, A&K's analogy of "inter-temporal 'Ramsey pricing'"[96] also remains a specious application of the first principle of the Ramsey intuition. Although taxing a large number of substitute products is efficient because it prevents buyers from averting the tax (by switching to the untaxed substitute), the analogy does not extend to patented inventions consumed at different points in time. To see why, consider that a new invention launched in 2006, will hardly be as desirable twenty years later in 2026, or even a few years later, for that matter. Thus, in later years, there are relatively more, not less, "untaxed" substitutes that are available to buyers, than would be the case during earlier periods. Extending patent term therefore violates the first principle of the Ramsey intuition, because it makes it more difficult for the patentee to raise profits without creating deadweight loss, when there are more available substitutes.

A&K's normative claim that broadening the territorial force of an uncertain patent claim would be efficient[97] is another illustration of their contention that generating profits through smaller price increases in a large number of markets is more desirable than earning all profits in a single (monopolistic) market. What this view overlooks, again, is that the nature of deadweight loss depends not solely on the price increase, but the elasticity of demand. If the demand for the patented inventions is more elastic in less affluent markets, deadweight loss may not be minimized, but instead may be increased relative to the case where no patent exists in such markets.

A proper application of the Ramsey intuition to the problem of patented inventions argues instead in favor of *increasing* the price of all *substitutes* (*i.e.*, apply a "broad tax") for the invention at the time it is introduced, so as to prevent buyers from averting increases in price during periods of patent enforcement. While this would undoubtedly reduce consumer surplus, it would allow patentees to increase profits, in a directly opposite manner as would PPs: it would reduce patent life and increase market power (by increasing the relative price of substitute goods (and even perhaps channeling some of the excess profits to the patentee) so as to reduce the deadweight loss per dollar of patentee profits. For a number of reasons[98] this is not likely to be a tenable policy. It does, however, illustrate that, if anything, the Ramsey intuition suggests that idealized patent enforcement can *more* efficient because it allows the patentee to price discriminate over time, that is, tax goods which are most inelastic at the highest rate, so as to reduce the deadweight loss per dollar of patentee profits.

To summarize, the efficiency of a given patent policy must be assessed in light of the anticipated changes in demand for the invention. Given that the demand for a new invention becomes more elastic over time, allowing the patentee to charge the highest price when the demand is least elastic, and gradually reduce price thereafter, can be a relatively efficient means of creating rewards for patentees. In this regard, increasing competition in the market for patented inventions is not the most efficient patent policy. The adverse consequences of PP's are, moreover, exacerbated if an increased risk of invalidation disrupts investment in R&D, as a result of reduced

[96] *See id*. at 991.

[97] *See* A&K, *supra note* 13 at 1028 (stating that, "...it would be more efficient to produce an equal reward with a smaller tax on N +1 countries. Thus the United States might usefully spend greater effort to better enforce intellectual property rights in the rest of the world rather than expending effort to increase the chance that valid patents will be enforced with certainty at home.").

[98] Lawmakers, may not know, for example, the relevant set of substitutes to which a "patent tax" should be applied.

expectations for licensing revenues. In the next Part, I examine how such uncertainty affects incentives for innovation.

V. THE EFFECT OF UNCERTAINTY IN PATENT PROTECTION ON THE PROCESS OF INNOVATION

If we accept that a number of factors outlined in the previous sections, namely increasing elasticity of demand and non-cournot competition, can prevent probabilistic patents from maintaining total expected patentee profits unchanged, even when patent term is extended, it becomes essential to consider how reduced patentee profits affect the supply of new inventions. Concerns about the deadweight loss patent monopolies create may, moreover, be unwarranted, if one considers that monopoly-creating patent polices can induce the creation of more valuable inventions that confer social benefits in excess of the costs of deadweight loss.

The difficulty in understanding whether such monopoly-creating policies are desirable resides in the fact that not all types of R&D are affected equally by uncertain patent rights. Inventions resulting from certain types of R&D may only provide small benefits such that any reduction in expected profits resulting from uncertain patent rights renders the project infeasible. Other types of R&D create inventions that are so valuable, they outweigh the value of the deadweight loss. In Section A, using the concept of an "invention production function" I show why reductions in the expected licensing revenues are more likely to adversely affect low technology fields of inventions than high technology fields of R&D (which produce more radical and valuable inventions). Further exploring this relationship, Section B shows how the characteristics of the invention production function determine the circumstances underwhich deadweight loss resulting from patentee market power is outweighed by the value of benefits attributable to new, improved inventions.

A. *The Effect of Probabilistic Patents on Investment in R&D*

Reducing the level of expected profits from patent enforcement under a regime of probabilistic patents undeniably reduces the incentives for investment in R&D. But not all types of projects are equally affected by lower expected profits. Because an R&D project must create an invention that generates enough profits to offset project costs, the feasibility of highly profitable (*i.e.*, valuable) inventions will be less adversely affected by a more competitive market structure than projects that result in marginally profitable inventions.

The economic model of investment in R&D assumes that investors operate according to two basic two rules: (1) that inventors (prospective patentees) continue to invest in R&D resources up to the point where the marginal benefits (*i.e.* marginal profits) from additional investments are just offset by the marginal costs of R&D inputs; and (2) an investment in an R&D project will be undertaken only if R&D outlays can be recovered.

The first condition, referred to by economists as the "stimulus"[99] effect, determines how much will be invested in R&D. The the second, referred to as the "Lebensraum"[100] effect, relates to a

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[99] *See* Scherer, *supra* note 88, at 426.

[100] *Id.*

positive profits criterion. Together, these criteria determine whether a project will be undertaken, and if so, the amount of profits that will be earned. Patent enforcement that reduces the amount of expected profits is more likely to jeopardize R&D projects for marginally valuable inventions, because it is more likely that a reduction in profits prevents the positive profits condition from being satisfied.

A geometric interpretation of these optimality conditions, first formalized by William Nordhaus, is presented in Figure 6.[101] For the case of a process invention that reduces costs of production, the reward the patentee earns per unit of cost reduction is determined by the quasi- rent function Q(B,T).[102] In Figure 6 (panels A and B), two different functions Q(B,T') and Q(B,T) represent different patent enforcement regimes, where the lower quasi-rent function represents a *higher* level of patentee profits, since Q appears on the x-axis, indicating that a larger profit is received for a process invention that provides a larger reduction in production costs.

Insert Fig. 6 about here.

The patentee's ability to create such cost reductions is given by the invention possibility function (IPF), which defines the relationship between R&D inputs (x-axis, in Figure 6) and resulting reductions in costs. This appears in Figure 6 as the non-linear function, B(R&D$^{\alpha}$). The first inflection in the IPF represents the relatively low initial returns to R&D efforts owing to a minimum amount of inputs that are needed to overcome initial learning and start-up efforts. The second inflection, however, represents the usual assumption of decreasing returns to scale of R&D inputs. The slope of the IPF between the two inflections thus indicates the productivity of R&D inputs in creating valuable inventions, where a steeper slope corresponds a higher productivity. IPFs of a steeper slope correspond to a larger elasticity of R&D (α), indicating that increasing R&D enables the creation of a more valuable invention which, in Figure 6, is shown as a larger increase in cost reduction (along the vertical axis), for a given increase in R&D inputs.

Since the elasticity of R&D indirectly measures the productivity of R&D inputs in reducing costs (creating benefits), highly elastic[103] IPFs will have sharper kink, resulting in a steeper IPF between its two points of inflection. We may regard relatively steep IPFs (large values of α) as representing high-technology fields of invention.[104] Thus, as shown in panel B of Figure 6, can often

[101] *See* WILLIAM NORDHAUS, INVENTION, GROWTH AND WELFARE (1969). Figure 6 has been adapted from Scherer, *supra* note 88.

[102] The term "quasi-rent" denotes interim profits that are sustained by the temporary market conditions afforded by patent enforcement. Economic rents are thus expected to be eroded through a competitive process in which non-infringing substitutes are priced at or below the price of the patented invention.

[103] Note that because the benefits of the invention, namely cost reduction appear on the y-axis, a relatively elastic IPF will appear relatively *steeper* than a less elastic IPF. Moreover, the more elastic is the IPF, the larger will be the value of α.

[104] By "high technology", I mean more radical forms of innovation which, in the example of a process invention, result in greater production cost savings for the licensee. Low technology inventions are those that provide marginal improvements over existing substitutes. I recognize that nothing prevents a large scale R&D project from resulting in a low technology invention. For the purposes of this analysis, however, I assume that large scale R&D projects are intended to produce more radical (high technology) inventions.

produce highly-valuable inventions.[105] Low-technology fields of invention in contrast, (shown in panel A of Figure 6) will have less steep IPFs, as a result of R&D efforts producing relatively less valuable inventions.

Consider what happens when expected value of a patent is reduced, as a result of increased uncertainty, or as a result of the patentee heavily discounting the value of a probabilistic patent right (*e.g.*, if he anticipates Bertrand, or other forms of competition). As shown in panel A of Figure 6, for a shift of the quasi-rent function from Q(B,T) to Q(B,T'), the optimal level of expenditure in low-technology fields of invention is reduced from an initial value of H, to a lower value of G. A change of the same magnitude in high-technology fields of invention (panel B), however, effects a much smaller change in R&D. This appears in Figure 6 as a reduction in R&D expenditures from the initial level of M to a final level of L.

Figure 6 also illustrates both the stimulus and Lebensraum investment decision rules described above. The optimal level of research expenditure is determined by the point of equal slope between the IPF and the quasi-rent function. Because of the greater sharpness of the kink in the IPF for high-technology inventions, a greater change in slope occurs along the IPF for high-technology than for low-technology fields of invention, implying that larger variations in profit will create smaller changes in investment levels in high-technology fields of invention.

The positive-profits (Lebensraum) condition is seen in terms of the relative position of the IPF and the quasi-rent function. For a given level of investment in R&D, the IPF, must lie strictly above the quasi-rent function. If low-technology fields of invention create less valuable inventions for a given level of R&D expenditure (shown in Figure 6A as less sharp kink in the IPF), the area above the quasi-rent function and below the IPF is likely to be inferior to the same area in the case of high-technology inventions.[106] Thus, for a given reduction in expected patentee profits, the R&D projects of low-technology inventions are more likely to be rendered infeasible than high-technology inventions, as a result of the smaller initial profit margin.

Although I characterize high-technology fields of invention as being more likely to endure variations in profit, it is more precisely the higher elasticity of R&D, (*i.e.*, the steeper the slope of the IPF), that brings about smaller changes in the optimal level of R&D. Consequently, if the shifts in the quasi-rent functions are re-interpreted as the range of variation in profits occurring under PPs as a result of the number of different competitive equilibria discussed in Part III, high-technology fields of invention would be less likely to be affected by introducing uncertainty in patent enforcement than low-technology R&D. This is simply because larger benefits provided by high-technology R&D are more likely to be able offset reduced profits due to increased competition of A&K's regime of PPs.

These productivity differences also raise the question of whether social welfare could be improved through the creation of more valuable inventions. The next section shows that this may be the case – even if society bears increased costs of deadweight loss.

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[105] Inventions of these kind are software or new drugs, which create large benefits by replacing the need for other more costly inputs like specialized labor.

[106] This is shown in Figure 6 the distance between the as arc of the IPF and the quasi-rent function which is nearly twice as large for the case of high-technology R&D than it is for the case of that the case of low-technology R&D.

B. *The "Schumpeterian Trade Off: Market Power vs. Welfare Gains from Innovation*

In order to understand when the benefits of more radical R&D outweigh the deadweight loss incurred by stable patent rights, it is useful to ask how the properties of the invention production function are related to a favorable tradeoff between deadweight loss and improved technical benefits – what economists refer to as the "Schumpetertian tradeoff."

In measuring both the changes in consumer surplus due to deadweight loss and technical change, economist Pankaj Tandon finds, not surprisingly, that where the elasticity of R&D is large, a more concentrated market structure which provides each firm with more market power increases social welfare more than one in which entry is open to a larger number of competitors.[107] With fewer firms (hence greater market power), each firm has greater incentives to invest in larger amounts of R&D and exploit scales efficiencies in R&D.[108] In Figure 6, this can be seen as as high-technology fields of invention providing larger benefits, (the second inflection of the IPF lies at a level strictly above that of the low-technology IPF) but requiring a larger amount of R&D expenditures (points L and M lie respectively, further to from the y-axis than points G and H). While Tandon's as well as increasing number of studies[109] investigating the so called "Schumpeterian tradeoff" are not directly comparable to A&K's model of interim infringement, the core insight of their finding remains relevant to conclusions about the desirability of uncertainty and delay in patent enforcement. Patent rights that provide a larger and more certain stream of profits enable large-scale R&D, which in turn provides welfare benefits in the form of improved products. Consumers, do not, however, necessarily reap all of benefits from such inventions during the early years of patent enforcement if, patent rights confer market power to the patentee.

Even so, such deadweight loss should not be understood as creating a net efficiency loss, since relative to the pre-invention equilibrium, consumers have lost nothing, but rather have gained in terms of an expanded choice set. Consumers who purchase the invention, do so because it provides them with a net benefit – even when purchased at the monopoly price. What the Schumpeterian tradeoff tells us in terms of probabilistic patents, is that market power is valuable to the patentee, and accordingly socially valuable, to the extent that it induces the creation of valuable inventions. Stable patent rights can therefore be efficient social policies, even though they might not always ensure an desirable distribution of benefits among producers and consumers.

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[107] *See* Pankaj Tandon, *Innovation Market Structure, and Welfare*, 74 AMER. ECON. REV. 394, 400 (1984) (stating that, "The greater the technological opportunities in an industry, the greater is the social payoff to the increased R&D incentives generated by concentration.").

[108] Tandon's theoretical analysis, moreover, shares some of the assumptions of A&K's model, in that in both cases, competitors are assumed to be Cournot oligopolists. A significant difference, however, is that the latter model does not assume that profits are maintained at the monopoly level through damage awards extended patent duration.

[109] *See* Partha Dasgupta and Joseph Stiglitz, *Industrial Structure and the Nature of Innovative Activity*, 90 ECON. J. 266 (1980). *See also* MORTON KAMIEN and NANCY SCHWARTZ, MARKET STRUCTURE AND INNOVATION (1982); Richard Nelson and Sidney Winter, *The Schumpterian Tradeoff Revisited*, 72 AMER. ECON. REV. 114 (1982).

VI. CONCLUSION

An important characteristic of a patent as a property right is that the exclusory privileges granted to the patentee may be rescinded after a patent has been issued. A patent may be invalidated or the effective scope of its claims reduced, as a result of courts reinterpreting the metes and bounds of a patent claim. An obvious concern for policy makers is that uncertainty reduces patentee incentives for innovation. However, as law and economics scholars have recently argued, such uncertainty in patent rights can also have perverse effects on economic (allocative) efficiency in markets for patented inventions.

As Lemley and Shapiro contend, uncertainty in patent rights, when combined with high litigation costs, can reduce economic efficiency by providing opportunities for patentee and a potential licensee to engage in collusive agreements that provide unusually favorable licensing terms for the licensee. Under such circumstances, patents of dubious validity remain unchallenged because some of the monopoly profits generated by such patents are redistributed to a licensee, in the form of reverse payments or extraordinarily low license fees.

In stark contrast to Lemley and Shaprio, Ayres and Klemperer contend that uncertainty in patent rights provides opportunity for increased competition in the market for the patented invention. A regime of probabilistic patents could therefore have the unforeseen virtue of driving down the price of the patented invention to levels where deadweight loss is reduced, albeit without significantly reducing patentee profits. From A&K's perspective, introducing uncertainty and delay in patent enforcement is efficiency enhancing because it provides for increased competition in the market for the invention, which in turn reduces deadweight loss.

Despite their counter-intuitive appeal, the prescriptions emanating from A&K's analysis are unlikely to improve the efficiency of the patent system. With uncertain patent rights, competitors may enter and supply the market in a number of different ways other than through the Cournot competition assumed by A&K. These include aggressive attempts to capture the entire market by market share by engaging in price wars. Moreover, notwithstanding the criterion of increased competition, policies that reduce deadweight loss do not necessarily increase efficiency of the patent system.

Given that the goal of the patent system is to create rewards for inventors, enabling the patentee to raise profits from consumers when they most willing to pay for the invention will be more efficient than a regime that facilitates interim infringement and requires to the patentee to recoup profits when the invention is likely to face obsolescence. In essence, A&K's analysis miscontrues the notion of efficiency by confusing strategies to minimize total deadweight loss with those that maximize patentee rewards per dollar of deadweight loss. This can be seen by the fact that they argue in favor of extending patent term, while at the same time acknowledging that allowing the patentee to raise profits during the period immediately following the grant, when the demand for the invention is least elastic, is most efficient.

Finally, in addition to deadweight loss, it is essential to consider how the prospect of larger profits may induce inventors to make larger investments in R&D, which can result in the creation of more valuable inventions. If the value of such inventions exceeds the deadweight loss, patent policies that create monopolies will be more desirable than those that strive to increase competition. However, not all types of R&D may be equally affected by uncertainty. Large-scale R&D (most often carried out by large, integrated firms) is least likely to be adversely affected by increasing uncertainty in patent rights. Increasing the uncertainty of patent rights is therefore likely to adversely harm small-scale R&D which produces less radical innovations, as a result of the lower expected license fees failing to provide the minimum return required to justify an investment in R&D.

Deconstructing the economics of probabilistic patents and R&D investment, suggests that the current efficiency analyses on probabilistic patents have provided a limited assessment of the likely impact of increased uncertainty in patent rights. As important as competition is, to economic welfare, assessments of patent policy should not be be confined to antitrust analysis. Instead, it begs a more encompassing approach which acknowledge that the supply and price of new inventions depends on how patentees actually contemplate opportunities for economic profit.

FIGURES

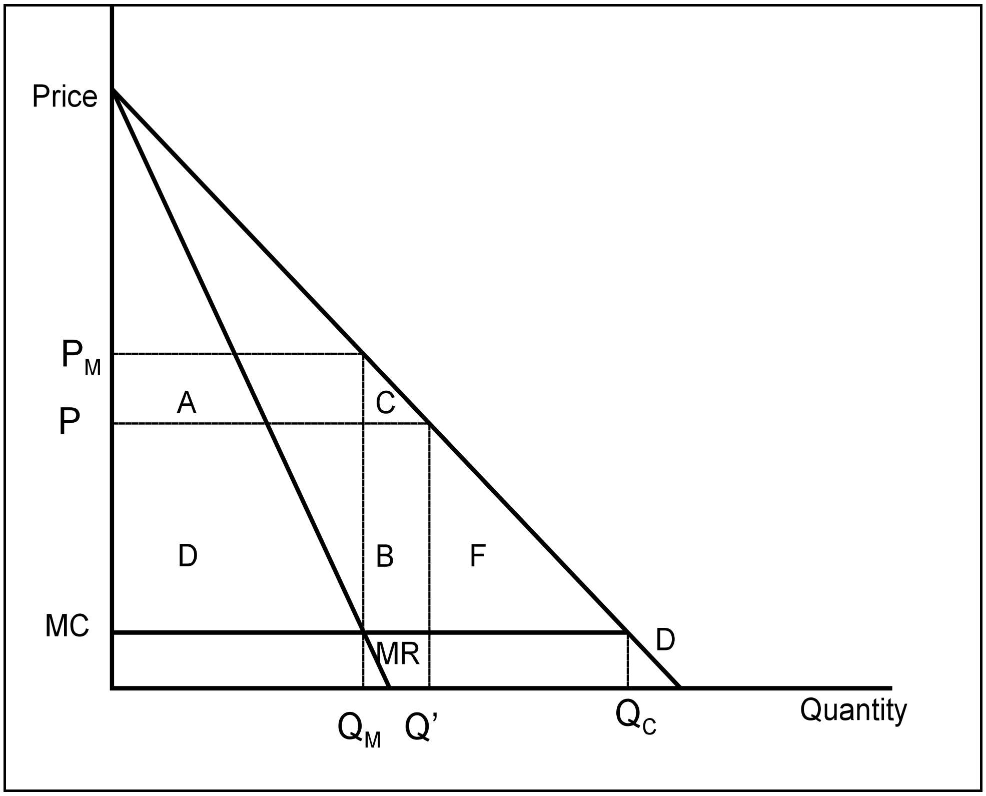

Figure 1. **Stationarity of patentee profits as illustrated along a demand curve**. Because P_M corresponds to a stationary point on the patentee's profit function, reducing price to *P* causes only a slight reduction in profits, since Areas (A+D) are approximately equal to Areas (D+B). What the patentee loses as a result of a lower price is approximately made up in increased sales volume, while deadweight loss due to monopoly pricing, (shown as area C) is eliminated at the lower price P.

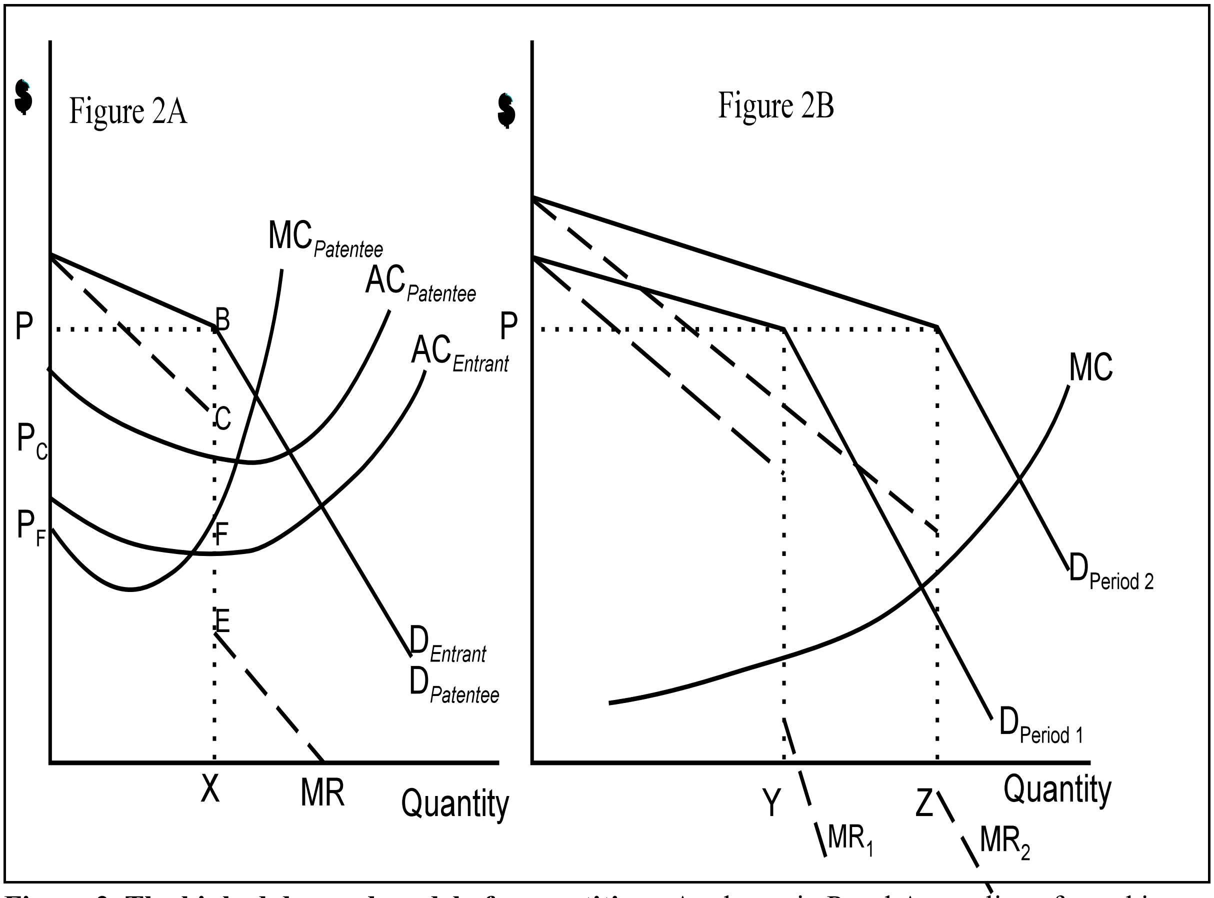

Figure 2. The kinked demand model of competition. As shown in Panel A, a policy of matching reductions in price but not increases favors entrants because they do not bear fixed costs of R&D. Panel B illustrates that following and increase in demand, rivals (patentee and entrant) continue to maintain price at the same level.

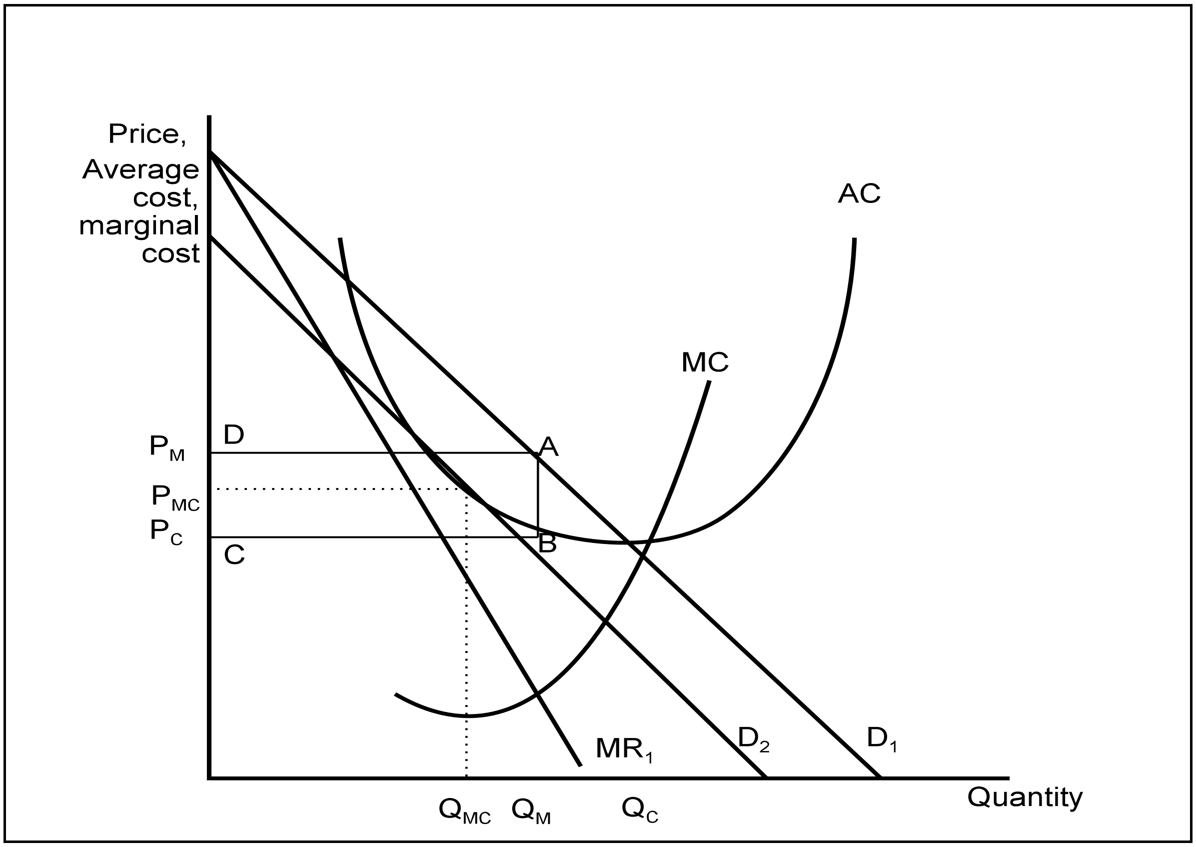

Figure 3. Long and short run competitive equilibria under monopolistic competition. Under monopolistic competition, each rival earns a profit in the amount of area ABCD in the short run, as a result of product differentiation that confers a limited degree of market power. As new rivals enter, however, each rival serves a smaller segment of the market (shown as a parallel inward shift of demand from D_1 to D_2). The resulting long-run equilibrium price P_{MC} is higher than the perfectly competitive price P_C, yet each rival earns zero profits.

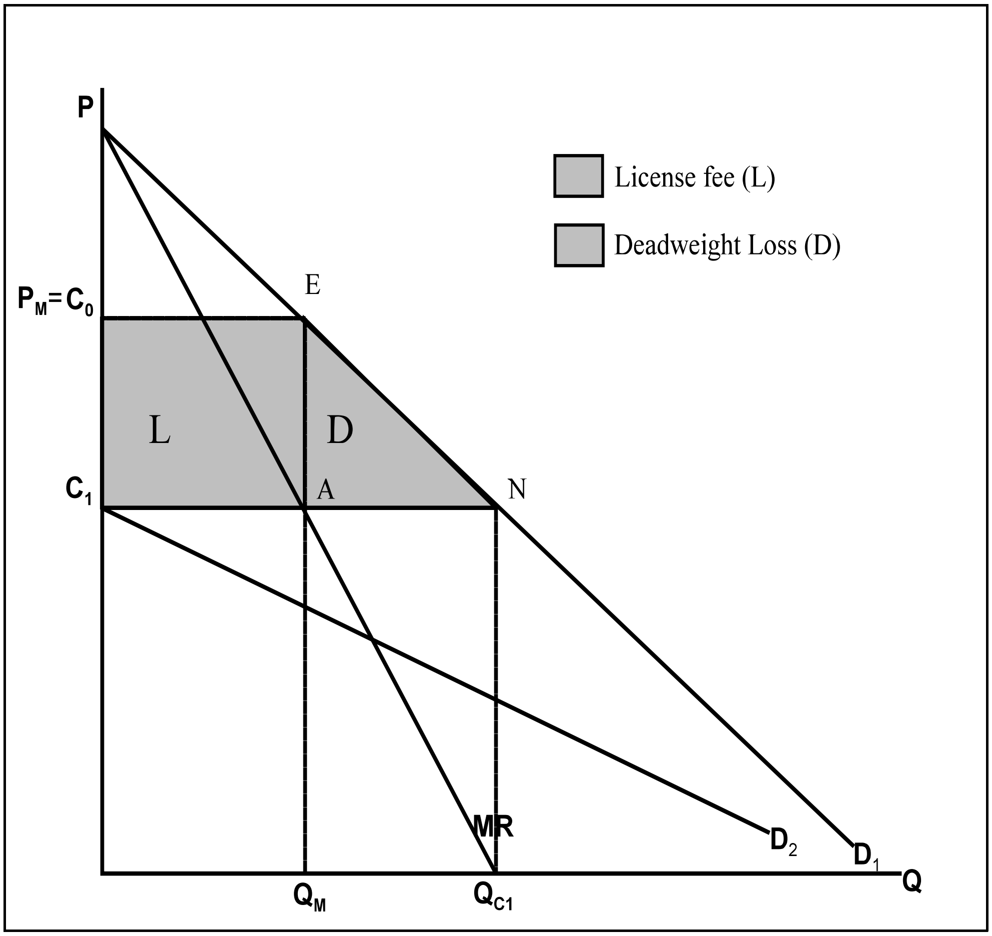

Figure 4 . Relative importance of deadweight loss to patentee profits resulting from patent enforcement. Following the introduction of a new invention that reduces cost from C_0 to C_1, the deadweight loss incurred by full monopoly pricing is shown as area EAN.

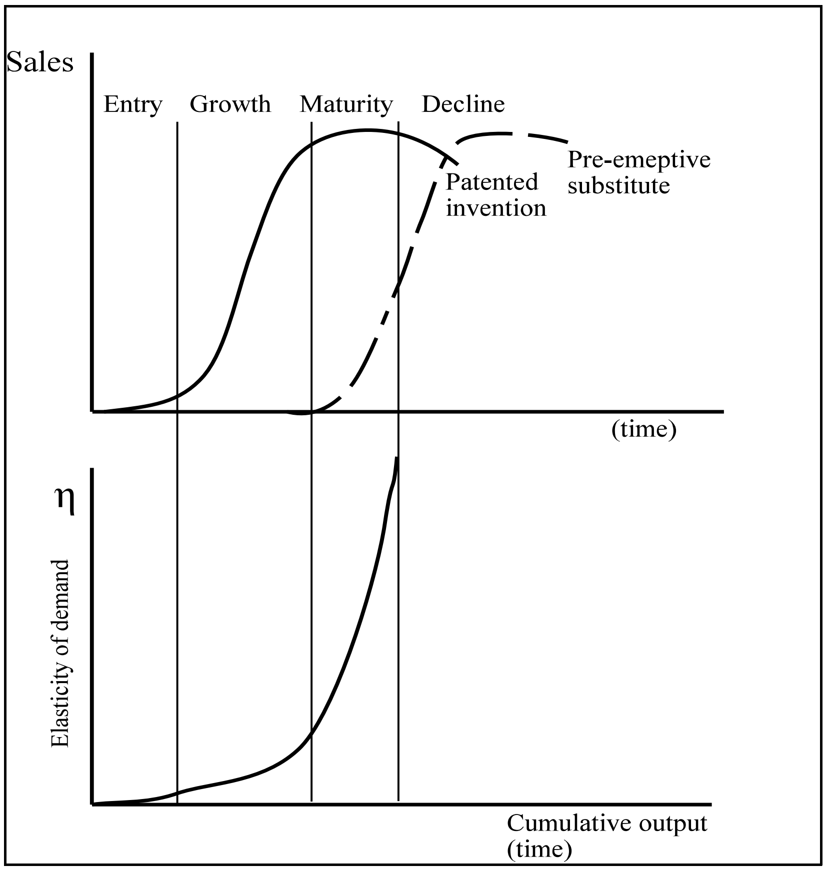

Figure 5. Time-varying changes in demand elasticity. Demand elasticity increases as the invention enters the maturity phase of the product life cycle and is eventually replaced by a newer invention (dashed line).

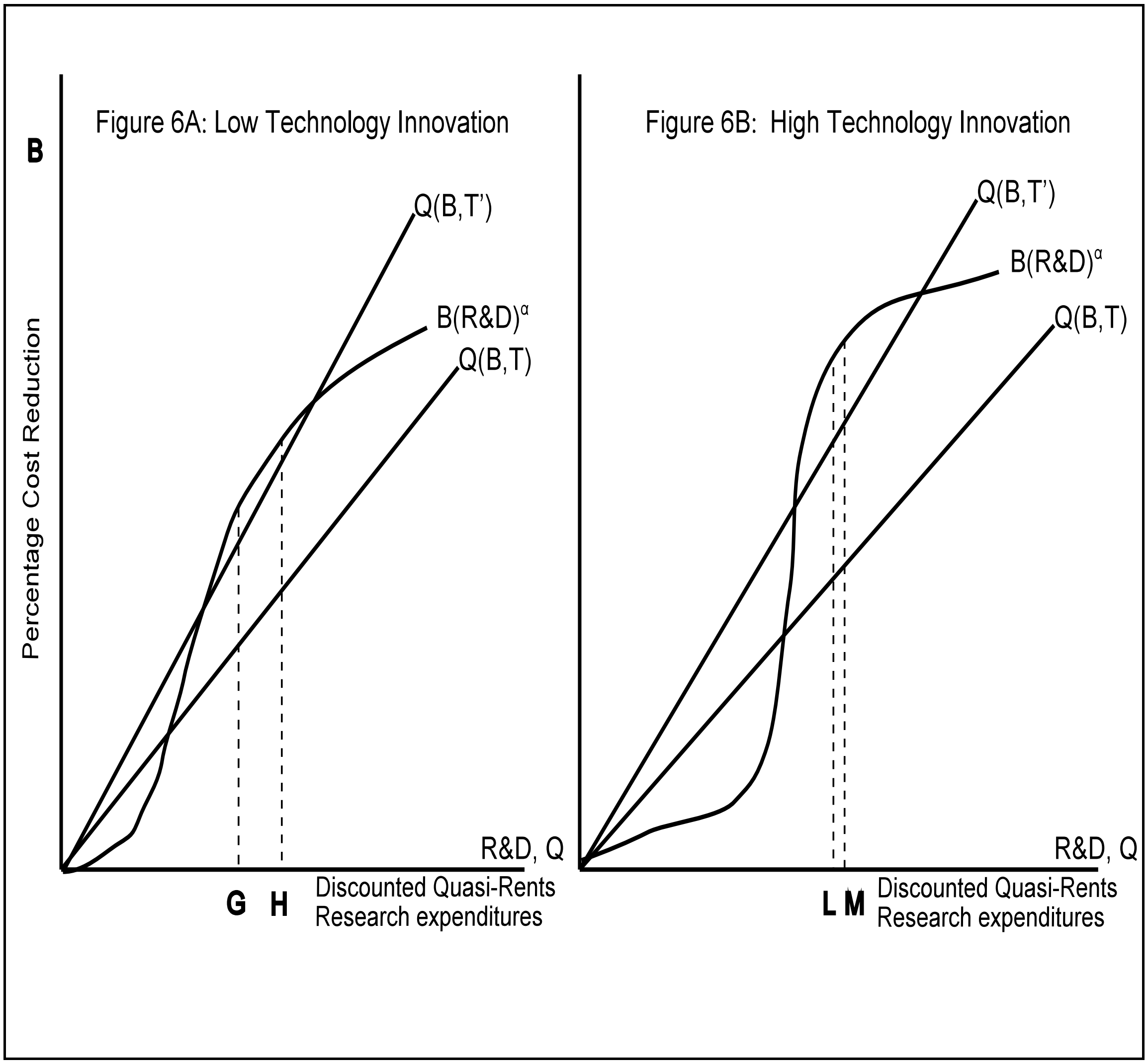

Figure 6. Optimal levels of investment in R&D in high and low technology fields of invention. Investment in high technology sectors (α large) is less sensitive to changes in patent policy than low technology.

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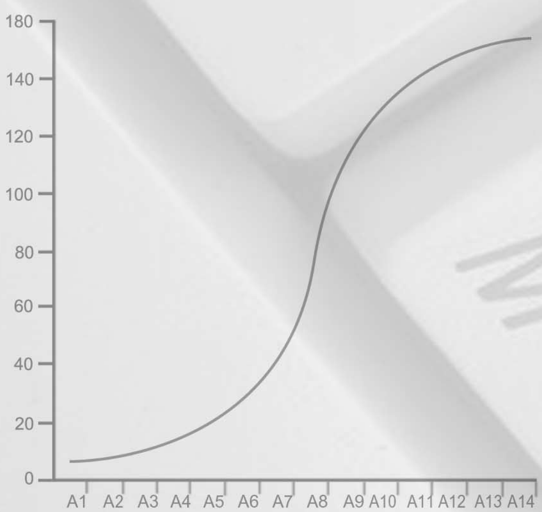

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