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Chapter 18

POTENTIAL COMPETITION, LIMIT PRICING, AND PRICE ELEVATION FROM EXCLUSIONARY CONDUCT

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Economists have made important progress in recent years in building quantitative models of the strategic interaction of sellers in markets that are imperfectly competitive. One important type of model deals with the possible entry of a new seller in competition with an incumbent monopolist or oligopoly. The analysis pictures the incumbent as creating an environment that depresses the expected profit of a potential entrant far enough to deter entry. The incumbents' conduct may create natural barriers to entry—such as the use of low prices to build a base of loyal customers—or it may include artificial barriers, possibly in violation of antitrust law. I review this new class of models from the perspective of antitrust impact and damages.

1. Introduction

Does potential competition limit the price of a product? Or does the price of an incumbent remain high until actual entry occurs? Modern competition theory provides clean answers to these questions. Potential competition *can* discipline price. Under certain conditions, the incumbent—acting before entry has occurred—will take actions that alter the environment in a way that reduces the payoff to entry *and* lowers the current price.

To take a simple example, an incumbent company fearing entry installs extra machinery. A potential entrant knows that the company will have a lower variable cost in the future. The low cost implies that the incumbent would set a lower price if entry occurs than if the incumbent did not have the extra machinery. As a consequence of the incumbent's extra capacity and lower cost, the potential entrant would receive a lower price. Under the right conditions, the entrant's price would be too low to cover all of its costs, so it would choose not to enter. Thus the incumbent's decision to install the extra machinery prevents entry. Further, as a result of having the extra capacity, the incumbent sets a lower price today, even though entry has not and will not occur. Potential competition has disciplined the price. If there were no possibility of entry, the incumbent would not choose the extra capacity, would have a higher level of cost, and would set a higher price. The possibility of entry limits the price that the incumbent will charge, which is why the phenomenon is called *limit pricing*.

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Potential competition limits prices only under particular conditions. First, the incumbent must be able to make entry unprofitable. In the above example, the incumbent expands output through purchase of additional machinery, reduces its price, and thereby reduces the profitability of entry by the potential entrant. It must be able to drive the profit of the potential entrant to a low enough point that the entrant decides not to enter. Second, the strategy of limit pricing must be economically beneficial to the incumbent—its benefit must exceed its cost. The benefit is the added profit available to the incumbent in a market free from competition from the potential entrant. The cost is the lowering of the incumbent's profit caused by setting the lower limit price rather than the full current profit-maximizing price.

In this chapter, I deal with potential competition as it arises in strategic models of limit pricing. The term potential competition also appears in other contexts in competition analysis. Some authors distinguish between *actual* potential competition and *perceived* potential competition. The first comprises firms that are capable of supplying in the market but are not currently doing so, while the second, the subject of this chapter, have not yet made any of the investments needed to supply. In the definition of relevant markets for antitrust purposes, the market may include actual potential competitors as well as actual competitors. The potential competitors have the capability to enter the market if some event, such as a merger, threatens to raise the price. A large body of related analysis deals with the barriers to entry that prevent a company from playing the role of a potential competitor in that sense. I do not pursue those concepts in this chapter. Potential competition, for the purposes of this chapter, refers to circumstances where the possibility of entry causes an incumbent to take actions that both prevent entry and lower the incumbent's price below the level that would prevail absent the possibility of entry.

2. The basic strategic model

The earliest discussions of limit pricing assumed that entrants inferred the price they would face upon entering from the price the incumbent set before entry. (A fuller discussion of the literature appears in Section 6 of this chapter.) Under this assumption, the incumbent sets a low price today to depress the profit that the entrant could earn. Modern limit pricing theory was born with the observation that there is no logical connection between the pre- and postentry prices of the incumbent. To deter entry, the incumbent must have a credible threat to set a low postentry price. The standard concept of credibility in modern economics is on-the-spot rationality—will the incumbent set a low price after entry occurs, to fulfill a threat of entry deterrence, or will the incumbent set a price based on the fundamentals and disregard any earlier threat that would cause pricing to depart from what is now rational? Modern economics requires the second and does not believe that companies will follow through on threats that are irrational on the spot, even though it would be highly beneficial if entrants believed the threat of low postentry pricing. Thus the incumbent has to take some action today—such as installing redundant machinery—that makes it rational to set low prices postentry.

Modern models of potential competition grew out of well-established models of actual competition. The workhorse is the Bertrand oligopoly model with differentiated

products. This model lies at the heart of the modern practice of merger simulation.[1] That research uses the differentiated products Bertrand model and calibrates a demand system using data from the firm's or publicly available data sources to test whether the effect of a merger is to permit the combined firm to unilaterally increase prices. The model is not used to test for the likelihood of explicit coordination or collusion. Although other models of oligopoly, such as the Cournot model, have places in competition analysis, the Bertrand model has been the most successful by far in merger simulation and its extensions.

The Bertrand model characterizes each seller as setting a price on the assumption that other sellers' prices will remain unchanged. The model does not draw its strength from the realism of this assumption; quite the contrary, firms respond to each other's price changes all the time. Rather, the model thrives on its ability to deliver reasonable predictions about price-cost margins and the effects of changes in costs and in the organization of the industry. The model has earned its role as the primary quantitative tool for understanding the effects of proposed mergers that could lead to unilateral anticompetitive behavior.

Economists have built so-called supergame models of collusion where sellers keep prices high because their rivals will set low prices in future periods to punish any defector who sets a low price in violation of the high pricing agreement. These models are outside the spirit of unilateral effects because they involve a form of coordination.

Luke Froeb, then serving as chief economist of the Federal Trade Commission's Bureau of Competition, explained the role of Bertrand merger simulation at a 2004 DOJ merger enforcement workshop:

> By 1990 game theory had displaced the structure-conduct-performance paradigm in Industrial Organization economics. Thinking on pricing and output coordination in oligopolies had evolved considerably from the view that fewness made coordination almost inevitable. While economists never entirely rejected coordinated effects theories for mergers, they did reject exclusive reliance on them, and they had more plausible theories for many cases. Thus, it was not surprising that unilateral effects analysis appeared prominently in the 1992 Horizontal Merger Guidelines, which were jointly promulgated by the FTC and the Department of Justice.
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> The unilateral effects analysis satisfied the attorneys' demand for a simple intuition they could understand and explain to a judge, and at the same time it satisfied the economists' demand for rigorous analysis. It wasn't long before economists began using structural, game-theoretic models to make quantitative predictions of unilateral competitive effects. In a price setting model, price goes up; in an auction models firms don't have to bid as aggressively to win; in a bargaining model the merged firm gains bargaining power…
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> The controversy surrounding unilateral effects analysis has focused on the application of structural game theoretic merger models to individual cases. Their main virtue is that

1. *See, e.g.*, Jerry A. Hausman, G. Leonard & D. Zona, *Competitive Analysis with Differentiated Products*, 34 ANNALES D'ECONOMIE ET DE STATISTIQUE (1994); Luke Froeb, Steven Tschantz & Phillip Cook, *Bertrand Competition with Capacity Constraints: Mergers among Parking Lots*, 113 J. ECON. 49 (2003); Gregory J. Werden & Luke M. Froeb, Unilateral Effects of Horizontal Mergers (unpublished manuscript 2004).

> they force assumptions to be made explicit, and provide a mapping from the facts of a case to the effects of a merger. The main shortcoming is that the models are necessarily unrealistic, and abstract away from important features of an industry.[2]

Customer choice defines a Bertrand industry model. A seller making the Bertrand assumption perceives an elasticity of demand based on the seller's beliefs about how customers respond to prices. As the seller considers higher prices, the seller will believe that customers will choose a lower total quantity of that seller's product. The elasticity is the number of percentage points of demand reduction per percent of price increase. The elasticity depends on the prices set by all sellers. A given seller has found the profit-maximizing price when the seller's price-cost margin (profit margin divided by price) equals the reciprocal of the seller's elasticity of demand. The industry is in Bertrand equilibrium when all sellers are at their profit-maximizing points.

The Bertrand equilibrium depends on the number of sellers. The demand faced by each firm is more elastic if there are more rivals and the seller has a lower market share. With a more elastic demand, the price-cost margin must be lower. Hence the Bertrand model satisfies the principle that more competition means lower prices. As a corollary, the model predicts higher prices for all sellers if two sellers merge. And the model, based on price-cost margins, predicts higher prices if the costs of one or more sellers rise.

3. The dynamic model

The Bertrand model as used in merger simulation is timeless—it makes predictions that apply to an unchanging environment for an industry. In the simple model, nothing connects one time period to the next, so one could solve the model again each period, based on that period's fundamentals—cost and demand.

The simple model implies that sellers disregard their memories. Thus, it rules out any form of implicit collusion supported by punishment in a period after defection occurs. A class of dynamic models called *Markov-perfect* captures the idea of unilateral effects in a dynamic model, by banning dependence of this period's prices on past conduct, except as that conduct has affected fundamentals. In the case of the simple Bertrand model, where today's prices have no effect on future fundamentals, Markov-perfect models involve no more than the repetition of the static Bertrand model period after period.

While potential competition is not a factor in the Bertrand model, the model can be used to show how an incumbent can make a credible threat to prevent entry. An incumbent cannot prevent entry in the next period simply by reducing price this period. In order to prevent entry, the incumbent must change the potential entrant's expected profits in future periods. Moreover, the incumbent's actions must be committed. To go back to the example of buying machinery, suppose that the incumbent bought a type of machinery that could be sold for full value next period. Then the rational step, having deterred entry, would be to sell the machinery. But then purchasing the machinery in

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2. Merger Enforcement Workshop, February 17-19, 2004, http://www.usdoj.gov/atr/public/workshops/docs/202613.htm.

the first place would not deter entry, as it would not cause potential entrants to believe that the purchase this period would influence the market next period. So the incumbent needs to find some irreversible step to take this period to be sure of influencing entry in the future.

Purchasing and installing equipment has many irreversible elements, so it remains a way to deter entry. Some of the other activities that might alter the profitability of a future entrant include building a durable brand name through advertising, establishing multiple retail outlets, building an installed base of products in the hands of customers where the products have switching costs, and promoting a product subject to network effects.

It is important to note that advertising may be a powerful entry deterrent, but it does not give rise to an effect of potential competition of the type considered in this chapter because an advertising campaign does not involve any actions that lower the current price. Firms advertise in order to stimulate demand and make it less elastic, so the firm can set a higher price as well as sell more. As I noted earlier, this chapter is restricted to irreversible actions in a given period that result in lower prices in that period as well as a less favorable environment for an entrant in future periods. It was previously mentioned that irreversible installation of machinery has that effect. A company with more productive capacity will set a lower price—even if it enjoys a monopoly—both this period and in the future, when the low price has the benefit of deterring entry.

The most interesting situations where potential competition delivers lower prices seem to arise from installed-base and network effects. The basic story here is simple. An incumbent uses all available tools to make its product ubiquitous. One of these is setting a low price. Getting as many users as possible to adopt a product means that the rival entering in the future has to persuade people to incur switching costs as well as pay the price of the new product. In order to induce users to switch, the entrant has to set a lower price or deliver an improved product, both of which reduce its profit. If, on the other hand, the incumbent set a high price initially, the incumbent would find many users who had not yet adopted the product, who would not incur switching costs. Switching costs are an important source of potential competition. Notice that the incumbent's investment in getting users to adopt its product is inherently irreversible.

Network effects are similar to switching costs and tend to arise in the same types of products. Later, the market for desktop software will be discussed, where both switching costs and network effects are prominent. People are reluctant to switch from the Microsoft Windows operating system to Macintosh for two reasons. First, they would have to learn new methods for accomplishing tasks they have already learned on Windows. This is the installed-base effect. Second, they would no longer have the benefit of the help from the Windows users around them. They would have to figure out how to use Mac on their own or join a community of Mac users. This is the network effect.

Figure 1 shows the basics of the analysis of potential competition and limit pricing. The upward-sloping line, labeled revenue, captures the lines of causation from the incumbent's current entry-deterring activities to the incumbent's current price, on the vertical axis, and the situation encountered by an entrant next period, on the horizontal axis. The line of causation to the current price may be direct—the incumbent sets a low

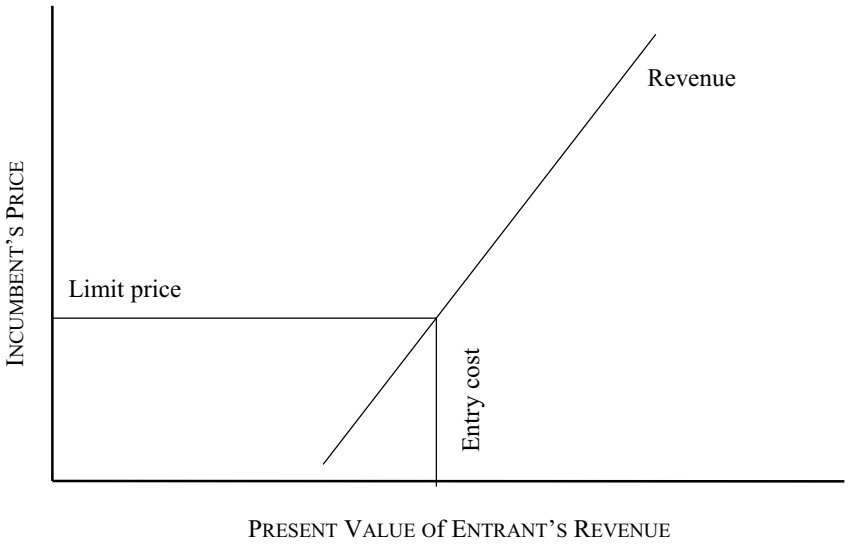

Figure 1.

Limit pricing.

price to expand the scope of the product's sales. Or it may be more indirect—the incumbent invests in extra productive capacity, which lowers costs and makes a lower price desirable. The horizontal axis measures the present value of the revenue that the entrant would earn, in the situation that would prevail if it competed with the incumbent starting next period. The present value of the entrant's future profit is higher under conditions that result in a higher price this period for the incumbent. If the incumbent holds back on investing in machinery, for example, it will make life easier for the entrant because the incumbent will not be able to expand its output as effectively in the next period in response to the entrant. Or if the incumbent sets a high price this period and fails to build much of an installed base or create positive network effects, the entrant will be able to earn more revenue in the future.

The vertical line in Figure 1 shows the cost of entry—both the initial cost of product development and the present value of the ongoing costs after entry. The use of present values for both revenue and cost takes account of the normal level of profit, in the sense of the return on funds previously invested. If the entrant cannot cover its costs, it will not enter. Thus, to deter entry, the incumbent needs to pick a price below the *limit price*, the price at the intersection of the sloping line and the entrant's cost. The incumbent must shrink the entrant's prospective revenue by enough to make entry unrewarding.

Will limit pricing occur? There are three possible outcomes to the situation for the incumbent, as described in Figure 1. The first is *irrelevance*. The incumbent may find that its profit maximizing price, if it did not worry about entry, actually lies below the limit price. In that case the limit price is not really a limit: the incumbent simply sets its profit-maximizing price ignoring the entrant. Potential competition has no constraining effect. The incumbent enjoys a natural monopoly.

Another possibility is *unprofitability*. The incumbent may find that the profitability of the optimal price that deters entry is less than simply setting a period-by-period profit-maximizing price that ignores potential entry. The likelihood of this outcome increases the smaller the entrant and the lower its impact on the incumbent's future sales. In this case, the incumbent would have to take strong actions to reduce the entrant's expected profitability enough to deter entry. On the other hand, allowing the entrant to enter has a relatively small effect on the incumbent's profitability.

In between these two cases is *limit pricing*, where potential competition disciplines the incumbent's price. The incumbent adopts the limit price, just below the price that would give the entrant enough profit to justify entry. Then limit price binds, in that the incumbent would set a higher price but for the hazard of entry.

3.1. Diagnosis of limit pricing

Important policy issues turn on whether a dominant firm is a limit pricer. If the firm uses limit pricing, a policy that makes entry easier—such as forbidding the incumbent to use customer contracts that impeded entry—will result in a lower price. If the dominant firm is in the situation where limit pricing is irrelevant, such policies have no benefit unless they alter conditions sufficiently to move the dominant firm to limit pricing. Incremental policies have no incremental benefits.

If limit pricing were unprofitable, the incumbent would have accommodated entry of a rival already. Finding an industry with a single major seller rules out the case of unprofitable limit pricing. The problem of diagnosis in such an industry is to distinguish limit pricing from irrelevance. This answers the question of whether the incumbent is a limit pricer, disciplined to some extent by potential competition, or whether the incumbent is a natural monopolist.

To make this distinction, the economist builds a model of single firm behavior. The model does not describe strategic behavior but does need to take account of ways that current sales affect future sales, through capacity, installed-base, or network effects. For simplicity, these collectively will be denoted installed-base effects. The calculation starts at a point 20 or so years in the future, at the end of the life of the product. In the final year, the firm is a simple monopolist—it extracts the maximum possible revenue from its position in the market. The installed base that the seller brings into the final period is unknown at this point, so the revenue that goes with each value of the installed base in the last year is recorded.

Now, consider the next-to-last period. The seller thinks about the price in terms of both the current revenue and the discounted revenue from the last period. A lower price this period results in more sales and a higher installed base—and so more revenue—next period. The seller shades the price below the single period monopoly price to capture the installed-base benefit next period. Again, the revenue that goes with each value of the installed base in the next-to-last year is recorded iteratively.

This process is iterated backwards to the present. Because the current installed base is known, one can solve for the price that gives the seller the maximum present value of revenue over the entire life of the product. This price is compared to the observed price.

If they are similar, then limit pricing is irrelevant and the firm enjoys a natural monopoly. If the calculated theoretical monopoly price exceeds the observed price, then one can conclude that the lower observed price is a limit price, held below the monopoly price to deter entry. In that case, the depression of the price reflects the potential competition of the seller who could enter, but does not actually enter.

Of course, the calculated monopoly price might be below the observed price, which would be a signal of error in the analysis or erroneous price setting by the incumbent.

3.2. Quantifying the entrant's revenue

If the diagnosis is limit pricing, one then proceeds to the next step, based on a model of the strategic interaction of incumbent and entrant. This is a counterfactual exercise, a determination of what would happen but for limit pricing. The result of this phase of the analysis is to create the quantitative version of Figure 1.

Figure 1 requires the measurement of the present value of the entrant's revenue. This calculation is similar in form to the solution of a merger simulation model but is technically more demanding. The calculation looks into the future because it considers the present value of all future revenue. It takes account of the influence of the two rival's activities in one period on the outcome of their rivalry in future periods.

Hall, Royer, and Audenrode[3] and Jenkins, Liu, Matzkin, and McFadden[4] discuss many of the details of this calculation. Like the monopoly calculation, the duopoly calculation starts at a point 20 or so years in the future, at the end of the life of the product. At this point, without any future to consider, the two firms engage in standard Bertrand rivalry. Solving the model is the same as solving merger simulation models. But there is one important complication. The outcome in the final period depends on what installed bases the two companies have accumulated from past interactions. It is initially unknown what installed base each rival will bring into the final period—one would have to solve the final period's market outcome for all possible combinations of the values of the two bases. At the same time, one could record the revenue each seller receives for each combination of the two bases.

Having done this, one considers the previous period. When each seller decides what price to set, taking as constant the price set by the rival, the seller counts not just the revenue from this period but also the discounted revenue from next period. Again, this analysis is performed for each combination of installed bases brought into the next-to-last period. The sum of the revenue is recorded from this period and the discounted revenue from the future period for each combination. Notice that the values of the two bases used to determine the discounted revenue from the future period are calculated as the current values adjusted by the effects of the prices chosen this period. The sellers set prices that reflect the advantage of shading the current price downward in order to have a larger installed base in the future.

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3. Robert E. Hall, Jimmy Royer & Marc Van Audenrode, Potential Competition and the Prices of Network Goods: Desktop Software (mimeo 2003), http://www.stanford.edu/~ rehall/.
4. Mark Jenkins, Paul Liu, Rosa L. Matzkin & Daniel L. McFadden, The Browser War: Econometric Analysis of Markov-Perfect Equilibrium in Markets with Network Effects (2004), http://emlab.berkeley.edu/users/mcfadden/.

This process of working backward in time is continued to the present. At the outset, the installed base of the incumbent is known, and the installed base of the entrant is zero. One then can calculate the present value of the entrant's revenue and the present value of the incumbent's revenue.

Two checks will verify the reasonableness of the results. First, the calculated present value of the entrant's revenue should be somewhat below the entrant's cost. This should be checked against any outside information about entry cost.

Second, the present value calculated from the incumbent's profits from a limit-pricing strategy applied over the remainder of the product life should exceed the present value of the incumbent's revenue from the duopoly. If not, limit pricing is not profitable and would not have been undertaken. The incumbent would have more profitably accommodated entry. A finding that entry would be profitable for the entrant and that limit pricing is not desirable for the incumbent, but no entry has occurred, is a contradiction of the principles of the model and a plain sign of trouble in the analysis.

If the analysis passes both of these tests, the quantitative versions of Figure 1 can be calculated. The earlier analysis yielded the intersection point in the figure. To find the upward sloping revenue line, consider counterfactual alternative policies of the incumbent. For example, the incumbent might have had a historical policy of setting a higher price and thus has achieved a lower current installed base. This would generate a point on the line up and to the right. Of course, this would have generated entry some time in the past, so this point is hypothetical. Similarly, the incumbent might have set a historical price at a lower level and generated a higher installed base, creating an environment even more unfavorable for the entrant. This point, down and to the left along the line, is also counterfactual because it represents unprofitable overkill by the incumbent.

4. Analysis of exclusionary and other conduct

4.1. Exclusionary conduct

Limit pricing is a more desirable form of exclusionary conduct than some other types of exclusionary conduct because consumers receive the benefit of lower prices while society avoids the cost of possibly duplicative product development. I assume the conduct that accomplishes limit pricing—capacity and market expansion—is lawful and legitimate. I further assume for the purposes of this discussion that certain types of exclusionary conduct have been found by courts to be unlawful. An example is long-term contracts with a large fraction of all customers. This chapter does not attempt to provide criteria for distinguishing unlawful or anticompetitive conduct, on the one hand, from natural barriers to entry or legitimate conduct, on the other. It focuses on one important issue—what is the effect of a particular type of conduct on prices, when the incumbent firm is using limit pricing to deter entry? The analysis of unlawful exclusionary conduct interacts with limit pricing because an incumbent will trade off limit pricing and unlawful exclusions. If unlawful conduct raises the cost of entry, the entrant's total cost rises and the limit price rises.

Figure 2 shows the analysis of unlawful conduct that raises an additional unlawful barrier to entry on top of the natural barrier arising from the entrant's legitimate costs of entry. When an added barrier raises the entrant's total cost of entry, the intersection with the upward sloping revenue line occurs at a higher price. The incumbent need not use legitimate entry deterring tools, such as added capacity and pricing for ubiquity, as aggressively. The incumbent still deters entry but can set a higher price. The price elevation caused by the unlawful exclusionary conduct is shown by the vertical arrow.

Notice that the analysis not only demonstrates that the exclusionary conduct is harmful to purchasers because it raises the price they pay, it *quantifies* the amount of the price elevation, as required in damages measurement.

4.2. Other conduct

The same type of model quantifies the effects of exclusionary and other harmful conduct in actual oligopolies rather than single-seller markets disciplined by potential competition. First, the model can provide a merger simulation in markets with installed-base and similar effects. Standard static merger simulation fails to consider that sellers use penetration pricing in the early phases of the development of a market. The standard model will treat a market with low prices as inherently competitive and therefore not much harmed by a merger, when in fact the low prices are a transitory feature, to be replaced by higher prices as the market matures. A standard model will understate price elevation from a merger, while a model with installed-base effects will give the correct answer.

Second, the new models can measure the effects of exclusionary conduct that hobbles one of the sellers in a market with installed-base and similar influences. The

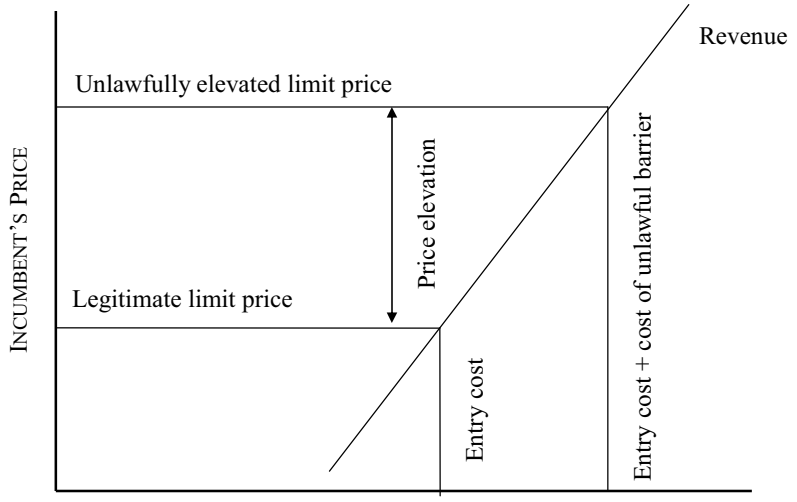

Figure 2.

Effect of unlawful added barrier to entry.

previously mentioned article by Jenkins, Liu, Matzkin, and McFadden[5] is an example of this type of analysis, studying the effects of Microsoft's conduct during the period when Netscape tried to expand its role in desktop software via the Internet browser. The analysis proceeds by developing an oligopoly model that fits the observed data and includes the extra costs that the exclusionary conduct imposes on one of the sellers. Then the analysis is repeated, using the same model but omitting the extra costs. The difference in price between actual and but-for model runs measures the harm to the consumer from an elevated price and the difference in profit earned by the victim of the conduct measures the victim's damages.

5. Example: Desktop software

This section—based on the Hall, Royer, and Van Audenrode manuscript mentioned above[6]—provides an extended example of a quantitative analysis of limit pricing. The example involves desktop software—a leading example of a product with extensive installed-base and network effects. There are two distinguishable components of the software: the operating system and the primary user package, the productivity suite.

The top seller in this market, by far, is Microsoft. This section considers how Microsoft defends Windows and Office from actual rivalry. Microsoft is portrayed as setting prices below the levels that it would choose if there were no threat of entry, in order to create an environment where entry would be marginally unremunerative. Low prices make Windows and Office ubiquitous and more difficult for a rival to supplant, because of network effects.

Network effects operate across both customers and time. For software with network effects, one customer is more likely to use a product if others are using it. Desktop software users often help each other with problems. They exchange files whose formats are unique to operating systems or application packages. They anticipate changing tasks or jobs so that knowledge gained in one place will be useful in another, if the same software is in use there. Over time, the experience a user gains from working with particular software is a capital asset—it makes the user more productive in future work. The critical variable that makes the user more productive is denoted the *experience base* rather than the installed base; it is not the physical survival of the product but the human capital specific to a brand of software that accounts for the network effects that are critical to the influence of potential competition.

Microsoft uses a variety of strategies to create an economic environment that depresses the profit of potential entrants sufficiently to discourage them from entering. In that environment, the revenue that an entrant would earn is too little to compensate for the resources required to build, launch, and support products that would compete with Microsoft's. A primary strategy is setting low prices to generate high volumes of sales and thus build a large experience base. Other strategies, including advertising, also expand the experience base, but do not lower price. The model takes advertising and

5. *Id.*
6. *See* Hall et al., *supra* note 3.

other promotional effort into account as endogenous variables. It is assumed that the remainder—including Microsoft's dealings with its customers and rivals—are aspects of the environment that do not automatically respond to other changes in the environment. The model provides a tool for estimating the effects on prices of changes in those exogenous determinants.

Windows and Office are complements; having one makes the other more useful, so customers tend to buy them together. Network effects are important for both products. In a market with network effects from complementary products, a would-be rival must make a frontal assault on both markets. Where businesses are linked by complementarities and sellers benefit from complementarities by selling in both businesses, the would-be rival would have the best chance of success by entering both businesses simultaneously. In other words, the contingency of greatest risk to Microsoft is that a rival—potentially an existing large, successful software or computer company—would invest several billion dollars coding a new operating system and productivity suite and then spend many billions of dollars more promoting and supporting these products. Although this frontal assault would be expensive, the returns are equally large—the entry scenario discussed later involves a present discounted value of revenue to the hypothetical entrant of many billions of dollars.

Accordingly, the analysis considers the case of entry to both the operating system and productivity suite businesses. Other types of entry are of less risk to Microsoft and therefore have a smaller role in constraining the pricing of Microsoft's products. First, entry into operating systems alone suffers the disadvantage that the rival would be depending on revenue from that product alone in competition with Microsoft. The entrant would be sacrificing the benefits of selling the complementary application suite. In addition—and probably more important—there would be little market for a new desktop operating system unless it could run all of the existing popular Windows or Macintosh applications. It is noted that achieving this level of compatibility is technically extremely difficult and prohibitively expensive.

The type of entry that Microsoft fears the most—and that therefore constrains its prices—is the frontal assault. Once the rival has made the investments needed to make that assault, Microsoft would suffer a substantial loss of profit. Hence Microsoft will—if it can—alter the economic environment to make those investments unremunerative. The model quantifies the relationship between the development costs faced by potential rivals and Microsoft's pricing and experience base. The result shows that Microsoft's prices for Windows and Office are substantially lower as a result of potential competition.

In addition to setting prices that recognize the effect of potential competition and promotional efforts that reduce the revenue available to a rival, Microsoft has used other practices that have been challenged in court under antitrust law as inappropriate limitations on the opportunities available to an entrant. This chapter does not study the legitimacy of the challenged practices. It broadly estimates the entry cost, including all the costs that an entrant would encounter, including those of overcoming the challenged practices.

The model portrays the evolution of the desktop software businesses for many years into the future. Potential entrants and Microsoft use the same logic in thinking through

the economics of entry. An entrant projects how, if it builds desktop software that can compete with Microsoft's products, the two sets of products will compete with each other. The demand for each product depends, among other things, on the size of the experience base that customers bring into the period, and the base depends on sales of that seller's software in earlier periods. Microsoft starts off with an advantage from its relatively substantial experience base, whereas an entrant starts without any experience base among potential customers.

Competition between the two sellers is characterized according to the standard principles discussed earlier in this chapter. The sellers are Bertrand rivals. Demand has a dynamic element: users gain experience from units sold today that stimulates demand for the product and brand in the future. As a result, both sellers set prices lower than they would otherwise. Competition between the sellers occurs in subsequent periods according to the same principles. The result is a forecast of sales well into the future. Each seller has to decide how much to shade its prices downward to capture the benefit of the enlarged subsequent experience base a lower price generates. They make this decision so as to maximize the present value of the revenue stream.

As described earlier in this chapter, a Markov-perfect equilibrium is assumed, such that each seller in a given period makes the Bertrand assumption about the other player—no price response—in the current period but understands the outcome of the game when played next period and uses that outcome to value the future implications of the prices set today. The model predicts a value for Microsoft's revenue stream and a value for the entrant's stream. These values depend on the size of Microsoft's experience base brought into the first period.

The first step is diagnosis: is Microsoft a limit pricer, constrained by potential competition? Without the discipline of potential competition, Microsoft would set a higher price and earn a higher stream of revenue. Specifically, according to the model applied to the single seller case, the combined price of Windows and Office would be $354 and the present value of revenue would be $191 billion. The actual price in 2002 was $143. This suggests that Microsoft is a limit pricer and that the consumer benefits from the potential for a rival to enter if Microsoft exerted its full market power.

A second step is to use the duopoly model to develop the revenue line in Figure 1. The actual price of $143 crosses the revenue line at a level of revenue of $38 billion, which is in line with the total costs of developing, maintaining, marketing, distributing, and supporting a full rival to Windows and Office. The model delivers a coherent account of Microsoft as a limit pricer.

Recall that the second check on the limit pricing model was to verify that limit pricing pays off. According to the model, Microsoft earns revenue worth $153 billion in present value if it sets the constrained price to ensure that no entry occurs. On the other hand, if Microsoft decided to accommodate entry and set a price in the period before entry to achieve maximum present value, it would earn somewhat lower revenue of $148 billion in present value. The analysis passes the second check, though not by a wide margin.

The slope of the revenue line in Figure 2 is an important quantitative result from the model. It measures the amount of price elevation caused by a given amount of increase

in the cost of entry. In the model, the slope is about $2 in price increase for each $100 million of elevated entry cost.

Microsoft's customers and rivals challenged a variety of the company's practices. In most cases, the challenges identified ways that Microsoft raised the cost of entry of rivals. Until 1994, Microsoft's contracts with some computer makers charged them for Windows for all computers in a product line, even if some of them did not actually have Windows. This type of contract raised potential entry costs because an entrant would need to buy out the contract provision for a period to induce a computer maker to switch to a new operating system. Microsoft's contracts with some computer makers also restricted their abilities to distribute browsers other than Internet Explorer. Again, a rival promoting a new operating system with its own browser would need to buy out these contract provisions. A number of challenges related to disclosure of information about interfaces and file formats. Because the users of a new operating system and productivity suite would need to interoperate with Microsoft software, entry costs would be higher if Microsoft kept this information secret than if it published it.

It is not possible to estimate, using public sources, the total increase in entry costs caused by all of the challenged conduct. Purely for the sake of illustration, suppose it were $150 million. Then the effect of the combined challenged conduct on the price of Windows and Office was $3 per computer.

One of the strengths of this approach to the measurement of price elevation is that it disaggregates in a natural way. If the court were to determine that only the contract terms were unlawful and that Microsoft did not have a legal duty to disclose interface and file format information, and if the entry-cost elevation associated with the contract terms was $50 million, then the price elevation would be $1 per computer.

6. Economic literature

Bain[7] launched the literature on limit pricing. He was the first to formalize an incumbent's decision to cut its prices to decrease the probability of entry. Friedman[8] observed that low prices had a limited commitment value since a credible threat to cut prices upon entry may deter entry as effectively, and more profitably, than a price cut prior to entry. Spence[9] was the starting point of the theory behind the model described in this chapter. In his model, a firm seeking to prevent the entry of a rival expands its capital stock so as to lower the price that it would charge in the event it faced a competitor in the next period. As a by-product, the current price is lower as well. In a more recent version, Fudenberg and Tirole[10] model the key variable as the installed base of the seller of a product with network effects. A firm seeking to prevent the entry of a rival sets a low current price to expand its customer base and reduce the size of the

7. Joe Bain, *A Note on Pricing in Monopoly and Oligopoly*, 39 AM. ECON. REV. 448 (1949).
8. James Friedman, *On Entry Preventing Behavior*, in APPLIED GAME THEORY (S.J Brams et al. eds., 1979).
9. A. Michael Spence, *Entry, Capacity, Investment, and Oligopolistic Pricing*, 8 BELL J. ECON. 534 (1977); *see also* A. Michael Spence, *Investment Strategy and Growth in a New Market*, 10 BELL J. ECON. 1 (1979).
10. Drew Fudenberg & Jean Tirole, *Pricing a Network Good to Deter Entry*, 48 J. INDUS. ECON. 373 (2000).

market available next period to a would-be rival. The framework in this chapter tracks Fudenberg and Tirole closely, with a generalization to multiple periods.

Milgrom and Roberts[11] explained limit pricing as a way for incumbents to hide the potential profitability of entry. The model assumes asymmetric information (the incumbent knows its costs, but the entrant does not).

Network externalities have been analyzed in several markets: Gandal[12] and Brynjolfsson and Kemerer[13] showed that consumers are willing to pay a substantial premium to purchase spreadsheet software compatible with the dominant standards. Ohashi[14] demonstrated network effects in video cassette recorders and Economides and Himmelberg[15] in facsimile machines.

Maskin[16] discusses Markov-perfect equilibria in games with observable actions (as in the framework of this chapter). They explain the benefits for applied work in restricting the set of equilibria to those that are Markov perfect. In an earlier paper, Maskin and Tirole[17] studied the properties of Markov-perfect equilibria in dynamic oligopoly games in a Cournot framework. Giovannetti[18] studies the Markov-perfect equilibrium of a dynamic Bertrand game with adoption of technologies. Finally, Chen and Rosenthal[19] consider the Markov-perfect equilibrium of a dynamic Bertrand game when consumers change their loyalties slowly. All of these papers are purely theoretical.

There is also a large body of literature on the empirical estimation of dynamic oligopoly games. These models—which most often consider Markov-perfect equilibria—have been used to measure the degree of collusion in oligopolies[20] and sticky prices.[21]

7. Concluding remarks

An economic model widely used in quantitative merger analysis—the differentiated products, Bertrand-equilibrium model assuming a Markov-perfect equilibrium—extends

11. Paul Milgrom & D. John Roberts, *Limit Pricing and Entry under Incomplete Information: An Equilibrium Analysis*, 50 ECONOMETRICA 443 (1982).
12. Neil Gandal, *Hedonic Price Indexes for Spreadsheets and an Empirical Test for Network Externalities*, 25 RAND J. ECON. 160 (1994).
13. Erik Brynjolfsson & Chris F. Kemerer, *Network Externalities in Micro-Computer Software: An Econometric Analysis of the Spreadsheet Market*, 42 MGMT. SCI. 1627 (1996).
14. Hiroshi Ohashi, The Role of Network Externalities in the U.S. VCR Market, 1978-1986 (mimeo 2001).
15. Nicholas Economides & Charles Himmelberg, Critical Mass and Network Size with Application to the US Fax Market (mimeo 1995).
16. Eric Maskin, *Markov Perfect Equilibrium I: Observable Actions*, 100 J. ECON. THEORY 191 (2001).
17. Eric Maskin & Jean Tirole, *A Theory of Dynamic Oligopoly, I: Overview and Quantity Competition with Large Fixed Costs*, 56 ECONOMETRICA 549 (1988).
18. Emanuele Giovannetti, *Perpetual Leapfrogging in Bertrand Duopoly*, 42 INT'L ECON. REV. 671 (2001).
19. Yongmin Chen & Robert W. Rosenthal, *Dynamic Duopolies with Slowly Changing Customers Loyalties*, 14 INT'L J. INDUS. ECON. 269 (1996).
20. Margaret E. Slade, *Empirical Games: The Oligopoly Case*, 28 CANADIAN J. ECON. 368 (1995).
21. Margaret E. Slade, *Optimal Pricing with Costly Adjustment: Evidence from Retail-Grocery Prices*, 65 REV. ECON. STUDIES 87 (1998).

nicely to study other topics in quantitative competition analysis. While the standard model describes only the effects of competition among the actual participants, the extended model describes the circumstances when potential competition disciplines prices and provides quantitative appraisals of important issues, such as the effect on price of specific conduct, such as long-term exclusive contracts that raise barriers to entry.

Should antitrust law condemn limit pricing? The implications of the modern analysis of limit pricing are ambiguous on this point. Modern dynamic models of potential competition recognize that incumbent firms may employ strategies that trade off some reduction in prices before entry to deter entry and thereby avoid the larger reduction in price that would occur upon entry of a rival. As a result, antitrust law is faced with a trade-off: should strategies that involve reductions in price relative to more static monopoly outcomes be allowed even though they also will allow incumbent monopolists to sustain their market power for longer periods of time, and thus cause markets to operate less efficiently over the long run? The models provide quantitative tools for answering this question, but the answer depends on the specific circumstances. The modern analysis does not provide a clean, universal answer.