PATENT DAMAGES AND REAL OPTIONS: HOW JUDICIAL CHARACTERIZATION OF NONINFRINGING ALTERNATIVES REDUCES INCENTIVES TO INNOVATE

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The legal framework under which courts calculate patent damages changed substantially after the Federal Circuit decided *Grain Processing Corp. v. American Maize-Products Co.* in 1999. Perhaps the most important question in the typical lost profits analysis is determining the fraction of the infringing sales that constitutes lost sales to the patent holder. The answer usually depends on the set of noninfringing substitute products to which the customers of the infringing product could have turned in the but-for world, where the infringing product was not available to them. Before *Grain Processing*, the case law as a legal matter generally restricted the set of noninfringing substitute products to include only products that were actually sold in the marketplace. For example, an infringer could claim that it would have continued to sell a noninfringing product that it had actually been selling and that this product would have captured some of the infringing sales. This argument would tend to limit the patent holder's lost sales. However, the infringer could not claim that it would have developed and introduced some new noninfringing product in the but-for world and that this product would have captured some of the infringing sales. *Grain Processing* eased this restriction, allowing an infringer to claim that it would have offered a noninfringing product that, although not actually sold in the marketplace, was technically feasible at the time and could have been made commercially available relatively quickly. The *Grain Processing* decision went even further and concluded that, in the particular case at issue, the plaintiff was not entitled to lost profits because the infringer's noninfringing product would have been identical from the point of view of customers (though more costly to the infringer). Damages were therefore calculated on a reasonable royalty basis only. Although *Grain Processing* has generated much scholarly commentary, we are unaware of any article considering the factor that we see as the decision's most important economic ramification: the grant of a "free option" to the infringer. By "free option," we mean that a firm may keep its options open by using potentially infringing technology rather than technology that definitely does not infringe. Under *Grain Processing*, such a firm has the opportunity to later claim that it would have used the noninfringing technology had it known the patent was valid and infringed. Thus, by choosing the patented technology, the firm keeps its options open, although at the risk of having to pay damages once the uncertainty regarding validity and infringement is resolved. *Grain Processing* substantially decreases this risk because it diminishes the size of the damages award. If the patent is found to be valid and infringed, the firm can argue under *Grain Processing* that it would have switched to the noninfringing technology in the but-for world, effectively making the switch retroactively. *Grain Processing* thereby makes the option essentially free. By providing potential infringers with increased option value if they use the patented technology, *Grain Processing* reduces the deter-

rent effect of litigation and therefore encourages infringement. Consequently, it reduces the returns to research and development, and so also the incentives to innovate.

I. INTRODUCTION

Patent damage awards have become an increasingly important feature of business strategy in the United States over the past 20 years. Jury awards exceeding $100 million were relatively rare before 1990 but now are common.[1] These large awards usually arise when damages have been calculated using a lost profits approach. A patent holder can lose profits to an infringer in several ways. By far the most important source of lost profits is the sales that the patent holder lost to the infringer.[2] Absent the infringement (often termed the "but-for" world[3]), the patent holder would have made some or all of the sales that the infringer made. The damages associated with these lost sales are the incremental profits that the patent holder would have made on the sales.[4] A second important source of lost profits is what is often called "price erosion."[5] Here, the increased competition from the infringer can lead to decreased prices and thus decreased profits. These two sources of lost profits can both occur in a given situation and often interact with each other.[6] Other sources of lost profits damages include the patent holder's lost "convoyed sales" (sales of unpatented products sold in conjunction with the patented product) and lost "learning by doing" opportunities that would have led to lower marginal costs and

1. *See* Paul McDougall, *How to Avoid the Patent Trap*, INFORMATIONWEEK, Oct. 30, 2006, at 23 ("Before 1990, only one patent damage award larger than $100 million had been awarded; in the past five years there have been at least 10 judgments and settlements of that size and at least four that topped $500 million, the Coalition For Patent Fairness says.").

2. Lost profits are at issue in every patent infringement case. Other types of damages, as described below, constitute only some fraction of lost sales because of the infringement.

3. *See, e.g.*, Rite-Hite Corp. v. Kelley Co., 56 F.3d 1538, 1545 (Fed. Cir. 1995) (en banc) ("To recover lost profits damages, the patentee must show a reasonable probability that, 'but for' the infringement, it would have made the sales that were made by the infringer.").

4. *See id.*

5. *See, e.g.*, Vulcan Eng'g Co. v. FATA Aluminium, Inc., 278 F.3d 1366, 1377 (Fed. Cir. 2002) ("For price erosion damages the patentee must show that, but for the infringement, it would have been able to charge and receive a higher price . . . . It is not required that the patentee knew that the competing system infringed . . . ." (internal citations omitted)).

6. *See, e.g.*, Minn. Mining & Mfg. Co. v. Johnson & Johnson Orthopedics, Inc., 976 F.2d 1559, 1577-80 (Fed. Cir. 1992). In the but-for world absent price erosion, a decreased quantity would be sold at the higher price.

thus higher profits for the patent holder in the absence of the infringement.[7]

By statute, a patent holder whose patent has been infringed is entitled to at least a "reasonable royalty" as damages.[8] Thus, if the court does not award lost profits damages, it calculates damages using a reasonable royalty approach.[9] Damages calculated under a reasonable royalty approach are typically, but not always, less than the damages calculated under a lost profits approach.[10] Part II of this Article discusses the traditional methods of calculating patent damages.

The legal framework under which patent damages are calculated changed substantially after the U.S. Court of Appeals for the Federal Circuit decided *Grain Processing Corp. v. American Maize-Products Co.* in 1999.[11] Perhaps the most important question in the typical lost profits analysis is determining the fraction of the infringing sales that constitutes lost sales to the patent holder. The answer usually depends on the set of noninfringing substitute products to which the customers of the infringing product could have turned in the but-for world where the infringing product was unavailable to them. Before *Grain Processing*, the case law as a legal matter generally restricted the set of noninfringing substitute products to include only products that were actually sold in the marketplace. For example, an infringer could claim that it would have continued to sell a noninfringing product that it had actually been selling and that this product would have captured some of the infringing sales, which would tend to limit the patent holder's lost sales. However, the infringer could not claim that it would have developed and introduced some new noninfringing product in the but-for world and that this product would have captured some of the infringing sales. *Grain Processing* eased this restriction on the

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7. *See* Peter E. Strand, *Back to Bedrock: Constitutional Underpinnings Set 'New' Standards for Patent Infringement Causation*, 8 B.U. J. SCI. & TECH. L. 375, 449-50 (2002).

8. 35 U.S.C. § 284 (2000) ("[T]he court shall award [the patentee] damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer.").

9. A hybrid approach is often used as well in situations where not all of the infringing sales represented lost sales to the patent holder. In that case, a lost profits approach is used to calculate damages on the infringing sales that represent lost sales to the patent holder and a reasonable royalty approach is used to calculate damages on the remaining sales.

10. This follows because the reasonable royalty is merely a fee for use of the patented item or technology, while lost sales include the market value of the final good produced with the patented item or technology.

11. *See* Grain Processing Corp. v. Am. Maize-Prods. Co., 185 F.3d 1341 (Fed. Cir. 1999).

set of noninfringing substitutes available in the but-for world by allowing an infringer to claim that it would have offered a noninfringing product that, although not actually sold in the marketplace, was technically feasible at the time and could have been made commercially available relatively quickly. Indeed, the *Grain Processing* decision went further to conclude that, in the particular case at issue, the plaintiff was not entitled to lost profits because the infringer's noninfringing product would have been identical from the point of view of customers (though more costly to the infringer). Damages were therefore calculated on a reasonable royalty basis only. Part III of this Article describes the *Grain Processing* decision.

The *Grain Processing* decision has led to considerable law review commentary. Most of the analysis is conjecture regarding the decision's implications for future infringement cases.[12] Though some commentators note the adverse impact that *Grain Processing* could have on the incentives of would-be infringers and the likelihood of litigation,[13] much of the commentary that evaluates *Grain Processing* applauds the decision.[14] No-

12. *See* Mark Chretien, *The Question of Availability:* Grain Processing Corp. v. American Maize-Products Co., 38 HOUS. L. REV. 1489, 1516 (2002) (discussing the practical impact of the decision); Susan Perng Pan, *Patent Damage Assessments After* Rite-Hite *and* Grain Processing, 42 J.L. & TECH. 481 (2002) (same); Margaret E. M. Utterback, *Substitute This! A New Twist on Lost Profits Damages in Patent Infringement Suits:* Grain Processing Corp. v. American Maize-Products Co., 2000 WIS. L. REV. 909, 922-40 (2000) (discussing the opinion and potential implications on patentees and potential defendants); *see also* Peter E. Strand, *Back To Bedrock: Constitutional Underpinnings Set 'New' Standards for Patent Infringement Causation*, 8 B.U. J. SCI. & TECH. L. 375 (2002) (discussing the likely impact of the decision within a broader discussion of causation in infringement cases).

13. *See, e.g.*, Michael Lambe, *Going Against the Grain?: The "Maize" of Lost Profits Awards in* Grain Processing Corp. v. American Maize-Products Co., 79 N.C. L. REV., 1189, 1199 (2001) (arguing that *Grain Processing* gives competitors an "incentive to test the boundaries of [a] patent" and will increase litigation as a result); Kelsey I. Nix & Nicholas Vogt, *Revisiting the Test for Calculating Patent Lost Profits: Federal Circuit Cases Expand Infringer's Ability to Rebut Inference on Causation*, N.Y.L.J., Feb. 3, 2003, S7, at S14 (describing the decision as giving infringers "more flexibility to reconstruct the market to negate claims of lost profits" but arguing that the Federal Circuit set a high standard for available substitutes).

14. *See, e.g.*, Roger D. Blair & Thomas F. Cotter, *Rethinking Patent Damages*, 10 TEX. INTELL. PROP. L.J. 1, 19 (2001) (describing the decision as consistent with the Federal Circuit's decisions in the area over the previous decade); Liane M. Peterson, Grain Processing *and* Crystal Semiconductor*: Use of Economic Methods in Damage Calculations Will Accurately Compensate for Patent Infringement*, 13 FED. CIR. B.J. 41, 42 (2003) (cataloguing methods of damages calculations and applauding the Federal Circuit's "openness to new methodologies"); John W. Schlicher, *Measuring Patent Damages by the Market Value of Inventions—The* Grain Processing*,* Rite-Hite*, and* Aro *Rules*, 82 J. PAT. & TRADEMARK OFF. SOC'Y 503, 532 (2000) (describing *Grain Processing* as

tably, no commentary addresses what we consider to be the decision's most important economic feature: *Grain Processing*'s grant of a "free option" to the infringer—by which we mean that the infringer benefits from being able to use the patented invention without forgoing any profits or other rights to obtain the option.[15]

As we explain in Part IV, free options can have large economic incentive effects on rational economic decisions. We find that the grant of a free option is contrary to the basic framework of the patent system in the United States. Although it is widely appreciated how *Grain Processing* has made it more difficult for patent holders to claim lost profits damages, it is less well understood how *Grain Processing* has affected the incentives of companies to risk litigation by using patented technology (without a license) rather than to avoid infringement by using an economically inferior noninfringing technology. Whether the patent is valid and infringed is unknown until the litigation occurs. A patent only provides the patent holder with the right to sue for infringement. A court decides whether the patent is valid and infringed.

Consider a firm facing a decision between these two alternatives. If it chooses to risk litigation and use the patented technology, it retains the option to switch to the noninfringing technology if the patent is later found to be valid and infringed. Of course, the firm will be liable for damages for the period of infringement. If, on the other hand, the firm chooses to use the noninfringing technology, it will not have the opportunity to learn whether the patent is valid and infringed.[16] Thus, the firm that uses the patented technology keeps its options open, although at the risk of having to pay damages once a court resolves the uncertainty regarding validity and infringement.

The *Grain Processing* decision substantially decreases the risk of litigation because it diminishes the size of the damages award. If a court finds the patent valid and infringed, the firm can argue under *Grain Processing* that it *would have switched* to the noninfringing technology in the but-for world, thereby effectively making the switch retroactively. *Grain Process-*

"achiev[ing] more sensibly the fundamental goal of the patent system"); Utterback, *supra* note 12, at 937-38 (stating that *Grain Processing* "ultimately furthers the purposes of patent law"). *But see* Chretien, *supra* note 12, at 1512-14 (criticizing *Grain Processing* and offering an alternative).

15. For a non-technical explanation of how legal rules can confer free options, see Jerry A. Hausman & J. Gregory Sidak, *A Consumer-Welfare Approach to the Mandatory Unbundling of Telecommunications Networks*, 109 YALE L.J. 417, 458 (1999).

16. It is possible that the patent holder would sue some other infringer, and the validity of the patent would be determined in that litigation. However, the question of infringement would often still remain.

ing thereby makes the option essentially free.[17] This option reduces the deterrent effect of litigation and therefore encourages infringement. As a consequence, the returns to research and development fall, as do the incentives to innovate.

We also address the conclusion of the *Grain Processing* decision that lost profits were inappropriate because the infringer could have offered an essentially equivalent noninfringing product in the but-for world, albeit at a higher cost of production. As we demonstrate below, this conclusion is not economically correct because the infringer would have had economic incentives to increase its price in this situation. As a result, the patent owner would have had greater sales and profits in the but-for world than in the actual world. We conclude that lost profits should not necessarily be precluded even if the infringer could have provided a noninfringing version of its product in the but-for world.

II. THE CALCULATION OF PATENT DAMAGES

A. Reasonable Royalty

Under American law, one method used to determine the appropriate reasonable royalty for patent infringement is an analysis of the outcome of a "hypothetical licensing negotiation" between the patent owner as a willing licensor and the infringer as a willing licensee, which is assumed to have taken place at the time of the first infringement.[18] Thus, one assumes that a license would always result from the hypothetical negotiation.[19]

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17. Two possible costs of this option—switching costs and litigation expense—do not change the analysis. First, to the extent they exist, the costs would be factored into the value of the option. It is extremely unlikely that attorneys' fees would exceed the value to the infringer of using the patented technology. Second, one can view switching costs as the infringer's marginal cost of using the new, noninfringing technology. By assumption, the infringer has made no sunk investment to be able to exploit the patented technology; so, even setting to one side the fallacy of sunk costs, the infringer would have no abandonment of sunk investment to dissuade him from switching to the noninfringing technology.

In many cases, there are no switching costs. Technology is typically adopted during the product design process; adopting the patented technology at that point does not require a switch from another technology because no technology has been previously adopted (the product is only now being designed).

18. Riles v. Shell Exploration & Prod. Co., 298 F.3d 1302, 1311 (Fed. Cir. 2002) ("A 'reasonable royalty' contemplates a hypothetical negotiation between the patentee and the infringer at a time before the infringement began." (citing Hanson v. Alpine Valley Ski Area, Inc., 718 F.2d 1075 (Fed. Cir. 1983))).

19. *See id.*

An economic approach to analyzing the hypothetical negotiation is to determine the bounds of the Edgeworth Box[20]—that is, the minimum royalty that the patent holder would accept (while still being better off than without a license) and the maximum royalty the infringer would be willing to pay (while still being better off than without a license). A negotiated royalty necessarily must fall between these upper and lower bounds, which define the "bargaining range."

The maximum royalty rate that the infringer would have been willing to pay is a function of the incremental profits that it would expect to earn by licensing the patents at issue as compared to not licensing. An important consideration is whether there exist any noninfringing "design-arounds" and the costs of implementing and using those design-arounds as compared to using the patented technology. For example, suppose that a design-around exists but would cost a certain amount to implement, would require greater ongoing marginal costs of production as compared to what could be achieved with the patented technology, and would lead to a lower quality product (and thus lower sales and a lower price) as compared to what could be achieved with the patented technology. In that case, the infringer would be willing to pay a royalty up to the increase in profits associated with the cost savings, the increased sales, and the increased price (but no more) in order to license the patented technology.

The minimum royalty that the patent holder would be willing to accept to grant a license is a function of the losses that it would sustain by licensing as compared to not licensing. For example, if the patent owner would lose other licensing opportunities when it licensed the infringer, the patent owner would demand a royalty that at least replaced the profits that these lost licensing opportunities would have generated. If the patent owner would lose sales to the infringer, the patent owner would demand a royalty that at least compensated for the loss of profits on those sales.

Once the bargaining range has been established, economic factors are used to estimate where within the bargaining range an agreement would result.[21] In addition, American courts have adopted a list of economic and business factors, called the *Georgia Pacific*[22] factors, that are used to aid in determining the amount of the reasonable royalty.

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20. *See* HAL VARIAN, MICROECONOMIC ANALYSIS 314-15 (3d ed. 1992).

21. In principle, the Edgeworth Box can be empty, in which case the infringer cannot pay the amount lost by the patent holder and still be profitable. This situation can occur, for example, when the patent holder is a significantly lower cost producer than the infringer.

22. Georgia-Pac. Corp. v. U.S. Plywood Corp., 318 F. Supp. 1116, 1120 (S.D.N.Y. 1970) (setting forth fifteen evidentiary factors for consideration).

B. Lost Profits

From an economist's point of view, the purpose of a lost profits damages award in a patent case is to compensate the patent holder for the profits on sales that it lost as a result of the infringement. This economic approach comports with the Supreme Court's view that damages for patent infringement should equal "the difference between [the patent owner's] pecuniary condition after the infringement, and what his condition would have been if the infringement had not occurred."[23] To determine the amount of profits that the patent holder lost, the first step is to determine the level of profits that the patent holder would have achieved had the infringement not occurred—that is, in the world as it would have been absent the infringement. This scenario is often called the "but-for" world. Damages are equal to the difference between the but-for profits and the actual profits of the patent holder.

As discussed in Section II.A, higher profits for the patent holder in the but-for world could have resulted from, among other things, greater sales or a higher price. In calculating the but-for profits, it is important to account for any additional costs the patent holder would have incurred to make the additional sales. For example, the incremental costs required to produce and sell the additional units (including the cost of capacity expansion if needed) must be accounted for when calculating the but-for profits.

In attempting to ascertain whether to award lost profits, American courts often refer to the "*Panduit* factors," all of which must be satisfied for an award of lost profits: (1) demand for the patented product, (2) absence of acceptable noninfringing substitutes, (3) manufacturing and marketing capability to exploit the demand, and (4) the amount of profit that would have been made.[24] Although the second *Panduit* factor is the primary focus of this Article, we will first discuss the other three factors.

To satisfy the first *Panduit* factor, courts require a demonstration that customers of the infringing product would have bought the patented product if the infringing product were unavailable. In many situations, the patented product will not capture all of the sales of the infringing product because some demand will go to competing noninfringing products. If the necessary data are available, one can estimate the amount of substitution using econometric methods that measure the cross elasticity of demand. The basic economic idea is that the price of the infringing product is in-

23. Aro Mfg. Co. v. Convertible Top Replacement Co., 377 U.S. 476, 480 (1964) (quoting Yale Lock Mfg. Co. v. Sargent, 117 U.S. 536, 552 (1886)).

24. Panduit Corp. v. Stahlin Bros. Fibre Works, Inc., 575 F.2d 1152, 1156 (6th Cir. 1978); *see also* Rite-Hite Corp. v. Kelley Co., 56 F.3d 1538, 1545 (Fed. Cir. 1995).

creased to its "virtual price" where its demand is zero, and the econometric model is used to determine the share of its sales relative to the patent owner's product and other competing products.[25]

The third *Panduit* factor, which involves determining whether the patent holder had sufficient manufacturing and marketing capability to make the additional sales, usually comes down to the ability of the patent holder to expand its current operations by adding a work shift at an existing manufacturing plant to expand output or to invest in additional manufacturing capacity.[26] Of course, this factor may be less significant in industries such as software and other products where an output increase is relatively easy to undertake, as compared to manufacturing industries such as chemicals.

Satisfying the fourth *Panduit* factor requires the estimation of the patent holder's incremental profit on the additional sales. As mentioned above, it is important to consider all of the potential incremental costs associated with the additional sales. Typically, one can calculate the incremental costs based on existing cost data from the patent holder.

We now consider the second *Panduit* factor, which concerns the absence of noninfringing substitutes. In principle, this factor comprises both a demand-side consideration (substitute noninfringing products already on the market) and a supply-side consideration (substitute noninfringing technologies that the infringer could have used). On the demand side, however, we know of no instance where U.S. courts have required the absence of noninfringing substitutes for an award of lost profits. Especially in an economic situation consisting of differentiated products, the relevant economic (and legal) question is not whether any noninfringing substitute product exists, but instead how much demand of the infringing product would shift to the patent holder's product as opposed to the noninfringing substitute products. We discussed above, in the context of the first *Panduit* factor, econometric techniques that permit estimation of the substitution among these competing products.

The more difficult economic question arises on the supply side. If the use of the patented technology was not available to the infringer, what techniques could it have substituted in place of using the patent holder's technology? In the but-for world, making this determination may be quite difficult because often no real world observations of production exist absent infringement. At one extreme, the infringer would have exited the

25. *See, e.g.*, Jerry A. Hausman & Gregory K. Leonard, *Competitive Analysis Using a Flexible Demand Specification*, 1 J. COMPETITION L. & ECON. 279, 299 (2005).

26. *See, e.g.*, Yarway Corp. v. Eur-Control USA, Inc., 775 F.2d 268, 276-77 (Fed. Cir. 1985) (holding that reasonable probability that manufacturing efforts are adequate is enough).

market in the but-for world since no substitution would have been possible. This situation sometimes arises in the pharmaceutical industry because a patent may cover the chemical compound that causes a given drug to work. In this situation, it may be impossible for the infringing firm to manufacture a competing drug without violating the patent.

At the other extreme, an infringer would claim that it would have costlessly "invented around" the patented technology and produced the identical product at the same cost as using the patented technology. Whether this claim is economically rational is questionable because the infringer rationally should have shifted to the alternative technology rather than risking having to pay patent damages. This question aside, a further problem exists in ascertaining whether the alternative technology could have been used at all, since it often was not actually used in real world operations. Courts are often reluctant to credit the use of an alternative technology by the infringer when the infringer did not actually use or actively investigate the substitute technology. Otherwise, it may be extremely difficult to determine whether claimed behavior in the but-for world has a factual basis.

However, two situations do exist where it may be reasonable to assume use of an alternative noninfringing technology in the but-for world. First, the infringer may claim that in the but-for world it would have adopted the same technology used in an existing noninfringing substitute product. Where the patent is a production process patent, the cost of production using the noninfringing technology is typically higher than using the patented technology, so that lost profits would still likely result because of less price competition. We discuss this fact further below. Alternatively, where the patent involved product features, use of noninfringing technology would likely lead to a product without all of the features of the patented product. Here, both lost profits from lost sales and price erosion may occur, leading to lost profits by the patent holder.

A second and closely related situation may occur when the infringer has previously used a noninfringing technology and subsequently adopted the infringing technology. In the but-for world, the infringer can claim that it would have continued to use the noninfringing technology. However, since the infringer would adopt the infringing technology only if it led to increased profits, again the older noninfringing technology would either be higher cost or lack some of the features of the infringing product. In either situation, lost profits would arise from either lost sales or price erosion or both.

III. THE *GRAIN PROCESSING* DECISION

The *Grain Processing* case lasted eighteen years and went to the Federal Circuit three times—a story worthy of a latter day Dickens. Grain Processing and its infringing competitor America Maize sold large quantities of maltodextrins, which are food additives that give treated foods properties such as binding and viscosity and preserve food properties at low temperatures.[27] Food processors use maltodextrins in products such as drinks, cereals, and frozen foods.[28] Grain Processing began manufacturing and selling maltodextrins in 1969 and owned a patent, "Low D.E. Starch Conversion Products," ("the '194 patent") that covered maltodextrins with particular attributes and processes for their production.[29]

American Maize began selling maltodextrins in 1974 and sold a particular maltodextrin, Lo-Dex 10, over the entire period that Grain Processing owned the rights for the '194 patent.[30] However, American Maize used four different production processes over the time period to produce Lo-Dex 10.[31] From 1974 to 1982, American Maize used a particular process for maltodextrin production that the Federal Circuit held to infringe Grain Processing's patent.[32] In 1982, American Maize changed its process, but Grain Processing claimed that the new process also infringed its patent.[33] The Federal Circuit agreed and enjoined American Maize from continuing to use either of the infringing processes.[34]

American Maize developed a third process to manufacture Lo-Dex 10, which it used from 1988 to 1991.[35] However, in 1990, Grain Processing once again claimed infringement. Overruling the district court, the Federal Circuit held that this third process infringed the '194 patent as well.[36] American Maize tried a fourth time and, in only two weeks, developed yet another Lo-Dex 10 manufacturing process, albeit one with a higher cost

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27. Grain Processing Corp. v. Am. Maize-Prods. Co., 185 F.3d 1341, 1343 (Fed. Cir. 1999).

28. *Id.*

29. *Id.* at 1344 (citing U.S. Patent No. 3,849,194 (filed Sept. 17, 1971)).

30. *Id.*

31. *Id.* at 1344-45.

32. *Id.* The original district court decision found that American Maize did not infringe. The Federal Circuit reversed that decision. Grain Processing Corp. v. Am. Maize-Prods. Co., 840 F.2d 902, 911 (Fed. Cir. 1988).

33. *Grain Processing Corp.*, 185 F.3d at 1345.

34. *Grain Processing Corp.*, 840 F.2d at 911.

35. *Grain Processing Corp.*, 185 F.3d at 1345.

36. *Id.* at 1346 (citing *Grain Processing Corp.*, 21 U.S.P.Q.2D (BNA) 1474 (Fed. Cir. 1991) (unpublished)).

than the preceding processes.[37] Grain Processing did not challenge it, and American Maize used it for six months in 1991 until the '194 patent expired.[38]

Regarding American Maize's third process, Grain Processing claimed lost profits based on "lost sales, price erosion, and American Maize's accelerated market entry after the patent expired."[39] The district court denied lost profits and instead granted a reasonable royalty of 3 percent, rather than the 28 percent Grain Processing sought.[40] The court based its decision to deny lost profits on Grain Processing's failure to satisfy the second *Panduit* factor, which requires the absence of acceptable noninfringing substitutes.[41] The district court ruled that American Maize could have produced a noninfringing substitute using the fourth process that it developed in 1991.[42] Although American Maize did not actually manufacture and sell the noninfringing product until the final six months before the '194 patent expired, the district court decided that its availability in the last six months of the patent's lifetime "scotches [Grain Processing's] request for lost-profits damages."[43] The district court ruled that buyers found that the infringing and noninfringing products were "indistinguishable from customers' standpoint," stating that "no one argues that any customer cared a whit about the product's descriptive ratio."[44] Thus, the court set the 3 percent reasonable royalty rate on the basis of an estimate of the cost difference between the noninfringing process and the third (infringing) process.[45]

Grain Processing appealed, claiming that it should have received lost profits, which presumably would have considerably exceeded the royalty based on the 3 percent rate.[46] Grain Processing's primary argument was that the district court's decision was based on "a non-infringing substitute that did not exist during, and was not developed until after, the period of

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37. *Id.*

38. *Id.* at 1346-47.

39. *Id.* at 1347.

40. Grain Processing Corp. v. Am. Maize-Prods. Co., 893 F. Supp. 1386, 1393 (N.D. Ind. 1995). This was a bench trial decided by Judge Frank Easterbrook of the Seventh Circuit, sitting by designation.

41. *See id.* at 1391-93.

42. *See id.* at 1391-92.

43. *See id.* at 1392. The noninfringing product was sold starting in May 1991, whereas the patent expired in November 1991. *See id.* at 1388, 1396.

44. *Id.* at 1390.

45. *Id.* at 1393.

46. *See* Grain Processing Corp. v. Am. Maize-Prods. Co., 185 F.3d 1341, 1347 (Fed. Cir. 1999).

infringement."[47] The Federal Circuit reversed the district court's decision, ruling that, to qualify as an acceptable noninfringing substitute, the product or process must be "available or on the market at the time of infringement."[48] The Federal Circuit remanded the case to the district court for further determination of lost profits.[49]

On remand, the district court again denied lost profits to Grain Processing, holding that the noninfringing process was actually available during the period of infringement.[50] The court held that American Maize could have adopted the noninfringing process in 1979 but did not do so because it was more expensive.[51] Because the products were equivalent apart from the manufacturing process, Grain Processing could not prove the *Panduit* factors, which the court interpreted as requiring "economically significant demand for a product having all . . . attributes" of the patented product.[52] Such a demand did not exist because the noninfringing process hypothetically could have met market demand.[53] Since Grain Processing and American Maize were the only two manufacturers of such maltodextrins, Grain Processing would have gained most of the sales made by American Maize if American Maize was not in the market. Thus, lost profits likely would have been substantial if calculated based on lost sales.

The Federal Circuit affirmed the district court's opinion, holding that the noninfringing product was an "acceptable substitute for the claimed invention":[54]

> [A] fair and accurate reconstruction of the "but for" market also must take into account, where relevant, alternative actions the infringer foreseeably would have undertaken had he not infringed. Without the infringing product, a rational would-be infringer is likely to offer an acceptable noninfringing alternative, if available, to compete with the patent owner rather than leave the market altogether. The competitor in the "but for" marketplace is

47. Grain Processing Corp. v. Am. Maize-Prods. Co., 1997 U.S. App. LEXIS 2885, at *3 (Fed. Cir. 1997) (unpublished opinion).

48. *Id.* at *5.

49. *Id.* at *7-*8.

50. Grain Processing Corp. v. Am. Maize-Prods. Co., 979 F. Supp. 1233, 1234-35 (N.D. Ind. 1997).

51. *Id.*

52. *Id.* at 1237.

53. *Id.*

54. Grain Processing Corp. v. Am. Maize-Prods. Co., 185 F.3d 1341, 1349 (Fed. Cir. 1999).

> hardly likely to surrender its complete market share when faced with a patent, if it can compete in some other lawful manner.[55]

Reflecting on the twelve years it took American Maize to develop a noninfringing manufacturing process, the Federal Circuit held that if an alleged alternative is not on the market during the period in which the patent owner claims damages, "a trial court may reasonably infer that it was not available as a non-infringing substitute at that time."[56] The burden then switches to the infringer who must demonstrate that the noninfringing substitute was in fact available during the infringement period.[57] "[M]ere speculation or conclusory assertions will not suffice to overcome the inference. After all, the infringer chose to produce the infringing, rather than non-infringing, product."[58] The Federal Circuit agreed with the district court that the lower cost of the infringing process was the "sole reason" that American Maize used it.[59] Further, the Federal Circuit affirmed the district court's ruling that the "substantial profit margins" on Lo-Dex 10 were sufficient to conclude that American Maize would have used the more costly noninfringing process without increasing its prices.[60] The Federal Circuit decided that American Maize could have used the higher cost noninfringing process throughout the period beginning in 1979, even though it actually did not use the process until 1991.[61]

Grain Processing marked a substantial change in the availability of lost profits as a form of patent damages. An infringer no longer has to rely on noninfringing alternatives actually sold in the marketplace, but instead the infringer can claim it could have feasibly offered a noninfringing alternative in the but-for world. As in *Grain Processing* itself, if the hypothetical noninfringing alternative that the infringer proposes is a close substitute in the eyes of consumers, the plaintiff may lose any claim to lost profits entirely.

IV. OPTIONS AND PATENTS

The U.S. patent system confers upon the patent holder the property right to exclude the use of its patented product or process for a specified period of time for the purpose of providing incentives for research and in-

55. *Id.* at 1350-51.
56. *Id.* at 1353.
57. *Id.*
58. *Id.*
59. *Id.* at 1354-55.
60. *Id.* at 1354.
61. *Id.* at 1354-55.

novation. Strictly speaking, a patent gives the holder the right to *sue* to exclude an infringer. A court, of course, may find that the patent is invalid.

One who uses the patented technology without a license to do so is subject to monetary damages to compensate the patent holder for the use of its property. In *Grain Processing*, American Maize infringed Grain Processing's patent from its issuance until six months before its expiration. Since both the district court and the Federal Circuit found "substantial profit margins" on the American Maize product,[62] it is reasonable to conclude that a duopoly situation likely existed with no close substitute for the products at issue. Thus, if American Maize were absent from the market, it is likely that Grain Processing would have enjoyed even greater profit margins, as it would have been in a position of considerable market power (presumably monopoly power) with no close substitutes to constrain the price. In our view, the *Grain Processing* decision gives infringers such as American Maize a "free option" that discounts the optimal price for infringement and thus decreases incentives for innovation.

A. Financial Options and Real Options

Options are a significant factor in financial markets and in economic decision-making. An option gives the right, but not the obligation, to engage in the purchase or sale of a financial instrument or real property.[63] A call option on a stock gives the owner the right to buy a share of the stock at a specified exercise price on or before the option's expiration date.[64] A put option gives the owner the right to sell a share of the stock at a specified exercise price on or before the expiration date.[65] For example, an Intel call option for $25 might give the owner the right, but not the obligation, to purchase 100 shares of Intel stock at $25 per share on or before the expiration date—say, December 31, 2006. If Intel's stock exceeds $25 on the expiration date, the owner will exercise the option. Otherwise, the option will expire without being exercised. Options are valuable. For example, on May 12, 2006, with Intel stock at about $19, a call option with an exercise price of $17.50 and an expiration date of June 30, 2006, sold in the market at a price of $1.80; a call option with an exercise price of $20 and the same expiration date sold for only $0.35.

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62. *See, e.g.*, *id.* at 1355; Grain Processing Corp. v. Am. Maize-Prods. Co., 893 F. Supp. 1386, 1392 (N.D. Ind. 1995).

63. *See, e.g.*, RICHARD BREALEY, STEWART MYERS & F. ALLEN, PRINCIPLES OF CORPORATE FINANCE 597 (8th ed. 2005); JOHN C. HULL, OPTIONS, FUTURES, AND OTHER DERIVATIVES 6 (5th ed. 2003).

64. HULL, *supra* note 63, at 6.

65. *Id.*

Real options, which involve "real" assets instead of financial assets, are similar to and closely associated with financial options. Real options involve the opportunity, but not the obligation, to modify a project. Some common examples are the option to expand a project, to abandon a project, or to modify a technology used in a project. Real options are valuable because having an option increases flexibility if circumstances change. Thus, a firm making an investment decision will often spend extra funds to maintain flexibility because the future is always uncertain. A greater ability to adapt to future uncertain outcomes is often worth the extra expenditure. Indeed, a leading finance textbook discusses the flexibility inherent in real options under the name of "production options."[66]

Although we have stressed the value of options, government regulation can often grant free options to certain firms. For example, the Federal Communications Commission's (FCC) application of the Telecommunications Act of 1996 required incumbent owners of telecommunications networks to rent their networks elements (for example, local loops) to new entrants on the basis of a monthly contract.[67] Although the investment in a telecommunications network is typically very long-lived and irreversible, often called a sunk and irreversible investment, the FCC permitted the new entrant to stop renting the network at any time without advance notice.[68] Thus, the FCC gave the new entrant the right, but not the obligation, to continue to rent the network elements. The FCC conferred this benefit upon new entrants often for free, since the new entrants were not required to sign a long-term contract or take on any obligation to continue renting the network element.[69] Since a free option is the transfer of value from one party to another, it will affect economic incentives. Specifically, the incumbent provider has less of an incentive to invest because the grant of a free option means that a portion of the value of its investment has been transferred to the new entrant. The telecommunications industry in the United States endured this negative effect on investment, and the FCC eventually changed its policy so as not to require incumbents to rent net-

66. BREALEY, MYERS & ALLEN, *supra* note 63, at 262.

67. *See* Telecommunications Act of 1996, 47 U.S.C. § 251(c)(3).

68. *See* Jerry A. Hausman, *The Effect of Sunk Costs in Telecommunication Regulation*, *in* THE NEW INVESTMENT THEORY OF REAL OPTIONS AND ITS IMPLICATIONS FOR TELECOMMUNICATIONS ECONOMICS (James Alleman & Eli Noam eds., 2002); Jerry A. Hausman, *Valuing the Effect of Regulation on New Services in Telecommunications*, 1997 BROOKINGS PAPERS ON ECON. ACTIVITY: MICROECONOMICS 1, 28-35 (1997); Hausman & Sidak, *supra* note 15.

69. *See* Telecommunications Act of 1996, 47 U.S.C. § 251(c).

work elements from their new investment in broadband telecommunications networks.[70]

B. Real Options and *Grain Processing*

We now apply real options analysis to the *Grain Processing* case. To simplify the analysis, we will ignore the last six months before patent expiration, when American Maize adopted a noninfringing production process, and assume that American Maize used a production process that infringed Grain Processing's patent throughout the patent term. We further assume that American Maize never used a noninfringing process, even though such a process was known and available throughout the period of infringement. When Grain Processing sues for patent infringement and claims lost profits for damages, American Maize can claim that it could have used the noninfringing process throughout the period. We also assume, as actually happened, that the courts will deny lost profits because Grain Processing did not satisfy the second *Panduit* factor, the absence of acceptable noninfringing substitutes. Instead, Grain Processing will only receive a reasonable royalty in the event that the courts find the patent is valid and infringed. Thus, if the court finds the patent to be either invalid or not infringed, American Maize need pay no damages to Grain Processing. Alternatively, if the court holds that the patent is valid and infringed, American Maize must pay no more than a reasonable royalty.

We analyze this situation in the context of a stylized model. A firm can choose between two technologies: technology 1, which may infringe a patent, and technology 2, which is noninfringing. The firm's per period profits are π_1 if it uses technology 1 and π_2 if it uses technology 2, with $\pi_1 \geq \pi_2$. There are two periods. If the firm has chosen technology 1, at the end of period 1 it is determined whether the patent is valid and whether technology 1 infringes the patent (we assume that the costs of this determination, that is, litigation costs, are zero).[71] The probability that the patent is valid and infringed by the first technology is θ. If the patent is found to be valid and infringed, the firm must switch to technology 2 in period 2 and it must pay damages in the amount D. For the purposes of this model, we assume that there is no discounting.

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70. For a discussion of this outcome, see Jerry A. Hausman & J. Gregory Sidak, *Did Mandatory Unbundling Achieve Its Purpose? Empirical Evidence from Five Countries*, 1 J. COMPETITION L. & ECON. 173, 194-203 (2005).

71. Litigation costs can be included by deducting them from profits.

If the firm chooses technology 2, its total expected profits over the two periods are $2\pi_2$.[72] If the firm chooses technology 1, its total profits are $\pi_1 + \pi_2 - D$ if the patent is found to be valid and infringed and $2\pi_1$ if the patent is found invalid or noninfringed. Thus, if the firm chooses technology 1, its total expected profits are

$$\theta(\pi_1 + \pi_2 - D) + (1-\theta)2\pi_1 = 2\pi_1 - \theta(\pi_1 - \pi_2) - \theta D\,.^{73} \quad (1)$$

The firm will choose technology 1 if its expected profit from infringing is greater than its expected profit from not infringing—that is, if

$$2\pi_1 - \theta(\pi_1 - \pi_2) - \theta D \geq 2\pi_2 \quad (2)$$

or, rearranging, if

$$\frac{2-\theta}{\theta}(\pi_1 - \pi_2) \geq D\,. \quad (3)$$

Thus, if the damages award D is sufficiently large, (that is, larger than the expected profit from potentially infringing), it will deter the firm from choosing the potentially infringing technology 1.

This model has the economic characteristics of a real option. In the investment context, real options considerations arise when the investment decision is at least partially irreversible (that is, some investment costs are sunk) and the decision to invest can be delayed until uncertainties are resolved.[74] Under these conditions, there is a value in waiting to sink costs until the uncertainties are resolved. This value derives from retaining flexibility (an option) to avoid sinking costs if the uncertainties resolve in an adverse fashion. In the model described above, by choosing technology 1, the firm retains the flexibility to switch to technology 2 if, when the uncertainty is resolved, the patent is found to be valid and infringed. This option is lost if the firm chooses technology 2 at the outset, a decision assumed to be irreversible.

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72. We assume that the firm cannot choose technology 2 in period 1 and then switch to technology 1 in period 2 since, in a more general model, the firm would be continuously subject to an infringement lawsuit.

73. That is, (probability of infringing) * (profits if infringing) + (probability of not infringing) * (profits if not infringing).

74. AVINASH K. DIXIT & ROBERT S. PINDYCK, INVESTMENT UNDER UNCERTAINTY 6 (1994).

One cost of retaining the option is that the firm will have to pay the damages award D in the event that the patent is found to be valid and infringed. Indeed, as seen above, in principle D can be sufficiently large to make maintenance of the option unprofitable. We now turn to the question of how the *Grain Processing* decision affected the value of using technology 1 and retaining the option.

As discussed above, *Grain Processing* has made it more difficult to prove lost profits damages, which are typically larger than reasonable royalty damages. Suppose that $D = \pi_1$. Before *Grain Processing*, a damages award of this magnitude was a possible outcome in the situation where the potentially infringing firm and the patent owner were the only suppliers of the product in question. In that case, the patent owner would argue that, in the but-for world where the infringing product was not on the market, it would have made all of the infringing sales itself. If the patent owner's price was essentially the same as the potentially infringing firm's price, the patent owner's profits on these additional sales (that is, its lost profit damages) would be equal to the potentially infringing firm's profits on these sales and damages would be $D = \pi_1$.[75] With the damages award at this level, the firm may or may not choose technology 1, depending on whether inequality (3) is satisfied. For a relatively small profit differential $\pi_1 - \pi_2$ and relatively high patent strength value θ it is likely that inequality (3) will not be satisfied and the firm will be deterred from choosing potentially infringing technology 1.

After *Grain Processing*, the potentially infringing firm could claim that an award of lost profits damages is inappropriate because it could have switched to technology 2 at the outset to avoid infringement. In that case, damages would be calculated on a reasonable royalty basis. As discussed in Section II.A, the largest the reasonable royalty could be is the upper end of the Edgeworth Box, or the infringing firm's maximum willingness to pay. The maximum royalty that the infringing firm would be willing to pay each period to obtain a license to use the patented technology is $\pi_1 - \pi_2$ because for any royalty greater than this amount, the infringing firm would prefer to switch to technology 2 rather than take a license to the patent. Thus, under *Grain Processing*, $D \leq \pi_1 - \pi_2$. But, this inequality implies

$$D \leq \frac{2-\theta}{\theta}(\pi_1 - \pi_2) \qquad (4)$$

75. The patent owner might additionally claim price erosion damages. In that case, $D > \pi_1$ is possible.

since $0 \leq \theta \leq 1$. Inequality (4) therefore implies that the firm will necessarily choose technology 1. In other words, the firm will not be deterred from choosing technology 1 by the prospect of having to pay the reasonable royalty damages award resulting from application of *Grain Processing*. Put another way, *Grain Processing* increases the value of the option inherent in choosing technology 1 to the point where it becomes essentially "free"—the firm would be irrational to reject it.

C. An Example of the Change in Option Value Due to *Grain Processing*

To illustrate how much of a difference *Grain Processing* makes to the value of choosing the potentially infringing technology, we performed calculations that approximate the case facts in *Grain Processing*. We assume that it takes 13 years for the patent to expire. The infringer's revenue each year is $100 and the profit margin when using the patented technology is 50 percent. Each year there is some probability that a finding of patent validity and infringement will occur, conditional on it not having occurred already. We assume that this "hazard rate" will be constant each year at 0.1, so that there will be an exponential density function.[76] If a finding of validity and infringement occurs, the infringer must pay damages for past infringement and switch to the alternative noninfringing technology for the remaining years; the profit margin for these years is reduced to 47 percent (to reflect the cost increase associated with using the noninfringing technology). The infringer discounts the future at a 6 percent rate.

We calculate the expected present discounted value as of year 0 of the infringer's cash flow stream under two scenarios. In the first scenario, damages after a finding of validity and infringement are calculated under a lost profits approach. We assume in this case that the patent holder's lost profits damages are equal to the profits that the infringer actually made. This assumption is reasonable if, in the but-for world, the patent holder would have made all of the infringing sales at the same price and profit rate as the infringer. In this scenario, the expected present discounted value of the cash flows to the infringer would be $325.

In the second scenario, we assume that damages after a finding of validity and infringement are calculated under a reasonable royalty approach because of the application of the second *Panduit* factor under *Grain Processing*. In particular, damages are assumed to equal 3 percent of the in-

76. We could change the constant probability assumption to allow an increasing or decreasing hazard over time using a Weibull distribution. Other distributions would allow for a non-monotonic hazard. However, the general form of the results does not depend on the particular distribution chosen.

fringing revenues. In this scenario, the expected present discounted value of the infringer's cash flows is $425. Thus, *Grain Processing* causes the value to the infringer for using the patented technology to increase by 31 percent. One would expect this change in values to have a significant effect on an infringer's decision whether to use the patented technology or avoid infringement through use of the noninfringing technology.

D. Changes in the Incentives of Firms to Engage in Research and Development

We have demonstrated how *Grain Processing* has substantially increased the incentives of firms to choose potentially infringing technologies rather than noninfringing technologies. In principle, this change in incentives can lead to greater amounts of litigation as patent owners are faced with more frequent cases of potential infringement.

Grain Processing also has changed the incentives of firms to engage in research and development (R&D). The smaller damages awards and the increased incentives on the part of potential infringers to infringe dampen the returns to R&D. As a consequence, the incentives to invest in R&D are weaker. This outcome may undermine the original goals of the U.S. patent system.[77]

V. LOST PROFITS IF THE INFRINGER ADOPTS A NONINFRINGING ALTERNATIVE TECHNOLOGY IN THE BUT-FOR WORLD

Until now, we have taken as given one of the underlying assumptions of the *Grain Processing* decision: that, having adopted the noninfringing alternative technology in the but-for world, American Maize would have retained its sales and the patent owner Grain Processing would have made no additional sales. This assumption underlies in part the conclusion in *Grain Processing* that damages should depend on a reasonable royalty approach rather than lost profits.

However, the assumption that American Maize would have retained all of its sales in the but-for world is inconsistent with well-established economic theory. If American Maize had switched to the noninfringing process, its marginal costs in the but-for world would have been higher by an amount approximately equal to 3 percent of the price. The *Grain Processing* decision assumes that American Maize would have absorbed the addi-

77. For a discussion of how economic returns to patents interact with the U.S. patent system's goal of increasing innovation, see Jerry A. Hausman & Jeffrey K. MacKie-Mason, *Price Discrimination and Patent Policy*, 19 RAND J. ECON. 253 (1998).

tional marginal costs and held its price at the same level it charged in the actual world. But, this course of action would not be optimal in most models of competition. Instead, American Maize's optimal response to an increase in its marginal costs would be to increase its price, which would lead to increased sales, an increased price, and increased profits for Grain Processing.

In other words, contrary to the conclusion of the *Grain Processing* decision, Grain Processing did sustain lost profits damages even under the assumption that American Maize would have turned to the alternative non-infringing process in the but-for world. We will demonstrate the extent of lost profits that the patent owner sustained in the context of two basic models of competition: Nash-Bertrand competition with differentiated products and Cournot competition with homogeneous products.[78]

A. Nash-Bertrand Competition with Differentiated Products

For simplicity, we assume the case of two firms, each selling one product, although the results generalize to N firms, with each selling multiple products. The patent owner is firm 1 and the infringer is firm 2. The demand faced by firm i (i = 1,2) is $Q_i(p_1,p_2)$. The marginal cost faced by firm i is c_i. (We assume that the marginal costs are constant over the relevant range of output.) The firms simultaneously set prices in a one-shot game. Firm i chooses p_i to maximize profits

$$(p_i - c_i)Q(p_i, p_j)^{79} \tag{5}$$

taking p_i as given.

We examine the resulting Nash equilibrium. Differentiating to maximize profits, the first order condition for firm i is

$$(p_i - c_i)\frac{\partial Q_i(p)}{\partial p_i} + Q_i(p) = 0\,. \tag{6}$$

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78. *See generally* Jeremy I. Bulow & Paul Pfleiderer, *A Note on the Effect of Cost Changes on Prices*, 91 J. POL. ECON. 182 (1983) (showing how a monopolist optimally changes its price in response to a marginal cost change); Jerry A. Hausman & Gregory K. Leonard, *Efficiencies from the Consumer Viewpoint*, 7 GEO. MASON L. REV. 707 (1999) (showing how marginal cost efficiencies resulting from a merger lead to lower prices in the context of several models of competition). For an overview of the Nash-Bertrand and Cournot models of competition, see JEAN TIROLE, THE THEORY OF INDUSTRIAL ORGANIZATION 209-21 (1998).

79. That is, (price – cost) * (quantity sold at that price).

The system of two equations of form (6) (that is, one equation for each firm) implicitly define the Nash equilibrium prices as functions of the costs of both firms.

Suppose now the cost of the infringing firm 2 increases because it has to adopt the more costly alternative noninfringing process. By differentiating first order condition (6) for firm 2 with respect to c_2 (while holding p_1 constant), we can obtain the derivative $\left.\frac{\partial p_2}{\partial c_2}\right|_{p_1}$, that is, the change in firm 2's optimal choice of price resulting from the decrease in its marginal cost:

$$\left.\frac{\partial p_2}{\partial c_2}\right|_{p_1} = \frac{\frac{\partial Q_2}{\partial p_2}}{(p_2 - c_2)\frac{\partial^2 Q_2}{\partial p_2^2} + 2\frac{\partial Q_2}{\partial p_2}}. \qquad (7)$$

The numerator is negative (because demand is downward sloping) and nonzero, and the denominator is negative by firm 2's second order condition. Thus, $\left.\frac{\partial p_2}{\partial c_2}\right|_{p_1} > 0$, which establishes that firm 2 would have the incentive to increase its price in response to the increase in its marginal cost rather than hold its price constant.

Equation (7) describes the change in firm 2's pricing incentives holding constant the price of firm 1. However, the increase in the marginal cost of firm 2 also gives firm 1 the incentive to increase its price. Thus, in equilibrium both prices change due to the increase in the marginal cost of firm 2. The change in the equilibrium price of firm 2 can be determined by differentiating the first order condition (6) for firm 2 with respect to c_2 without holding firm 1's price constant.[80] We obtain

$$\left(\frac{\partial p_2}{\partial c_2} - 1\right)\frac{\partial Q_2}{\partial p_2} + (p_2 - c_2)\left[\frac{\partial^2 Q_2}{\partial p_2^2}\frac{\partial p_2}{\partial c_2} + \frac{\partial^2 Q_2}{\partial p_2 \partial p_1}\frac{\partial p_1}{\partial c_2}\right] + \frac{\partial Q_2}{\partial p_2}\frac{\partial p_2}{\partial c_2} + \frac{\partial Q_2}{\partial p_1}\frac{\partial p_1}{\partial c_2} = 0. \qquad (8)$$

80. For a general approach to comparative statics in this type of situation, see Avinash Dixit, *Comparative Statics for Oligopoly*, 27 INT'L ECON. REV. 107 (1986).

Note that equation (8) includes the term $\frac{\partial p_1}{\partial c_2}$, which is the change in the equilibrium price of firm 1 caused by a change in firm 2's cost. Equation (8) can be rearranged to take the following form:

$$\frac{\partial p_2}{\partial c_2}\left(2\frac{\partial Q_2}{\partial p_2}+(p_2-c_2)\frac{\partial^2 Q_2}{\partial p_2^2}\right)+\frac{\partial p_1}{\partial c_2}\left(\frac{\partial Q_2}{\partial p_1}+(p_2-c_2)\frac{\partial^2 Q_2}{\partial p_2 \partial p_1}\right)=\frac{\partial Q_2}{\partial p_2}. \tag{9}$$

The term inside the first parentheses on the left-hand-side of (9) is negative by the second order conditions for firm 2's maximization problem. The second term on the left-hand-side of (9) is positive if the firm's products are strategic complements. Thus, the equilibrium prices are increasing in c_2. The magnitude of the increase in price for a given increase in c_2 depends on the slope and curvature of the two demand curves.

The change in the profits of firm 1 as a result of the increase in c_2 can be determined to first order by differentiating firm 1's equilibrium profit function

$$\pi_1(c_2)=\left(p_1(c_2)-c_1\right)Q_1\left(p_1(c_2),p_2(c_2)\right) \tag{10}$$

with respect to c_2 (where we have suppressed the additional dependence of the equilibrium profit function on c_1). This differentiation yields

$$\frac{\partial \pi_1}{\partial c_2}=\frac{\partial p_1}{\partial c_2}Q_1+(p_1-c_1)\frac{\partial Q_1}{\partial p_1}\frac{\partial p_1}{\partial c_2}+(p_1-c_1)\frac{\partial Q_1}{\partial p_2}\frac{\partial p_2}{\partial c_2} \tag{11}$$

The first two terms are zero due to the envelope theorem. The third term demonstrates that firm 1's equilibrium profits increase when c_2 increases, and that, to first order, this increase in profits is equal to the increase in firm 1's quantity sales resulting from the increase in firm 2's price, multiplied by firm 1's pre-existing per unit profit margin.

As a concrete example, consider the case of linear demand where the demand functions take the form

$$Q_i=\alpha-\beta p_i+\gamma p_j \tag{12}$$

where $\beta \geq \gamma > 0$. In that case, equation (9) simplifies to

$$\frac{\partial p_2}{\partial c_2}(-2\beta)+\frac{\partial p_1}{\partial c_2}\gamma=-\beta \tag{13}$$

and the corresponding equation derived from differentiating the first order condition (6) for firm 1 with respect to c_2 is

$$\frac{\partial p_1}{\partial c_2}(-2\beta)+\frac{\partial p_2}{\partial c_2}\gamma=0 \tag{14}$$

Solving these two equations for $\frac{\partial p_i}{\partial c_2}$ yields

$$\frac{\partial p_2}{\partial c_2}=\frac{2\beta^2}{4\beta^2-\gamma^2},\quad \frac{\partial p_2}{\partial c_2}=\frac{\beta\gamma}{4\beta^2-\gamma^2}. \tag{15}$$

Thus, in the boundary case where $\beta=\gamma$, for each \$1 increase in c_2, p_2 would increase by \$0.67 and p_1 would increase by \$0.33. The fact that p_2 increases more than p_1 implies that firm 1 would gain market share after an increase in c_2.

We will now calibrate the parameters to approximate the *Grain Processing* case facts and calculate the lost profits that firm 1 sustains as a result of firm 2's infringement, assuming that in the but-for world firm 2 would use the alternative noninfringing technology (that is, under the assumptions of the *Grain Processing* decision). When both firms are using the patented technology, we assume equal costs ($c_1 = c_2 = 50$). The parameters are chosen ($\alpha = 100$, $\beta = 2$, and $\gamma = 2$) so that each firm sells $Q_i = 100$ at a price of $p_i = 100$. The firms therefore split the market evenly when both use the patented technology. Each firm has profit $\pi_1 = 5000$.

If the infringer, firm 2, is forced to use the noninfringing technology, its costs rise to $c_2 = 53$. In that case, the equilibrium prices are $p_1 = 101$ and $p_2 = 102$ and the equilibrium quantities are $Q_1 = 102$ and $Q_2 = 98$. The profits of the patent holder, firm 1, increase to $\pi_1 = 5202$. Thus, the patent holder sustained lost profits even if the infringer would have used the noninfringing technology in the but-for world.

Damages in these circumstances would be calculated using a hybrid lost profits-reasonable royalty approach. In addition to the lost profits of \$202, a reasonable royalty of \$3 (3 percent of the \$100 selling price) would be applied to the 98 infringing units that did not represent lost sales to the patent owner. Thus, total damages would be \$496. This damages

award would substantially exceed the reasonable royalty-only damages award of $300 ($3 royalty on 100 infringing units).

B. Cournot Competition with Homogeneous Products

We now analyze lost profits under a model of Cournot competition with homogeneous products. Inverse market demand is denoted by $P(Q_1 + Q_2)$, where Q_1 is the quantity supplied by firm i. Again we assume constant marginal costs c_i. The first order condition for firm i is

$$\frac{\partial P}{\partial Q} Q_i + \left(P(Q_1 + Q_2) - c_i\right) = 0 . \tag{16}$$

The two first order conditions implicitly define the equilibrium quantities, which are functions of the marginal costs. To determine the effect of a change in c_2 on the equilibrium quantities, we differentiate (16) with respect to c_2 and rearrange to obtain

$$\frac{\partial Q_1}{\partial c_2} = -\frac{\partial Q_1}{\partial c_2} \frac{\frac{\partial P}{\partial Q} + Q_1 \frac{\partial^2 P}{\partial Q^2}}{2\frac{\partial P}{\partial Q} + Q_1 \frac{\partial^2 P}{\partial Q^2}} . \tag{17}$$

Because the numerator and the denominator of the second term of equation (17) are both negative, we have: $sign\left(\frac{\partial Q_1}{\partial c_2}\right) = -sign\left(\frac{\partial Q_2}{\partial c_2}\right)$, and under the usual conditions $\frac{\partial Q_1}{\partial c_2} > 0$. Thus, an increase in the infringer's cost will cause the patent holder to expand its output although the infringer contracts its output.

In the case with linear demand $P = \alpha \beta Q$, we have $\frac{\partial Q_1}{\partial c_2} = \frac{1}{3\beta}$. We now calibrate the linear demand case to the facts of the *Grain Processing* case. As before, we assume that, when both firms are using the patented technology, they have equal costs ($c_1 = c_2 = 50$). The parameters are chosen ($\alpha = 200$ and $\beta = 0.5$) so that each firm sells $Q_1 = 100$ at a price of $P = 100$. The firms therefore split the market evenly when both use the patented technology. Each firm has profit $\pi_1 = 5000$.

If the infringer, firm 2, is forced to use the noninfringing technology, its costs rise to $c_2 = 53$. In that case, the equilibrium price increases to $P = 101$ and the equilibrium quantities are $Q_1 = 102$ and $Q_2 = 96$. The profits of the patent holder, firm 1, increase to $\pi_1 = 5202$. Thus, again, the patent holder sustained lost profits even if the infringer would have used the noninfringing technology in the but-for world. Also, the total (hybrid) damages award of $490 (the $202 lost profits damages plus the $288 reasonable royalty damages on the 96 infringing units that the patent holder would not have made in the but-for world) again substantially exceeds the $300 damages award that would result from a reasonable royalty-only approach.

VI. CONCLUSION

The patent system allows firms to exclude competitors, thereby creating incentives for innovation. Firms enforce their right to exclude via infringement suits with attendant damage awards and injunctions. Damage awards in patent litigation are supposed to compensate the patent owner for economic harm that the infringement created. The *Grain Processing* decision has decreased the expected value of damages from infringement because it has conferred a free option on the infringer. Under *Grain Processing*, courts permit an infringer to claim that in the but-for world it would have adopted an existing noninfringing technology despite the fact that the infringer had never done so. This free option transfers economic value to the infringer and transfers economic value away from the patent holder. Thus, it decreases the economic incentives to innovate, which is one of the primary goals of the U.S. patent system.

We also demonstrate that standard models that economists use to analyze firm behavior and profit maximization contradict the conclusion of the district court in *Grain Processing* with respect to the absence of lost profits. When a firm's marginal costs increase, it typically will increase its price. Thus, if the infringer were to adopt the higher cost noninfringing technology, prices would typically increase and the patent holder would both increase its price and gain greater sales. Calculation of lost profits in most economic models, plus a reasonable royalty on those infringing units that do not represent lost sales to the patent holder, will then exceed the cost difference between the infringing low cost technology and the noninfringing high cost technology multiplied by the sales made by the infringer. From this calculation, the hybrid lost profits and reasonable royalty damages award will typically exceed a reasonable royalty-only damage award by a substantial margin. Thus, the district court's conclusion in

Grain Processing that no lost profits existed if the infringer were assumed to have adopted the noninfringing technology is at odds with standard economic theory.