

Real Options and Patent Damages:  
The Legal Treatment of Non-Infringing Alternatives,  
and Incentives to Innovate

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**I. Introduction**

Patent damage awards have become an increasingly important feature of business strategy in the United States over the past 20 years. While jury awards in excess of \$100 million were relatively rare before 1990, they are now quite common. These large awards usually arise when damages have been calculated using a lost profits approach. Increased competition from an infringer can cause a patent holder to lose profits in several ways. By far the most important source of lost profits is the sales that the patent holder lost to the infringer. Absent the infringement (often termed the “but-for” world), 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. A second important source of lost profits is what is often called “price erosion.” 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 may often interact with each other.<sup>2</sup> Other sources of lost profits damages include the patent holder’s lost sales of “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 thus higher profits for the patent holder in the absence of the infringement.

The US patent statute states that a patent holder whose patent has been infringed is entitled to at least a “reasonable royalty” as damages. Thus, in the event that lost

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<sup>2</sup> See e.g. *Minnesota Mining & Mrg. Co. v Johnson & Johnson Orthopedics, Inc.*, 976 F.2d 1559, 24 USPQ2d 1321 (Fed. Cir 1992). As the first author pointed out in that case, in the but-for world absent price erosion, a decreased quantity would be sold at the higher price.

profits damages are not awarded, damages are calculated based using a reasonable royalty approach.<sup>3</sup> Damages calculated under a reasonable royalty approach are typically (but not always) less than the damages calculated under a lost profits approach.

The legal framework under which patent damages are calculated changed substantially after the decision by the US Court of Appeals for the Federal Circuit (CAFC) in a case called *Grain Processing* in 1999. Perhaps the most important question in the typical lost profits analysis is determining the fraction of the infringing sales that constitute lost sales to the patent holder. The answer to this question usually depends on the set of non-infringing 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. Prior to *Grain Processing*, the case law as a legal matter generally restricted the set of non-infringing 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 non-infringing 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 non-infringing 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 set of non-infringing substitutes available in the but-for world by allowing an infringer to claim that it would have offered a non-infringing product that, while 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 then went further and concluded that, in the particular case at issue, the plaintiff was not entitled to lost profits because the infringer's non-infringing 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.

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<sup>3</sup> 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.

The *Grain Processing* decision has led to an enormous amount of law review articles and additional commentary.<sup>4</sup> We do not attempt to review this outpouring of articles. However, we are unaware of any article considering a factor that we see as an important economic consideration: the grant of a “free option” by the *Grain Processing* decision to the infringer. 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 US

While 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 non-infringing technology. Whether the patent is valid and infringed is not known until the litigation takes place. 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 non-infringing technology if the patent is later found to be valid and infringed. Of course, it will be liable for damages for the period of infringement. If, on the other hand, the firm chooses to use the non-infringing technology, it will not have the opportunity to learn whether the patent is valid and infringed.<sup>5</sup> 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.

The *Grain Processing* decision has the effect of substantially decreasing this risk by decreasing 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

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<sup>4</sup> We do not review this commentary here. Much of it is in student-edited law reviews. An interested reader can find the material using either Westlaw or Lexis in a university library.

<sup>5</sup> 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.

non-infringing technology in the but-for world, thereby effectively making the switch retroactively. The *Grain Processing* decision thereby makes the option essentially free. By providing potential infringers with increased option value if they use the patented technology, *Grain Processing* reduces the deterrence effect of litigation and therefore encourages infringement. As a consequence, the returns to research and development are negatively affected and the incentives to innovate are decreased. These effects of *Grain Processing* are the first subject of this paper.

We also address the conclusion of the *Grain Processing* decision that lost profits were inappropriate because the infringer could have offered an essentially equivalent non-infringing 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 non-infringing version of its product in the but-for world.

## **II. Background on Calculation of Patent Damages Under US Law**

### **A. Reasonable Royalty**

Under US law, one of the methods used to determine the appropriate reasonable royalty 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 first infringement.<sup>6</sup>

An economic approach to analyzing the hypothetical negotiation is to determine the bounds of the Edgeworth Box, i.e., the minimum royalty 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.”

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<sup>6</sup> Thus, the assumption is made that a license would always result from the hypothetical negotiation. A similar framework is used in numerous other countries to determine royalty damages after infringement has occurred.

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 non-infringing “design-arounds” and the costs of implementing and using these 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 on-going 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 these sales.

Once the bargaining range has been established, economic factors are used to estimate where within the bargaining range an agreement would result.<sup>7</sup> In addition, courts in the US have adopted a list of economic and business factors called the *Georgia Pacific* factors that are used to aid in determining the amount of the reasonable royalty.

### **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.<sup>8</sup> In order to determine the amount of profits that the patent

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<sup>7</sup> 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.

<sup>8</sup> This approach is consistent with the US Supreme Court approach to damages as “The

holder lost, the first step is to determine the level of profits that the patent holder would have achieved had the infringement not occurred, i.e., 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 above, 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 an award of lost profits should be made, US courts often refer to four so-called “Panduit factors,” all of which must be satisfied for an award of lost profits:<sup>9</sup>

- (1) Demand for the patented product
- (2) Absence of acceptable non-infringing substitutes
- (3) Manufacturing and marketing capability to exploit the demand
- (4) The amount of profit that would have been made.

Panduit factor (1) requires a demonstration that customers of the infringing product would have bought the patented product in the but-for world where the infringing product would not have been available to them. In many situations, the patented product will not capture all of the sales of the infringing product because some demand will go to competing non-infringing products. An estimate of the amount of substitution can be estimated using econometric methods that measure the cross elasticity of demand if the

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difference between [the patent owner’s] pecuniary condition after the infringement, and what his condition would have been if the infringement had not occurred.” *Aro Mfg Co. v. convertible Top Replacement Co.*, 377 U.S. 476, 84 S.Ct. 1526.

<sup>9</sup> *Panduit Corp. V. Stahl Brothers Fibre Works, Inc.* 575 F.2d 1152, 197 USPQ 726 (6<sup>th</sup> Cir. 1978). See also *Rite-Hite Corp. V. Kelley Co., Inc.*, 56 F3d 1538, 35 US2d 1065 (Fed. Cir. 1995)

necessary data are available. The basic economic idea is that the price of the infringing product is increased to its “virtual price” where its demand is zero, and the share of its sales to the patent owner’s product and other competing products is determined from the econometric model.<sup>10</sup>

Panduit factor (3), which asks whether the patent holder had sufficient manufacturing and marketing capability to make the additional sales in the but-for world, usually comes down to the ability of the patent holder to expand its current operations by adding an additional shift at an existing manufacturing plant to expand output or to invest in additional manufacturing capacity. This factor may not be as important 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.

Panduit factor (4) requires that an estimate of the patent holder’s incremental profit on the additional sales be calculated. As mentioned above, it is important to consider all of the potential incremental costs associated with the additional sales. Typically the incremental costs can be calculated based on existing cost data from the patent holder.

We now turn to Panduit factor (2), which concerns the absence of non-infringing substitutes. This factor is the main focus of this paper. In principle, it comprises both a demand-side consideration (substitute non-infringing products already on the market) and a supply-side consideration (substitute non-infringing technologies that the infringer could have used). On the demand side, however, US courts do not require that no non-infringing substitutes exist 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 non-infringing substitute product exists, but instead how much demand of the infringing product would shift to the patent-holder’s product as opposed to the non-infringing substitute products. We discussed above econometric techniques that permit estimation of the substitution among these competing products.

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<sup>10</sup> See e.g., J. Hausman and G. Leonard, “Competitive Analysis Using a Flexible Demand Specification,” *Journal of Competition Law and Economics*, 1, 2005.

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, this determination may be quite difficult because often no real world observations of production exist absent infringement. At one extreme, the infringer might have exited the 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 may claim it could have costlessly "invented around" the patented technology and produced the identical product at the same cost as using the patented technology. Questions regarding the economic rationality of this claim arise 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 ascertaining whether the alternative technology could have been used, 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 non-infringing 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 non-infringing substitute product. Where the patent is a production process patent, the cost of production using the non-infringing 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 non-infringing 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 closely related situation may occur when the infringer has previously used a non-infringing technology and subsequently adopted the infringing technology. In the but-for world, the infringer can claim that it would have continued to use the non-infringing technology. However, since the infringer would adopt the infringing technology only if it led to increased profits, again the older non-infringing 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.

### **C. The *Grain Processing* Decision**

#### **1. History of the Litigation**

The *Grain Processing* case lasted eighteen years and went to the CAFC three times—a story worth of a latter day Dickens. Grain Processing and its infringing competitor America Maize sold large quantities of maltodextrins, which are food additive which food properties such as binding and viscosity and preserve food properties at low temperatures.<sup>11</sup> Food processors use maltodextrins in products such as drinks, cereals, and frozen foods. Grain Processing owned a patent, “Low D.E. Starch Conversion Products,” which patented maltodextrins with particular attributes and processes for their production. Grain Processing manufactured and sold maltodextrins since 1969.

American Maize began selling maltodextrins in 1974. American Maize sold a particular maltodextrin, Lo-Dex 10, over the entire period that Grain Processing owned the rights for the patent at issue. However, American maize used four different production processes over the time period to produce Lo-Dex 10. From 1974 to 1982, American Maize used a particular process that was found to infringe Grain Processing’s patent by the Court of Appeals for the Federal Circuit (CAFC).<sup>12</sup> In 1982, American Maize changed its process, but Grain Processing claimed that the new process also

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<sup>11</sup> The details of the case are taken from the final Appeals court decision, *Grain Processing Corp. v. American Maize-Products Co.*, 98-1081, U.S. Court of Appeals for the Federal Circuit.

<sup>12</sup> The original district court decision (the lower court) found that American Maize did not infringe. This decision was reversed by the CAFC. Absent exceptional circumstances the CAFC is the final decision in patent litigation because the Supreme Court only very rarely reviews patent decisions.

infringed its patent. The CAFC found that the new process also infringed the patent. American Maize was enjoined from continuing to use either of the infringing processes.

American Maize developed a third process to manufacture Lo-Dex 10. The District Court found that American Maize's customers judged this new product to be equivalent to the product from the first two processes. American Maize used the third process over the period 1988-1991. However, in 1990, Grain Processing once again claimed that the new process infringed its patent. While the District Court did not find infringement, the CAFC found that the new process did infringe the patent.

American Maize tried a fourth time and developed yet another process to manufacture Lo-Dex 10. The District Court found that it took American Maize only two weeks to develop this new process. However, this new process had higher cost than the preceding processes. Grain Processing did not challenge this new process and American Maize used the process for 6 months in 1991 until the patent expired.

## **2. Damages Claims in *Grain Processing***

Regarding American Maize's third process, Grain Processing claimed lost profits based on lost sales. The District Court denied lost profits and granted a reasonable royalty of 3%, rather than the 28% asked for by Grain Processing.<sup>13</sup> The basis of the Court's decision to deny lost profits was Grain Processing's failure to satisfy Panduit factor (2): absence of acceptable non-infringing substitutes. The District Court ruled that American Maize "could have produced" a non-infringing substitute using the fourth process that it developed in 1991. While American Maize did not actually manufacture and sell the non-infringing product until the final six months prior to patent expiration, the District Court decided that its availability in the last six month of the patent's lifetime "scotches [Grain Processing's] request for lost-profits damages." The District Court ruled that buyers found that the infringing and non-infringing products were equivalent. The District Court stated that "no one argues that any customer cared a whit about the products' descriptive ratio." Thus, the District Court set the 3% reasonable royalty rate

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<sup>13</sup> *Grain Processing Corp. v. American Maize-Products Co.*, 893 F. Supp. 1386, USPQ2d (N.D. Ind. 1995). The trial was a bench trial (no jury), so Judge Easterbrook decided the case.

based on an estimate of the cost difference between the non-infringing process and the third (infringing) process.

Grain Processing appealed the District Court's decision, claiming that it should have received lost profits, which presumably would have considerably exceeded the royalty based on the 3% royalty rate. Grain Processing's main claim was that the District Court's decision was based on "a noninfringing substitute that did not exist during, and was not developed until after, the period of infringement."<sup>14</sup> The CAFC reversed the District Court's decision, ruling that to qualify as an acceptable non-infringing substitute the product or process must be "available or on the market at the time of infringement." The CAFC remanded the case to the District Court for further determination of lost profits. On remand, the District Court again denied lost profits to Grain Processing. It found that the non-infringing process was actually available during the period of infringement. The District Court claimed that American Maize could have adopted the non-infringing process in 1979 but did not do so because it was a more expensive process. The District Court found the products to be equivalent independent of the manufacturing process and therefore found a failure of the Panduit factors, which it interpreted as requiring "economically significant demand for a product having all...attributes" of the patented product. The District Court found that such a demand did not exist because market demand could have been met hypothetically by the non-infringing process. Since Grain Processing and American Maize were the only two manufacturer of this type of maltodextrins, if American Maize were not in the market, Grain Processing would have gained most of the sales made by American Maize. Thus, lost profits likely would have been substantial based on lost sales.

The CAFC affirmed the District Court's opinion, stating that the non-infringing product was an "acceptable substitute for the claimed invention." The CAFC ruled that "...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

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<sup>14</sup> *Grain Processing Corp. v. American Maize-Products Co.*, 108 F.3d 1392 (Fed. Cir. 1997)

owner rather than leave the market altogether. The competitor in the “but for” marketplace is hardly likely to surrender its complete market share when faced with a patent, if it can compete in some other lawful manner.”<sup>15</sup>

The CAFC considered the question that it took American Maize over 12 years to develop a non-infringing process to manufacture maltodextrin. The CAFC found that if an alleged alternative is not on the market during the period in which the patent owner claims damages, “a trial court may reasonable infer that it was not available as a non-infringing substitute at that time.” The burden then switches to the infringer who has to demonstrate that the non-infringing substitute was in fact available during the infringement period. The CAFC stated that “mere 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.” Here the CAFC agreed with the District Court that economic reasons were the “sole reason” that American Maize used the infringing process because it cost less to use. Further, both the CAFC and the District Court found the “substantial profit margins” on Lo-Dex 10 were sufficient to conclude that American Maize would have used the more costly non-infringing process without increasing its prices. The CAFC decided that American Maize could have used the higher cost non-infringing process throughout the period beginning in 1979, even though it did not actually use the process until 1991.

### **III. Options and the US Patent System**

The US patent system, which dates to the 18<sup>th</sup> century, was based on the British system. The basic idea is that a patent confers upon the holder the property right to exclude the use of its patented product or process for a given period of time.<sup>16</sup> In return for the period of exclusivity, the patent holder has to describe the nature of the patented invention so that, after the expiration of the patent, the product or process will enter the public domain where it can be used for free by the public.

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<sup>15</sup> *Grain Processing Corp. v. American Maize-Products Co.*, 98-1081, U.S. Court of Appeals for the Federal Circuit.

<sup>16</sup> Strictly speaking, a patent gives the holder the right to sue to exclude an infringer. The court may find that the patent is invalid.

If an infringer uses the patent without a license to do so, it is subject to monetary damages to compensate the patent holder for the use of its property. In *Grain Processing* the infringing company, American Maize, made an infringing use of the patent until the last six months of the lifetime of the patent. Since both the District Court and CAFC found “substantial profit margins” on the American Maize product, we find it reasonable to conclude that a duopoly situation likely existed with no close substitute for the products at issue. Thus, in the absence of American Maize from the market it is likely that the patent holder Grain Processing would have made even greater profit margins since it would have been in a position of considerable market (monopoly) power with no close substitutes to constrain the price. However, instead American Maize infringed the patent and made “substantial profit margins.” In our view, the *Grain Processing* decision gives infringers such as American Maize a “free option.”

#### **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. 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. 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. 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 option will be exercised. Otherwise, it 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.

Real options are closely associated with financial options. Real options involve “real” assets instead of financial assets. Thus, real options involve the opportunity but not the obligation to modify a project. Some common examples are the option to expand a project, the option to abandon a project, or the option to modify a technology used in a project. Real options are valuable for a firm 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. The ability to better adapt to future uncertain outcomes is often worth the extra expenditure. Indeed, a leading finance textbooks discuss this flexibility real option under the name of “production options.”<sup>17</sup>

While we have stressed the value of options, government regulation can often grant “free options” to certain firms. For example, under the US Federal Communications Commission’s application of the Telecommunications Act of 1996, incumbent owners of telecommunications networks were required to rent their networks elements (e.g., loops) to new entrants on the basis of a monthly contract. Thus, while 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. 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. Hausman (1997, 2002, 2003) termed this type of regulation a “free option.”<sup>18</sup> Since a free option is the transfer of value from one party to another, it will have consequences on economic incentives. As explained by Hausman, grant of a free option will have negative economic consequences on investment by the incumbent provider since a portion of the value of its investment has been transferred to the new entrant. This outcome occurred in the US, and the FCC has now changed its policy so as

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<sup>17</sup> R. Brealey, S. Myers, F. Allen, *Principles of Corporate Finance*, (New York: McGraw Hill, 8<sup>th</sup> ed.), 2005, p. 262, Ch. 22, pp. 597ff.

<sup>18</sup> See J. Hausman, "Valuation and the Effect of Regulation on New Services in Telecommunications," *Brookings Papers on Economic Activity: Microeconomics*, 1997; "The Effect of Sunk Costs in Telecommunication Regulation," in J. Alleman and E. Noam, eds, *The New Investment Theory of Real Options and its Implications for Telecommunications Economics*, 2002 and "Regulated Costs and Prices in Telecommunications," in G. Madden ed. *International Handbook of Telecommunications*, 2003.

not to require incumbents to rent network elements from their new investment in telecommunications networks.<sup>19</sup>

### **B. Options and *Grain Processing***

We now apply a real options analysis to the decisions in the *Grain Processing* case. To keep the analysis straightforward, we will ignore the last 6 months of the damage period before patent expiration when American Maize adopted a non-infringing production process. Thus, we assume that throughout the period that American Maize used a production process that infringed Grain Processing's patent. We further assume that American Maize never used a non-infringing process, but such a process was known and available for American Maize to adopt throughout the period. When Grain Processing sues for patent infringement and claims lost profits for damages, American Maize will be able to claim that it could have used the non-infringing process throughout the period, although in actuality it never adopted the non-infringing process. We further assume, as actually happened, that the courts will deny lost profits because Panduit factor (2) is not satisfied. Instead, Grain Processing will only receive a reasonable royalty in the event that the patent is found valid and infringed. Thus, if the patent is found by the Court to be either invalid or not infringed American Maize need pay no damages to Grain Processing. Alternatively, if the patent is found to be 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 non-infringing. The firm's per period profits are  $\pi_1$  if it uses technology 1 and  $\pi_2$  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, i.e., litigation costs, are zero).<sup>20</sup> The probability that the patent is valid and infringed by the first technology is  $\theta$ . If the patent is found to be valid and infringed, the firm must

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<sup>19</sup> For a discussion of this outcome see J. Hausman and G. Sidak, "Did Mandatory Unbundling Achieve Its Purpose? Empirical Evidence from Five Countries," with G. Sidak, *Journal of Competition Law and Economics*, 1, 2005.

<sup>20</sup> Litigation costs can be included by deducting them from profits.

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.

If the firm chooses technology 2, its total expected profits over the two periods are  $2\pi_2$ .<sup>21</sup> 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 non-infringed. Thus, if the firm chooses technology 1, its total expected profits are

$$\theta(\pi_1 + \pi_2 - D) + (1 - \theta)2\pi_1 = 2\pi_1 - \theta(\pi_1 - \pi_2) - \theta D. \quad (1)$$

The firm will choose technology 1 if

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

or, rearranging, if

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

Thus, if the damages award  $D$  is sufficiently large, 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 (i.e., some investment costs are sunk) and if the decision to invest can be delayed while uncertainties are resolved.<sup>22</sup> Under these conditions, there is a value to 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

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<sup>21</sup> 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.

<sup>22</sup> Dixit, A. and R. Pindyck, *Investment Under Uncertainty*, Princeton Univ. Press, Princeton, NJ, 1994. p. 6.



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.

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 value of using technology 1 and retaining the option is affected by the *Grain Processing* decision.

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  $D = \pi_1$ . Prior to *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 (i.e., its lost profit damages) would be equal to the potentially infringing firm's profits on these sales and damages would be  $D = \pi_1$ .<sup>23</sup> 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  $\theta$ , 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 above, 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

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<sup>23</sup> The patent owner might additionally claim price erosion damages. In that case,  $D > \pi_1$  is possible.

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

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

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 turn it down.

### C. 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*. There are assumed to be 13 years until patent expiration. The infringer’s revenue each year is \$100 and the profit margin when using the patented technology is 50%. Each year there is some probability that a finding of patent validity and infringement will occur, conditional on it not having occurred already. This “hazard rate” is assumed to be constant each year at 0.1 so that we assume an exponential density function.<sup>24</sup> If a finding of validity and infringement occurs, the infringer must pay damages for past infringement and switch to the alternative non-infringing technology for the remaining years; the profit margin for these years is reduced to 47% (to reflect the cost increase associated with using the non-infringing technology). The infringer discounts the future at a 6% rate.

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<sup>24</sup> We could change the constant probability assumption to allowing 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 do not depend on the particular distribution chosen.

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 Panduit factor (2) under *Grain Processing*. In particular, damages are assumed to equal 3% of the infringing revenues. In this scenario, the expected present discounted value of the infringer's cash flows are \$425. Thus, the value to the infringer of choosing to use the patented technology increases by 31% due to *Grain Processing*. This change in values would be expected to have a significant effect on an infringer's decision whether to use the patented technology or avoid infringement through use of the non-infringing 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 non-infringing 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 US patent system.<sup>25</sup>

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<sup>25</sup> See e.g. J. Hausman and J. MacKie-Mason, "Price Discrimination and Patent Policy," *Rand Journal of Economics*, 19, 1988 for a discussion of how economic returns to

#### **IV. Lost Profits If the Infringer Adopts a Non-Infringing Alternative Technology in the But-For World**

Up until now, we have taken as given one of the underlying assumptions of the *Grain Processing* decision: that, having adopted the non-infringing 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 be based 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 non-infringing process, its marginal costs in the but-for world would have been higher by an amount approximately equal to 3% of the price. The *Grain Processing* decision assumes that American Maize would have absorbed the additional 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. This increase in American Maize's price would, in turn, 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 sustained by the patent owner in the context of two basic models of competition: Nash-Bertrand with differentiated products and Cournot with homogeneous products.<sup>26</sup>

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patents interact with the U.S. patent system's goal of increasing innovation. .

<sup>26</sup> J. Bulow and P. Pfleiderer, "A Note on the Effect of Cost Changes on Prices," *Journal of Political Economy*, 91, 1983 showed how a monopolist optimally changes its price in response to a marginal cost change. J. Hausman and G. Leonard, "Efficiencies From the Consumer Viewpoint," *George Mason Law Review*, 1999 showed how marginal cost efficiencies resulting from a merger lead to lower prices in the context of several models of competition.

### A. Nash-Bertrand 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  $c_i$ .<sup>27</sup> The firms simultaneously set prices in a one-shot game. Firm  $i$  chooses  $p_i$  to maximize profits

$$(p_i - c_i)Q(p_i, p_j) \quad (5)$$

taking  $p_j$  as given.

We examine the resulting Nash equilibrium. The first order condition for firm  $i$  is

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

The system of two equations of form (6) 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 non-infringing 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

$\left. \frac{\partial p_2}{\partial c_2} \right|_{p_1}$ , i.e., the change in firm 2's optimal choice of price resulting from the decrease in

its marginal cost:

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

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<sup>27</sup> We assume that the marginal costs are constant over the relevant range of output.

The numerator is negative and non-zero 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 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.<sup>28</sup> We obtain

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

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:

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

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 prices 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.

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<sup>28</sup> For a general approach to comparative statics in this type of situation, see A. Dixit, "Comparative Statics for Oligopoly," *International Economic Review*, 27, 1986.

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

$$\pi_1(c_2) = (p_1(c_2) - c_1)Q_1(p_1(c_2), p_2(c_2)) \quad (10)$$

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

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

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

$$Q_i = \alpha - \beta p_i + \gamma p_j \quad (12)$$

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

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

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

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

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

$$\frac{\partial p_2}{\partial c_2} = \frac{2\beta^2}{4\beta^2 - \gamma^2}, \quad \frac{\partial p_1}{\partial c_2} = \frac{\beta\gamma}{4\beta^2 - \gamma^2} \quad (15)$$

Thus, in the boundary case where  $\beta = \lambda$ , 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 firm 1 sustains as a result of the infringement by firm 2, assuming that in the but-for world firm 2 would utilize the alternative non-infringing technology (i.e., 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  $\pi_i = 5000$ .

If the infringer, firm 2, is forced to use the non-infringing 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 non-infringing 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% 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

Denote inverse market demand by  $P(Q_1 + Q_2)$  where  $Q_i$  is the quantity supplied by firm  $i$ . Again we assume constant marginal costs  $c_i$ . The first order condition for firm  $i$  is

$$\frac{\partial P}{\partial Q} Q_i + (P(Q_1 + Q_2) - c_i) = 0 \quad (16)$$

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

$$\frac{\partial Q_1}{\partial c_2} = - \frac{\frac{\partial Q_1}{\partial c_2} \frac{\partial P}{\partial Q} + Q_1 \frac{\partial^2 P}{\partial Q^2}}{2 \frac{\partial P}{\partial Q} + Q_1 \frac{\partial^2 P}{\partial Q^2}} \quad (17)$$

Because the numerator and the denominator of the second term of equation (17) are both negative, we have that  $\text{sign}\left(\frac{\partial Q_1}{\partial c_2}\right) = -\text{sign}\left(\frac{\partial Q_1}{\partial c_2}\right)$ , 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 while 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  $Q_i = 100$  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 non-infringing 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 non-infringing 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.

## V. Conclusion

Patent litigation has become an increasingly important consideration in business strategy. Damage awards in patent litigation are supposed to compensate the patent owner for economic harm created by infringement. The *Grain Processing* decision has decreased the expected value of damages from infringement by conferring a “free option” on the infringer. The infringer is permitted to claim that in the but-for world it would have adopted a non-infringing technology, if such a technology exists. The infringer does not actually have to practice the technology; the existence of the technology is sufficient. 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 the conclusion of the District Court with respect to the absence of lost profits is contradicted by most models of firm behavior and profit maximization. When a firm’s costs increase, it typically will increase its price. Thus, if the infringer were to adopt the higher cost non-infringing 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 non-infringing 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 substantially

exceed a reasonable royalty-only damage award. Thus, we conclude that the Court's decision that no lost profits existed if the infringer were assumed to have adopted the non-infringing technology is inconsistent with most economic analysis. The economic basis for the *Grain Processing* decision is at odds with most models of profit maximization by firms acting in an economically rational manner.

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