

Lost Profits and Price Erosion in Patent Infringement Cases: Implications of *Crystal Semiconductor*

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I. Introduction

A U.S. patent confers on a patentee an exclusive but temporary intellectual property right for the invention of a useful, novel, and non-obvious product, process, or design.¹ This property right over the life of the patent—a “patent monopoly”—encourages innovation by allowing patentees to internalize any returns to their invention either by excluding others from the manufacture, use, or sale of the patented invention or technology, or by licensing its use. Without such protection, the incentive for potential patentees to devote resources to R&D likely would be diminished. Because patents are valuable, patentees might find themselves in the position of having to protect this type of intellectual property from infringers. In such matters, experts often are retained to estimate damages which may take the form of a lost profits analysis.

When seeking lost profits in patent infringement cases, a plaintiff-patentee often claims lost profits on the units sold by the infringer and on the units sold by the patentee during infringement. That is, the two components to a total lost profits claim typically are (1) lost profits on lost sales, and (2) lost profits on actual sales. The former is meant to compensate a patentee for the profits on that part of the infringer’s sales that would have been made by the patentee absent infringement. The latter is meant to compensate a patentee for the change in market structure due to the “entry” of the infringer which may have forced the patentee to lower prices on its actual sales during infringement (“price erosion”). When properly calculated, these two components yield a total lost profits award that fully compensates the patentee for the infringement.

In estimating damages due to price erosion, however, one needs to explicitly recognize the role that price elasticity of demand plays in estimating the effect of a higher “but-for” price on volume sold. This is especially important in light of the recent admonition by the Court of Appeals for the Federal Circuit (“CAFC”) in *Crystal Semiconductor*² not to ignore this aspect of damage calculations. With

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¹The U.S. Constitution (Art. 1, Sec. 8, Cl. 8) explicitly authorizes the establishment of a U.S. patent system. Patents in the United States are granted by the federal government through the U.S. Patent and Trademark Office. The enabling “patent statute” can be found in Title 35 of the U.S. Code.

²*Crystal Semiconductor Corp. v. TriTech Microelectronics International Inc.*, Fed. Cir., No. 99-1558 (March 7, 2001). Subsequent to the Federal Courts Improvement Act of 1982, the Court of Appeals for the Federal Circuit (CAFC) in Washington, D.C. was created and given the exclusive jurisdic-

a simple example, this paper illustrates the theoretical basis for the CAFC's concern, and demonstrates (in a general way) several methods to compute total lost profits in patent matters that properly consider elasticity issues.

II. The CAFC's View on Lost Profits and Price Erosion

Lost Profits

The discussion of patent damages in this paper is confined to lost profits.³ A commonly used and accepted practice by patentees seeking lost profits due to infringement is to use the four-part "test" enumerated in *Panduit*,⁴ perhaps the leading case concerning lost profits in patent infringement matters. This test requires that the patentee prove (1) demand for the patented product, (2) absence of acceptable non-infringing substitutes, (3) possession of manufacturing and marketing ability capable of exploiting the demand, and (4) the amount of profit the patentee would have made absent infringement. Patentees historically were able to prove damages to the courts based upon lost profits if they "passed" this test.

The *Panduit* decision has generated a substantial quantity of literature with a significant amount of it criticizing the second part of the *Panduit* test.⁵ Simply put, under *Panduit's* second factor, lost profits damages often were barred if non-infringing substitutes were shown to be present; if not, then patentees typically were assumed to have been able to make all the infringer's sales.⁶ Over time, however, the CAFC's economic reasoning has evolved beyond the mechanical application of *Panduit*. For example, in *State Industries*,⁷ the CAFC recognized that the mere existence of acceptable non-infringing substitutes should not preclude recovery of lost profits when more than two suppliers exist in the relevant market.

The CAFC's economic reasoning concerning lost profits has evolved in other areas, too, and in ways that most economists likely would find reason-

tion over appeals in patent matters. Patent matters still may be appealed to the U.S. Supreme Court.

³In many situations (e.g., where actual lost profits cannot be shown, where the patent holder does not make—or have the ability to make—the patented product at issue, or where the infringement occurs solely in markets that the patentee does not or cannot serve), a "reasonable royalty" may be more appropriate in compensating the patentee. A reasonable royalty approach estimates the royalty rate that would have been determined in a hypothetical negotiation between a willing licensor and licensee prior to the alleged infringement. The *Georgia Pacific* case enumerates 15 factors for determining a reasonable royalty in a patent damages case. (*Georgia-Pacific Corp. v. U.S. Plywood Corp.*, 318 F.Supp. 1116, 1120 (S.D.N.Y. 1970); 446 F.2d 295 (2d Cir. 1971); cert. denied, 92 S.Ct. 105 (Oct. 12, 1971)).

⁴*Panduit Corp. v. Stahl Bros. Fibre Works, Inc.*, 575 F.2d 1152 (6th Cir. 1978).

⁵See, for example, Epstein (2000) and O'Brien (2000).

⁶In most instances, some of the infringer's sales likely are made at the expense of non-infringing sellers. In any event, it often does not make (economic) sense to assume that the patentee would have made all of the infringer's sales. For example, the infringer may have added value such as marketing/distribution in order to reach areas not possible for the patentee. Also, if a patented product has many "economic" (as opposed to "technical") substitutes, it is unlikely that a patentee will possess patent-related market power. Hence, it is unlikely that the patentee would suffer significant lost sales in the face of infringement.

⁷*State Industries, Inc. v. Mor-Flo Industries, Inc.* 883 F.2d 1573 (Fed. Cir. 1989). See Epstein (2000) for a detailed economic analysis of *State Industries*.

able. Most notably, this evolution in thinking concerns product differentiation and the construction of the “but-for” world. For example, in *BIC Leisure Products*,⁸ the CAFC addressed the degree of substitutability between a patentee’s product and an infringer’s product. There, the CAFC held that it was appropriate *not* to award lost profits to the patentee because the products at issue—although deemed to be in the same market—were sufficiently differentiated so that the infringement did not cause lost sales to the patentee. In *Comair Rotron*,⁹ the CAFC again addressed the issue of product heterogeneity in noting that “if the products are not sufficiently similar—in terms of price, product characteristics, and marketing channel—to compete for the same customers, the infringer’s customers will not necessarily transfer their demand to the patentee’s product in the absence of the infringing product.” (p. 17-18)

In *Grain Processing*,¹⁰ the CAFC emphasized that the “but-for” condition of *both* the patentee and the infringer should be considered in constructing the “but-for” world. In essence, an infringer here may be able to illustrate that “but-for” its infringement, it would have made and sold in competition with the patentee a non-infringing product and still have competed with the patentee. In doing so, the infringer would still be in the market in the “but-for” world of non-infringement (albeit with a non-infringing product), and this competition with the patentee could offset (or completely negate) any harm to the patentee as a result of the infringement. And, in *Crystal Semiconductor*, the CAFC was unconvinced that Crystal (the plaintiff), arguing that in the “but-for” world it would have charged higher prices, could have done so “without evidence of barriers to entry and expansion that would have prevented competitors from taking over Crystal’s supply.” (p. 50)

Price Erosion

In contemplating total lost profits, courts have recognized that—in addition to lost sales—patent infringement causes price erosion.¹¹ Price erosion may translate into lost profits on each unit sold under infringement if the “but-for” price exceeds the actual price under infringement.¹² Also, with downward-sloping demand, the higher “but-for” price implies that the patentee’s lost unit sales are less than those garnered by the infringer. How much less depends on the price elasticity of demand. Therefore, one needs to ascertain how much higher the price—and lower the quantity demanded—would have been absent infringement. This, of course, involves price elasticity issues. If one ignores the phenomenon that the unit sales of the patentee in the “but-for” world generally

⁸*BIC Leisure Products, Inc. v. Windsurfing International, Inc.*, 1 F.3d 1214 (Fed. Cir. 1993).

⁹*Comair Rotron, Inc. v. Nippon Densan Corp.*, 33 U.S.P.Q.2d 1929 (Fed. Cir. 1995).

¹⁰*Grain Processing Corp. v. American Maize Products* 185 F.3d 1341, 1351 (Fed. Cir. 1999). See O’Brien, et al. (2001) for a more detailed analysis of *Grain Processing*.

¹¹For example, as recognized in *In re Mahurkar Double Lumen Litigation*, 28 U.S.P.Q.2d 1801 (N.D. Ill. 1993), aff’d, 71 F.3d 1573 (Fed.Cir. 1995), the “infringer’s activities do more than divert sales to the infringer. They also depress the price.”

¹²For this to occur, the patentee’s short-run static profit-maximizing price must be higher absent infringement. If this was not true and the patentee could have increased its short-run profits by lowering price unilaterally, then profit-maximizing behavior dictates such a move absent infringement.

will be lower than the total unit sales in the actual world (i.e., patentee plus infringer) when arguing for price erosion, then one needs a solid explanation for this violation of economic principles. As noted by Keeley (1999):

In some cases, experts testify that they can ignore the decrease in quantity demanded caused by the higher price because demand is (perfectly) inelastic. That is, quantity demanded is not responsive to price. However, this argument contradicts a basic economic proposition: a firm does not usually price in the inelastic portion of its demand curve. The reason is simple. If demand is inelastic at the current price, the firm can improve profits by increasing price. A profit-maximizing firm will increase price until it is no longer in the inelastic portion of its demand curve. (p. 8)

While it is a basic result in economics that a “static” profit-maximizing monopolist should always operate on the elastic portion of its demand curve, economic theory suggests several reasons why a firm may, in a short-run equilibrium, charge a price below the static monopoly price that very well may place it on the inelastic portion of its demand curve.¹³ However, while economists can argue whether demand is relatively elastic or inelastic and how this comports with various economic theories, what is clear is that ignoring a potential decrease in quantity demanded caused by a higher “but-for” price in claims of price erosion may not find favor in the CAFC, especially in light of these comments in *Crystal Semiconductor*:

Moreover, in a credible economic analysis, the patentee cannot show entitlement to a higher price divorced from the effect of that higher price on demand for the product. In other words, the patentee must also present evidence of the (presumably reduced) amount of product the patentee would have sold at the higher price. (p. 41)

All markets must respect the law of demand. See Paul A. Samuelson, *Economics* 53-55 (11th ed. 1980). According to the law of demand, consumers will almost always purchase fewer units of a product at a higher price than at a lower price, possibly substituting other products ... Markets typically have an elasticity greater than zero and less than infinity ...Crystal, however, presented no evidence of the elasticity of demand of the PC sound card CODEC market. Nor did Crystal make any estimates as to the number of sales it would have lost or kept had it increased its prices by 89¢ per unit. Thus, Crystal did not make a showing of ‘but for’ causation of price erosion. (p. 47)

¹³For example, it may be that the patentee is a multi-product firm producing complementary products with dependent demands (but separable and constant costs). In this case, it is possible that the pricing policy of the firm is to sell, say, the patented product below its short-run optimal price so as to raise the demand for its other good(s). Or, it may be the case that a patent monopolist producing only a single good may be pricing with respect to dynamic considerations (e.g., lower prices early on in the product’s life cycle are expected to raise demand in later periods, the production process of the patentee is characterized by learning-by-doing which gives the patent monopolist the incentive to produce more “now” than “later” so as to lower subsequent production costs, etc.). Such pricing practices are well-recognized examples that will cause the inverse of the price elasticity of demand to exceed its Lerner index, meaning that its price will be below the textbook “optimal” level.

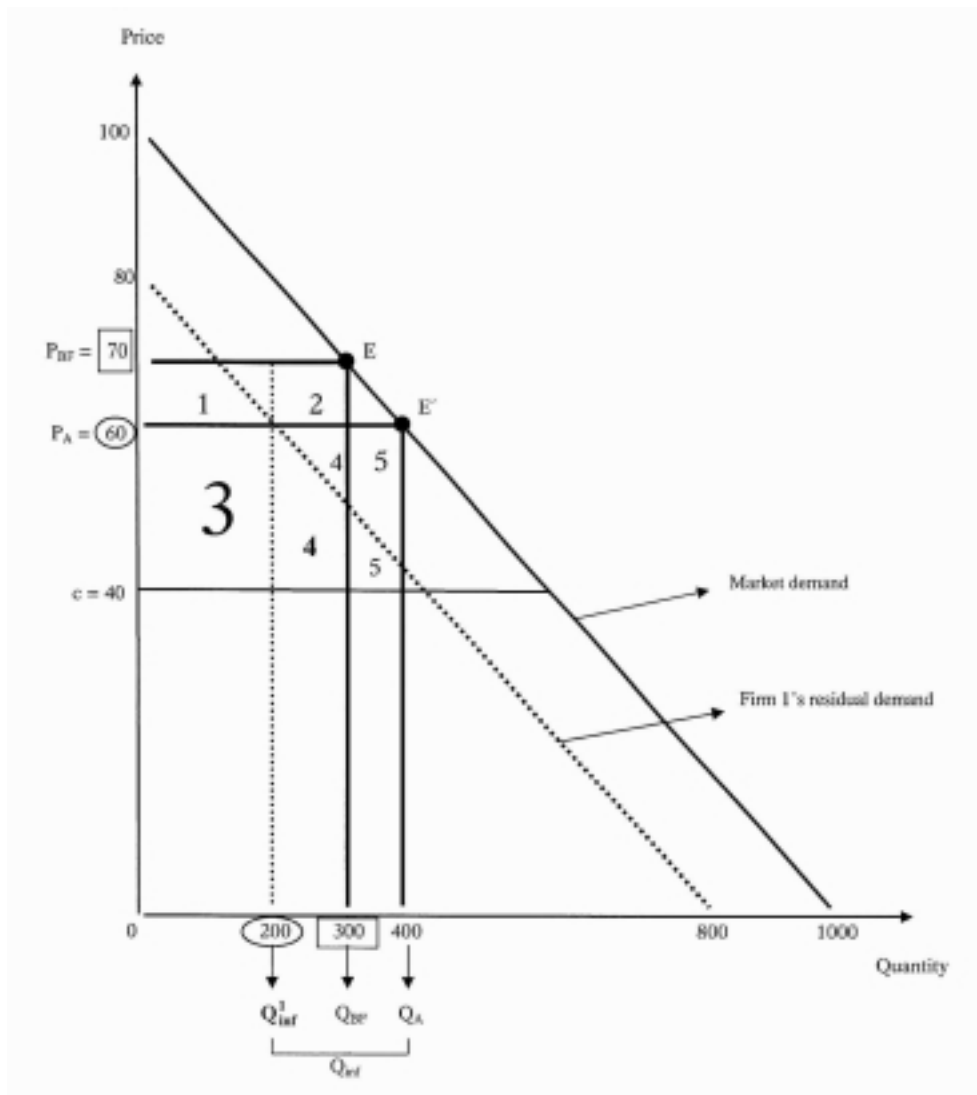


Figure 1

A Graphical Example

A simple example best illustrates the two parts of a total lost profits claim. This example adopts the demand and cost conditions contained in Werden, et al. (1999a, 1999b) and Epstein (2000); namely, that market (inverse) demand is linear of the form $P = a - bQ$ ($a = 100$, $b = 0.1$) and marginal cost, assumed to be constant over the relevant range of output and common to all firms, equals

\$40/unit (denoted as “c” in the derivations below).¹⁴ It is assumed that consumers view the product at issue as homogeneous. Absent the patent infringement, assume that Firm 1 would be a monopolist.¹⁵ With infringement (denote the infringing firm as Firm 2), Firms 1 and 2 constitute a duopoly interacting in a standard oligopoly fashion.¹⁶

Given the stated demand and cost conditions, Point E in Figure 1 illustrates Firm 1’s short-run profit maximizing price-quantity combination without infringement (\$70 and 300, respectively), with profits of \$9,000 (indicated by area 1+2+3+4). With infringement, Firm 1 no longer faces the market demand curve but now faces a residual demand,¹⁷ and finds it optimal to produce 200 units at a price of \$60/unit. As Firm 1 finds itself in a more competitive environment after the “entry” of the infringer, the demand facing it becomes more elastic, hence its price and profit margin fall relative to the situation absent infringement.¹⁸

Given the symmetry of this example, Firm 2 also finds it profit-maximizing to sell 200 units at a price of \$60/unit. With infringement, market output now is 400 units sold at \$60/unit (Point E’ on the market demand curve in Figure 1.) Market output is higher and market price is lower with infringement vis-à-vis non-infringement (compare Point E’ with E). Firm 1’s profit under infringement (indicated by area 3) equals \$4,000. Therefore, in order to make Firm 1 “whole,” a total lost profits award of \$5,000 is necessary.¹⁹

Figure 1 illustrates the two components of Firm 1’s total lost profits: lost profits on lost sales during infringement equal \$3,000 (indicated by area 2+4), and lost profits due to price erosion equals \$2,000 (indicated by area 1). The sum of these two damage components equals Firm 1’s total lost profits of \$5,000 (area 1+2+4). When added to Firm 1’s actual profits of \$4,000 during infringement, the patentee is returned to the same economic position that would have existed without infringement (\$9,000 in profit).²⁰

If damages were to be awarded on the assumption that all of Firm 2’s 200 units sales should go to Firm 1, Firm 1’s damages would be \$4,000 [200 times

¹⁴In calculating lost profits on lost sales, all variable (and semi-variable) costs should be considered as the incremental or marginal cost of making the lost sales. If no additional plant and equipment are required to make these additional sales, then any truly fixed costs should be excluded from this calculation.

¹⁵Even with a patent monopoly, however, the patentee may not be able to exercise market power if the presence of non-infringing substitutes is sufficient to render unprofitable any significant price increase in excess of economic costs.

¹⁶The Cournot model of oligopoly is used here. See Epstein (2003b) where the “homogeneous product” assumption is relaxed in the context of a Cournot oligopoly.

¹⁷In this example, Firm 1’s residual inverse demand curve is $P = 80 - 0.1Q$.

¹⁸As a monopolist, Firm 1’s margin is approximately 42.8% implying price elasticity of *market* demand equal to -2.34 (at Point E in Figure 1). As a duopolist, Firm 1’s margin is approximately 33.3% implying a price elasticity of *residual* demand of -3.0.

¹⁹Established case law in patent damages holds that the main purpose of awarding patent damages is to “make whole” the patentee. That is, the patentee ought to be returned to the same economic position that it would have been in absent infringement.

²⁰As noted by Hall and Lazear (2000), a different yet equivalent way to calculate total lost profits would be to (1) calculate the patentee’s “but-for” revenue, and (2) subtract from it both the patentee’s revenue under infringement and the patentee’s incremental cost of producing the extra quantity in the “but-for” versus the actual world, or $\$21,000 - \$12,000 - \$4,000 = \$5,000$.

(\$60-\$40), or area 4+5 in Figure 1].²¹ If Firm 1's damages were calculated in this manner, it would be inappropriate for Firm 1 also to seek damages for price erosion by arguing that *all* 400 units could have been sold at the higher price (\$70 versus \$60). Doing so would result in a damage award for price erosion equal to \$4,000 which, when added to the first \$4,000, would result in total damages of \$8,000—well in excess of the proper damage award of \$5,000. Lack of consideration for the price *and* quantity that would obtain in the “but-for” world generally will overstate the damages necessary to return the patentee to its pre-infringement profitability.²²

III. Calculating Total Lost Profits with Proper Attention Paid to Price Elasticity

An Example with Two Firms

Total lost profits consist of those due to lost sales and price erosion. To calculate total lost profits in practice, one can proceed as follows. First, compute the expression equivalent to the total unit sales of the infringer (Q_{inf}) multiplied by the patentee's incremental margin under infringement ($P_A - c$)

$$(1) \quad Q_{\text{inf}} \times (P_A - c)$$

The three variables in expression (1) ought to be observable to the expert. Next, assume either (i) that based upon historical pre-infringement prices, the patentee would have increased its prices on average, say, x% per year so that during infringement we can observe the patentee's actual and “but-for” prices (based upon the pre-infringement trend or amount),²³ or (ii) that a market-share approach is used to calculate the patentee's estimated “but-for” quantity.²⁴ In using the former approach—consistent with the law of demand—it can

²¹It would be inappropriate to use Firm 1's pre-infringement margin in calculating these damages because the higher market quantity under infringement (400 units) is sold at a lower market price (\$60) compared to the pre-infringement situation of 300 units being absorbed at a market price of \$70.

²²Sometimes, in practice, lost profits on lost sales are computed as the total revenues of the infringer derived from infringing sales multiplied by the contribution margin of the patentee (i.e., 1-variable cost percentage, or that amount of revenue going toward fixed costs and profit, if any). In this example, such a calculation yields \$4,000 using the patentee's post-infringement margin and \$5,143 using the pre-infringement margin.

²³Such an approach has legal precedent. See, *Minnesota Mining & Mfg. Co., v. Johnson & Johnson Orthopaedics*, 976 F.2d 1559, 1579, 24 U.S.P.Q.2d 1321, 1337, Fed. Cir. 1992, (“price erosion was calculated based on pre-infringement prices because the patentee and infringer occupied almost the entire market.”).

²⁴The CAFC (in *State Industries*), recognizing that the mere existence of acceptable non-infringing substitutes should not preclude recovery of lost profits when more than two suppliers exist in the relevant market, held that lost profits are owed to a patentee for the share of the infringing sales that would have gone to the patent owner “but-for” the infringement based upon the patentee's overall market share. In essence, the court multiplied the infringer's unit sales by the patentee's share of the total market (*including* the infringer). As pointed out by numerous commentators, it may have been more sensible to do the lost-profits-on-lost-sales calculation *excluding* the infringer from the market (i.e., use the patentee's share of *non*-infringing sales). Under such a “market share approach,” courts sometimes then award a reasonable royalty on the remainder of infringing sales. Such a bifurcated damage approach was upheld in *Crystal Semiconductor*. See Epstein

be expected that at the higher “but-for” price, the “but-for” quantity will be lower than the market output under infringement. How much less can be estimated using the price elasticity expression,

$$\varepsilon_p = \frac{\% \Delta Q_d}{\% \Delta P},^{25}$$

which can be rearranged to estimate the patentee’s “but-for” quantity, Q_{BF} ,

$$(2) \quad Q_{BF} = \left[1 + \left(\frac{P_{BF} - P_A}{P_A} \right) \times \hat{\varepsilon}_p \right] \times Q_A$$

In equation (2), P_A is the patentee’s actual price under infringement, P_{BF} is the patentee’s “but-for” price, Q_A is the actual market quantity, and $\hat{\varepsilon}_p$ is the estimated price elasticity of market demand (a negative value). Of course, to use equation (2), it is assumed that $\hat{\varepsilon}_p$ is known and that other relevant supply and demand factors—unrelated to the infringement but which affect prices, quantities, and profits—are unchanged pre- and post-infringement.²⁶ Once equation (2) is used to compute Q_{BF} , the following expression can be calculated:

$$(3) \quad [(P_{BF} - P_A) \times Q_{BF}] - [(Q_A - Q_{BF}) \times (P_A - c)]$$

Combining expressions (1) and (3) yields the expression for total lost profits,

$$(4) \quad \underbrace{Q_{inf} \times (P_A - c)}_{1st \ Term} + \underbrace{[(P_{BF} - P_A) \times Q_{BF}]}_{2nd \ Term} - \underbrace{[(Q_{inf} + Q_{inf}^1 - Q_{BF}) \times (P_A - c)]}_{3rd \ Term}$$

where $Q_A = Q_{inf} + Q_{inf}^1$, and Q_{inf}^1 is Firm 1’s output under infringement.

Using the numbers from the example, equation (2) yields the patentee’s “but-for” quantity, Q_{BF} (given $P_{BF} = 70$ and $\hat{\varepsilon}_p = -1.5$), or 300.²⁷ Once Q_{BF} is calculated, expression (4)—total lost profits—yields \$5,000 when using $Q_{inf} = 200$, $P_A = \$60$, $c = \$40$, $P_{BF} = \$70$, $Q_{BF} = 300$, and $Q_{inf}^1 = 200$. These results can be seen in Graph 1. The 1st term in expression (4) (area 4+5) plus the 2nd term (area 1+2) minus the 3rd term (area 5) equals area 1+2+4 identified above as the proper amount of damages according to the example (i.e., \$5,000).

(2003a) for a detailed discussion and analysis of the “market-share approach” in light of *Crystal Semiconductor*.

²⁵In other words, the price elasticity of demand (ε_p) = $\frac{\text{the percentage change in the quantity demanded}}{\text{the percentage change in price}}$.

²⁶One way empirically to estimate $\hat{\varepsilon}_p$ (and to control for variation in market-relevant factors unrelated to the infringement) is to estimate the demand curve for the product under study using proper econometric techniques. From this estimation, a price elasticity of demand can be obtained and used in equation (2).

²⁷Note that at Point E’ in Graph 1, $\varepsilon_p = -1.5$. Since profit-maximization in the Cournot model properly incorporates elasticity issues, there is no need to empirically estimate $\hat{\varepsilon}_p$ if one decides to proceed using the Cournot model.

Using Critical Loss Analysis from Antitrust

“Critical loss analysis” and the use of “critical elasticities” have become standard analytical tools in antitrust (especially as it relates to horizontal merger analysis). These techniques properly consider price elasticity issues and readily can be found in the antitrust and industrial organization literature.²⁸ Critical loss is the maximum percentage loss in unit sales that a hypothetical monopolist will endure and still find a given price increase (e.g., 5%) profitable; the critical elasticity is the highest market elasticity of demand that a hypothetical monopolist could face and still find a given price increase (e.g., 5%) profitable. When used in practice, if the estimated loss from, say, a 5% price increase exceeds the calculated critical loss, or if the estimated price elasticity of market demand (pre-merger) exceeds the calculated critical elasticity, then such a price increase would not be profitable for a profit-maximizing monopolist.

The example in this paper is analogous to a merger to monopoly because, absent infringement, the patentee is assumed to be a patent monopoly. As a result, critical loss analysis is applicable and a key equation from this literature—which properly incorporates price elasticity considerations—can be used in the calculation of damages due to patent infringement. For example, it is well-established that under linear demand, an expression for the critical elasticity of demand (ϵ_p^c), in absolute value, is

$$(5) \quad \epsilon_p^c = \frac{1}{m + 2 \cdot \Delta P}$$

where “m” is the pre-merger margin (when doing merger analysis), and ΔP is the hypothesized post-merger percentage price increase.²⁹ From the example in this paper, $m = 0.3333$ and $\Delta P = 0.1667$. Using these values in equation (5) yields $\epsilon_p^c = 1.5$. With this estimated elasticity, equation (2) can be used to estimate the “but-for” quantity and total lost profits properly can be calculated using expression (4), or \$5,000. The advantage of using critical loss analysis and equation (5) is that the price elasticity of demand does not require econometric estimation.

An Example with Two or More Firms

One way to estimate total lost profits when the “but-for” world consists of more than the patentee, and in a manner that properly considers price elasticity issues, is through the use of non-cooperative oligopoly models. In practice, one method utilizing this approach is simulation. This technique is similar to that used in estimating post-merger price increases in horizontal merger

²⁸See, for example, Church and Ware (2000), at 607-610; Werden and Froeb (2002), and O’Brien and Wickelgren (2003).

²⁹This is Equation (19.10) in Church and Ware (2000), at 608.

analysis with differentiated products.³⁰ In patent infringement matters, the equilibrium absent infringement is simulated by imposing a marginal cost on the infringer such that its quantity goes to zero at which point the patentee's profits are estimated (Weiskopf (2000)). In such models, however, one still has to estimate (or assume) a matrix of own and cross-price elasticities, often with restrictive assumptions (e.g., invoking a symmetry of cross-price elasticities).

A detailed development of the simulation approach is not the focus of this paper. However, by exploiting several static equilibrium conditions of the Cournot model, one can illustrate how oligopoly models may be used to calculate total lost profits in a manner consistent with *Crystal Semiconductor* without the complexity (and data requirements) inherent in implementing the simulation approach. Under this framework, the use of several simple equilibrium relationships suffices to illustrate that long-standing models of oligopoly properly incorporate the price elasticity of demand in the computation of total lost profits.

Useful and well-established equilibrium conditions defining each firms' profit (Π) from the symmetric Cournot model are ³¹

$$(6) \quad \Pi_1 = \frac{(a-c)^2}{4b} = (P_1 - c) \cdot Q_1$$

$$(7) \quad \Pi_2 = \frac{(a-c)^2}{9b} = (P_2 - c) \cdot Q_2$$

The subscripts refer to the number of firms in the industry. Here, 2 is the number of firms in the actual world under infringement (duopoly); 1 is the number of firms absent infringement (monopoly). Dividing equation (6) by (7) yields the ratio of market profits in the "but-for" world to actual market profits,

$$(8) \quad \frac{\Pi_1}{2\Pi_2} = \frac{(P_1 - c)Q_1}{2(P_2 - c)Q_2} = \frac{9}{8}$$

³⁰The *International Journal of the Economics of Business*, 7(2), July 2000, is devoted entirely to the use of simulation techniques in a wide variety of industrial organization applications. In a typical simulation exercise, demand parameters are estimated econometrically using a variety of specifications (e.g., Almost Ideal Demand System, logit, log-linear, etc.) with high-frequency data (e.g., store-level scanner data) which allow for the recovery of an elasticity matrix consisting of own and cross-price elasticities. These estimated elasticities from the "front end" of the simulation exercise are combined with observed market data (e.g., prices, quantities, or market shares) to calibrate the demand system. After calibration, the profit maximization conditions of a differentiated products oligopoly then are manipulated in the "back end" and used to simulate the "but-for" market.

³¹Here, market (inverse) demand is assumed to be linear ($P = a - bQ$) and marginal costs constant. Therefore, "a" represents the intercept of the linear demand curve, "b" is the slope coefficient, and "c" is a constant marginal cost. Equations (6) and (7) are derived from equation (8.26) in Church and Ware (2000), at 244.

Using a market-share approach consistent with the symmetric Cournot model, the patentee's "but-for" quantity (as a monopolist) is $Q_1 = 300$.³² P_2 is the actual market price under infringement, or \$60. Given that $Q_2 = 200$, the "but-for" price (P_1) can then be solved for using equation (8) (i.e., $P_1 = \$70$). With this information, expression (4) can be used to estimate total lost profits equal to \$5,000.

This approach easily generalizes to an industry where there are n firms with infringement and $n-1$ firms without. For example, consider the case with three firms: the patentee, the infringer, and a non-infringing competitor ($n=3$). If each had equal shares of the relevant market during the period of infringement, then in the "but-for" world the plaintiff and the third competitor would share the market equally ($n=2$). Here, useful Cournot equilibrium conditions in an n firm industry are³³

$$(9) \quad \Pi_n = \frac{(a-c)^2}{(n+1)^2 b} \qquad (10) \quad Q_n = \frac{(a-c)n}{(n+1)b}$$

$$(11) \quad q_n = \frac{(a-c)}{(n+1)b} \qquad (12) \quad P_n = \frac{a+nc}{(n+1)}$$

In equilibrium, equation (9) gives each firm's profit (Π_n), equation (10) gives total market output (Q_n), equation (11) gives each firm's output (q_n), and equation (12) gives equilibrium market price (P_n). Using equation (9) for $n=2$ and $n=3$, the ratio of market profits in the "but-for" world to market profits in the actual world is

$$(13) \quad \frac{2\Pi_2}{3\Pi_3} = \frac{2(P_2-c)Q_2}{3(P_3-c)Q_3} = \frac{32}{27}$$

Given the demand and cost parameters in the example, under infringement each firm produces 150 units (from equation (11)), total industry output = 450 units (from equation (10)), market $P = \$55$ (from equation (12)), and each firm's profit = \$2,250 (from equation (9)). Using a market-share approach consistent with a symmetric Cournot oligopoly to calculate the patentee's "but-for" quantity yields $Q_2 = 200$.³⁴ This results in $P_2 = \$60$ (solved for using equation (13)). With this information, expression (4) can be used to estimate total lost profits (\$1,750). This also can be calculated by subtracting the patentee's "but-for"

³² Q_1 equals the patentee's actual unit sales under infringement (200) plus its market share with infringement (50%) multiplied by the infringer's unit sales (200), or 100.

³³Equations (9) through (12) can be found in Church and Ware (2000), at 243-244.

³⁴That is, the patentee's "but-for" quantity (300) equals actual unit sales under infringement (150) plus its market share *with* infringement (33.3%) multiplied by actual market output (450), or 150. Note that the "but-for" world here is the world under infringement in the previous example (i.e., a symmetric Cournot duopoly).

profits (\$4,000, using equation (7)) from actual profits under infringement (\$2,250).

IV. Conclusion

In *Crystal Semiconductor*, the CAFC has reminded practitioners of the importance of “elasticity issues” by explicitly calling for a greater emphasis on its consideration in construction of the “but-for” world, especially with respect to price erosion claims. In particular, by holding that “[e]conomists can define hypothetical markets, derive a demand curve, and make price erosion approximations without relying on inapposite benchmarks,” (p. 46) the CAFC acknowledges that the standard tools of economics are well-suited to such a task. This paper illustrates that such an acknowledgement by the CAFC is well founded.

In particular, the paper demonstrates that existing economic models and methodologies—such as the direct estimation of the price elasticity of demand and its incorporation into damage calculations, the use of existing oligopoly models, and the use of techniques from antitrust analysis (e.g., critical loss analysis)—all properly incorporate elasticity issues in computing total lost profits for patent damages. Such methods, illustrated through their application in a simple numerical exercise, yield a total lost profits award that is both necessary to fully compensate the patentee for the infringement and consistent with the CAFC’s focus on properly accounting for the law of demand in price erosion claims.

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