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Buyers' Strategies, Entry Barriers, and Competition

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ABSTRACT

This paper develops an analysis of buyers' strategies. We analyze markets in which sellers have significant customer or market-specific investments but that buyers can make credible, albeit costly and time consuming commitments to obtain alternative sources of supply. Because of sellers' specific assets, *de novo* entry would be naturally blockaded in a standard oligopoly model. We show, however, that once buyers' strategies are considered in markets with these characteristics, the market power of sellers is more attenuated than models with unsophisticated buyers would predict. In particular, current prices and the decision to switch suppliers (including via vertical integration) are related, so that limit pricing (against switching or vertical integration) is a likely form of equilibrium pricing, even in the presence of full information. Limit prices are shown to increase with the amount of time it takes to switch, and with the level of buyers' switching costs, but to fall with the level of sunk investments. Thus, in such markets, although sunk costs can be a barrier to *de novo* entry, suck costs restrain, rather than increase, the ability of sellers to exert market power. This paper, then, questions the standard oligopoly model prediction of an inverse relationship between market performance and sunk investments, and shows the relevance of buyers' strategies for predicting market performance.

I. Introduction

Modern oligopoly theory accords little latitude for factors other than impediments to effective collusion among existing producers to discipline competition. For example, in markets with significant scale economies and sunk costs, entry is likely to be blockaded by low post entry prices, and in the absence of informational asymmetries, pre-entry prices are unrelated to entry decisions by informed potential entrants. Protected from the threat of entry, price competition only arises to the extent there are limitations on the ability of incumbents to effect tacit or explicit collusion. Building on this result, the strategic literature is abundant in models of incumbents making strategic commitments to investments analogous to sunk costs in order to deter entry.

Another literature examining the relationship between sunk costs and competition is transactions cost theory.[1] Klein, Crawford and Alchian (1978), and Williamson (1979), for example, examine the implications of the possibility that a seller's sunk costs may be expropriated by his sophisticated customers if those customers can credibly threaten to vertically integrate. In this literature sunk costs place the seller at risk to the threat of "entry" by a sophisticated buyer, and the only resolution of this risk may be *ex ante* vertical integration.

Modern oligopoly theory and transactions costs theory thus make quite different predictions about the relationship of sunk costs and competition. In oligopoly theory sunk costs allow oligopolies to exploit their customers without fear of the discipline of entry, limited only by impediments to collusion. In transactions cost theory, on the other hand, the direction of potential exploitation is reversed, with sunk investments leaving sellers at risk of exploitation by their customers.

One important reason for these contradictory predictions is that in most oligopoly

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[1] See, Coase (1937) and (1987), and Williamson (1975), (1979), (1983) and (1985).

models buyers are simply demand curves. Such modelling is generally unrealistic, since most industries produce intermediate goods sold to other producers or distributors (like supermarkets). Such customers are not only well aware of the consumer surplus derived from their transactions, but are likely to be as able as their suppliers to engage in strategic behavior.[2]

U.S. automobile manufacturers, for example, have long used a number of strategies, not limited to the threat of vertical integration, to discipline their suppliers (see Porter (1983)). Supermarkets facing manufacturers with apparent market power engage in sophisticated nonlinear pricing of their purchases (including lump sum fees for shelf space called "slotting allowances"), various forms of all-or-none bargaining, and contract for the manufacture of store brands that compete with major suppliers' products. Markets in which the major customers can usefully be modelled as demand curves are largely limited to retail off-the-shelf consumer products. A more accurate modelling of most markets in our economy would have surplus-conscious buyers who may be able to engage in strategic behavior.

This paper sets out a simple model in which suppliers are protected from *de novo* entry by sunk investments, but buyers have the ability to make credible threats to switch sources of supply. We assume that switching takes time and requires some up front investment, so that incumbent suppliers have substantial short run market power. Our model encompasses general strategies involving commitments to switch sources of supply, with vertical integration being just one example. The switching we are considering here is not what is normally thought of as input substitution, such as, say, a baker switching from one grade of wheat flour with a given protein content to another in response to a change in

[2] Most transactions in intermediate good industries arise from bargaining between sales representatives and purchasing agents. In those cases, sales are effected essentially by bargaining between the sellers and buyers. For this reason alone, modelling buyers as passive demand curves is generally inappropriate.

the protein premium. Rather, we are interested in situations in which a buyer cannot substitute for a particular input in the short run, but can substitute, in time, by making suitable, specific investments. In such situations, suppliers of the input may have substantial potential market power in the short run. This paper is concerned with the impact of credible, but costly, time-consuming switching on the exercise of that short run market power.

We show that seller sunk costs and the time required for buyers to switch to alternative sources of supply are critical factors in the determination of supplier and buyer power, and therefore, of the state of competition. In particular, contrary to the predictions of standard oligopoly theory, our model predicts that sunk costs are inversely related to the extent of exercised market power, but that the length of time required to switch is positively related to the extent of exercised market power. Finally, our results have important implications for the theoretical underpinnings and application of the 1982 Department of Justice Merger Guidelines.

The variety of switching strategies.

Input substitution that takes time and investment arises in a variety of forms. In general, such substitution may involve switching to a different type of input, or switching to an alternative supplier of a similar input, perhaps, via vertical integration or long term contracting. Consider input switching first. Many manufacturers requiring containers for their products regularly evaluate the desirability of using glass or rubber or plastic or steel or aluminum, or different types or grades of glass, etc., based to some extent on the relative costs of these inputs.[3] For example, over time brewers have considered switching from glass bottles to steel cans to aluminum cans; soft drink bottlers have considered switching from glass to plastic bottles; manufacturers of household appliances have considered

[3] For the evolution of the threats of substitution of purchasers of metal cans, see Bower (nd), and Hammermesh, Gordon, and Reed (nd).

switching from metal to plastic appliance housings; and supermarkets have considered switching from paper to plastic bags. Other companies regularly evaluate the desirability of using PC's or non-computer substitutes, or PC's or minicomputers (see Porter 1985, pp. 290-291), captive or contract transportation, etc. In cases such as these, switching takes time and requires investment in both physical and human capital. Switching from glass to plastic bottles, for example, requires modifications in bottling operations that take time an money. And switching from paper to plastic bags requires a supermarket to invest in bag holders and to train employees.

The sort of switching we are considering requires time to effect. That time is generally required to switch to a different input is not surprising. But time can be required even to switch between suppliers of a similar input. For example, concern with precision and quality control sometimes lead manufacturers to "qualify" only a few potential suppliers, since the qualification process may require time and investment by both the manufacturer and the potential supplier. Porter (1985, p.286) describes the case of a computer manufacturer that took one year to qualify a supplier for a 64K chip. As another example, most major domestic textile manufacturers generally qualify only domestic polyester fiber producers, a process taking time and money,[4] but the textile manufacturers could switch to foreign sources of fiber by making the expense and taking the time to qualify foreign suppliers.[5] Finally, manufacturers of aircraft jet turbine engines typically qualify only a few (sometimes only one) of the potential suppliers of superprecision bearings, since the qualification process is very costly and can take up to five years.

The variety of customer-specific sunk costs.

Customer-specific sunk investments arise in many forms. For example, Hammermesh

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[4] It is important that the fiber does not "gum up" the looms which are very costly to shut down.

[5] The expense and time involved arises from making test runs on their working looms.

and Gordon (nd, p.4) found that in the steel can industry, ".. plants were often set up to supply a particular customer, [so that] the loss of a large order from that customer could greatly cut into the manufacturing efficiency and company profits." Similar dependencies on customers exist in the glass container industry, where, for example, a particular plant may be largely specialized to a particular bottle for a particular customer that requires specific investments in terms of molds and down time if production must be switched. In other cases, customer-specific investments are more subtle, involving investments in qualifying with a customer.[6] For example, the customer list of an industrial firm is generally an asset with significant value to an acquirer of the firm. The value of the list generally does not arise because it reveals otherwise-unknown potential customers. Instead, its value arises because it reflects the relationship between the firm and its customers, i.e., the firm is a qualified supplier for that customer. A good customer is one that will continue buying from the firm as long as its prices are competitive. For such a customer the firm does not have to bear the qualification costs for each new sale.

Summary and outline of the paper

To summarize, in this paper we examine the effect of the ability of customers to make credible, but costly and time consuming threats to switch suppliers on the exercise of short run market power by incumbent suppliers. We show that the length of time and level of the investment required to switch to a new input or newly qualified vendor provides incumbent suppliers with strategic leverage, but that customer-specific investments by suppliers provides strategic leverage to buyers. The result of these two forms of leverage is likely to be more competitive pricing than would be suggested by entry protected short run market power.

In connection with our experience with antitrust investigations at the FTC we have

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[6] Here we use qualification in a general sense, including, for example, the need for the salesman to develop a relationship with the purchasing agent.

observed that customers of concentrated industries often have no complaint with major mergers of their suppliers. We postulate that an important reason for this is that customers have strategic options, including their ability to make credible threats to eventually obtain alternative sources of supply, and that such strategies have the apparent effect of substantially moderating the exercise of short run market power by incumbent suppliers.[7] This, despite the fact that the short run can be lengthy and costly,[8] and that buyers' apparent demand curves have sometimes been extremely inelastic.[9] This paper, then, provides an analytical foundation to such admittedly anecdotal evidence.

Although in oligopoly models with well informed entrants there is no role for limit pricing (pre-entry prices are irrelevant to the entry calculus), and sunk costs allow incumbents to raise price without fear of *de novo* entry, in our model with credible switching, limit pricing (against switching) is a likely form of equilibrium.[10] In addition, contrary to traditional oligopoly theory, the limit price declines with the level of customer-specific sunk costs, and the limit price may be at approximately the competitive level, even in the presence of substantial potential short run market power. Therefore, with credible

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[7] One particularly striking example was the superprecision bearings for commercial jet turbine aircraft engines described above. As the consequence of a proposed merger in this industry, reviewed during the 1980's by the Federal Trade Commission, some of the jet turbine engine manufacturers (for commercial aircraft) would be confronted by a sole source for some of their bearings, and because of the qualification process, new suppliers could not be qualified for five years. These manufacturers, however, were not concerned by being faced with a "monopoly" supplier post-merger, despite having no enforceable long term contracts. We postulate that one important factor behind their lack of concern is that the superprecision bearing producers make substantial sunk investments. (Further information cannot be disclosed because of federal confidentiality statutes).

[8] A costly five year qualification period in the case of some superprecision bearings, and a costly period of at least a few months for polyester fiber.

[9] Due to fixed proportions and the minor role of the bearings in total value added, the short run demand for particular superprecision bearings is extremely inelastic.

[10] See Milgrom and Roberts (1982) for a framework in which limit pricing arises as an equilibrium in the presence of uninformed entrants.

switching and customer-specific sunk costs, actual market power will generally be significantly less than the apparent short run market power that would be indicated by customers' apparent demand elasticities.

Besides our contribution to oligopoly theory, our analysis has significant implications for merger enforcement. Under the 1984 *Department of Justice Merger Guidelines*, markets are defined and concentration measured according to what products a customer would switch to in response to a short run anticompetitive price increase by its current suppliers.[11] If the buyer cannot switch and entry could not occur in the short run, a merger resulting in a significant increase in concentration in a concentrated market is presumed likely to lead to higher prices. In this paper we show that this presumption is not generally correct in markets in which the customers can make credible commitments to switch.

In the next section we set out a simple general model of switching that includes vertical integration as one type of switching. In the following section we then present a more general approach to switching suppliers, in which credible switching may require the actions of more than one buyer. We show that the results are similar to the vertical integration model. The final section of the paper examines the implications of our analysis for the Department of Justice Merger Guidelines.

II. The General Model

In our models incumbent suppliers are sheltered from *de novo* entry by sunk costs. But in intermediate product industries buyers may be the most likely "entrants," either by vertical integration, contracting with entrants, or switching to alternative inputs or suppliers.[12] After all, it is intuitively more plausible that unhappy customers rather than

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[11] See DOJ (1984) and Scheffman and Spiller (1987a).

[12] For a nice example of a purchaser arranging for entry by contract, see "GE Refrigerator Woes Illustrate the Hazards in Changing a Product," Wall Street Journal, May

a *de novo* entrant would perceive market power, especially an increased exercise of market power as might arise from a merger. Sexton and Sexton (1987) show that for a group of buyers (in their case, an agricultural cooperative) considering vertical integration, the entry calculus of standard oligopoly theory is incorrect. A *de novo* entrant has to expect to make at least a normal rate of return on his investment for entry to be profitable. But what is relevant to a buyer is whether his total profits if he "enters" are larger or smaller than his profits in the alternative of facing oligopoly pricing. That is, pre-entry prices are related to the entry decision of a buyer.

We show in this section that if suppliers have customer- specific investments, and buyers can make credible threats to switch but that switching requires time and customer-specific investments, then the resulting equilibrium pricing will differ from that predicted by models featuring sunk costs as entry barriers (e.g. Spence (1977), Dixit (1980)). Since we intend to highlight the role played by the ability of buyers to make strategic commitments, the models are constructed so that if buyers were characterized simply as demand curves, entry would be blockaded by sunk costs and Bertrand competition.

We begin with a market with one buyer and one seller in an infinite horizon framework. This addresses a case in which suppliers have significant customer-specific investments. The case of one buyer has a broader application than may be initially anticipated. In intermediate product industries, although there are generally price lists, transactions prices are typically determined by bargaining between the sales and purchasing agents, and prices generally differ across customers who have imperfect knowledge about what other customers pay.[13] Under such circumstances, to the extent that a supplier (or

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7, 1990, P. 1.

[13] Experience at the FTC in reviewing of dozens of intermediate good industries in connection with merger investigations shows a marked lack of uniformity of prices across customers. See also Stigler and Kindahl (1970).

supplier oligopoly) has significant customer-specific sunk costs, our single buyer model will apply.

In later sections we develop models with multiple buyers and finite horizons. The multiple buyer case addresses a situation in which a supplier's investments are specific to a group of buyers. Our multiple buyer model shows that the ability to make credible threats to switch generates an equilibrium price dispersion in a model where if firms would be considered simply as demand curves, buyers would be charged identical prices. Finally, we show that the basic results are obtained in a finite horizon model.

A. A Single Buyer, Infinite Horizon Model

Suppose that the single buyer, **B**, has an inelastic demand for one unit of the relevant input, *widgets*, which is produced by a single seller, S, both facing an infinite horizon.[14] B can purchase an alternative input at a price, α, from a competitive industry. This input has other uses, and will be produced at price α whether or not B purchases it. Widgets are preferred by B as long as their price is not greater than α. In the longer run B can switch to an alternative input, gadgets (or, in one model, vertically integrate into widgets). We will discuss the economics of such switching in a moment.

Supplier economics:

The assumptions about the supplier's condition are as follows. The marginal production costs for serving B are c_S. The assets devoted to serving B have book value of I_S. A portion of these assets are customer-specific, with γI_S being the salvage value of the assets that are dedicated to B (thus, the extent of specificity of the seller's assets is

[14] The basic results derived from this formulation would hold for more general downward sloping demand functions as well. Since in the current formulation there are no inefficiencies associated with a price above marginal cost, there is no need for vertical integration or for multiple part tariffs to either extract monopoly rents or solve a successive-monopoly problem. This allows us to focus on the use of credible switching strategies.

represented by $1-\gamma<1$). We assume that supplying widgets to B is profitable even in the event that S has B as a customer for only T periods (after which time, for example, B switches to an alternative input) as long as during that time it can sell its widgets to B at a price just below α (that is, $(\alpha-c_s)(1-\delta^T) > I(1-\delta)$).[15]

Switching economics:

B can switch to an alternative input, gadgets. Switching requires an irreversible investment decision of I_B (which for technical convenience, is payable at time T), that results in a switch to gadgets at time T. After switching, by assumption, B can no longer use widgets (without making an investment of time and money). Thus, switching involves a change in B's production process that makes widgets incompatible or uneconomic. This assumption can be interpreted in a number of ways. B might have to replace some machinery or change the final product in order to use gadgets. Alternatively, the use of gadgets may require adjusting machinery (implying machine down time) or qualifying gadgets - with either process being costly and time consuming. Finally, the switching may involve vertical integration by B who is no longer, then, a customer for the previous supplier because of B's ability to obtain the input at marginal cost.

The marginal cost of gadgets for B after switching (at time T) are c_B. In the case of switching by vertical integration, c_B is marginal production costs.[16] In the case of switching to an alternative input, c_B is the price B has to pay for the alternative input. We assume that widgets are the economically efficient inputs for the buyer, in the sense that the total *ex ante* average total cost of supplying widgets to B (given the investment in B-specific assets) are less than the *ex ante* average total costs of gadgets (the next best

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[15] We are assuming here that fixed investments cannot be sold in the period they are used for production (notice that $(1-\delta) = r/(1+r)$).

[16] In the vertical integration interpretation, widgets and gadgets are obviously perfect substitutes.

alternative), i.e.,

$$c_S + (1-\delta)I_S < c_B + (1-\delta)I_B. \qquad (1)$$

We also assume that switching is more profitable for B than paying α for gadgets in perpetuity, i.e.,

$$-I_B(1-\delta)\delta^T + (\alpha - c_B)\delta^T > 0 , \qquad (2)$$

where δ is the discount rate ($\delta = 1/(1+r)$, for interest rate r).[17]

Given assumption (2), if the buyer had the option of using an alternative input consistent with (2) *ex ante*, it must be explained why *ex post* he is captive to his supplier. One possibility is that a structural change in his supplier's market, such as a merger, occurred after the buyer committed to his current input use. For example, suppose that the buyer originally had two widget suppliers merged after the buyer's commitment to widgets. This situation is of particular interest for merger analysis and the proper implementation of the *Merger Guidelines*. But our model provides a more general explanation. If reliance on the supplier is economically efficient (minimizes social costs), we will show that there are equilibria in which the buyer is assured a price that makes choice of the efficient supplier profitable, despite being captive to that supplier in the short run, even without enforceable contracts.

Switching via vertical integration:

The model we have sketched thus far easily incorporates switching through vertical integration. Suppose, for example, that rather than switching to an alternative input, B has access to exactly the same technology of producing widgets as used by S. Then $c_S = c_B$, and $I_S = I_B$. This will be the case when B vertically integrates physically or enters into a

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[17] Recall that the investment expense, I_B, is incurred at the time the plant is completed, T periods after the commitment to switch. Also, (1) assumes that during the T periods before B can actually switch, B buys widgets from S at a price just below α.

contract with a new widget producer. Assume that with more than one producer competition in the widget industry results in Bertrand (i.e. marginal cost) pricing.[18] Finally, suppose that S has just started production, with no prior contractual arrangement with B.[19] Under these assumptions, if B is passive, S is protected from entry by sunk costs and post-entry Bertrand competition, and so S can sell widgets at the monopoly price, α, without stimulating de novo entry. That is, under these conditions it would not pay a *de novo* entrant to enter as a widget supplier. Nonetheless, by (2) it pays for B to switch (i.e. to vertically integrate) rather than paying α in perpetuity.

1. A Simultaneous Move Game.

To begin, consider a game with simultaneous moves by B and S. Given that the buyer makes a commitment to switch, the seller's best response is to charge the monopoly price in all future subgames. Similarly, if the buyer expects the seller to charge the monopoly price in all future periods, since by assumption, switching is more profitable than paying α, then B's best response is to switch during the first period. A subgame perfect equilibrium in this game has the seller charging the monopoly price, α, for T periods and exiting, and the buyer committing to switch in the first period.[20] Since, by assumption, switching is inefficient, the equilibrium is inefficient.[21]

The simultaneous move game, then, yields an equilibrium that looks like the standard oligopoly model result. S, sheltered from competition for T periods sets the

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[18] The model could easily incorporate any post-entry equilibrium concept that makes independent entry unprofitable.

[19] Our analysis could easily be modified to model a situation where S and B bargain ex-ante over the purchase by B of the widget technology.

[20] The equilibrium is subgame perfect because once B vertically integrates, all subsequent (T-1) subgames will feature a price of α.

[21] Because of our assumption of inelastic demand there is only technical inefficiency, no allocative inefficiency.

monopoly price. But this is a result that may not be in the interest of either B or S, as can be seen from the inefficiency of the equilibrium. Of course if B and S could costlessly write enforceable contracts, there would be no switching by S. We will show that this result can also arise as a result of market equilibrium in non-cooperative, non-simultaneous move games. In order to describe such games, we first examine the tradeoffs involved for B and S for switching by B.

2. Tradeoffs involved in switching.

Consider a hypothetical scenario (not an equilibrium or strategy) in which as long as B does not switch, the price is $P^L<\alpha$, but if B switches the price reverts to α. (Below we discuss games with strategies of this type).

Tradeoffs for B

For it not to be in B's interest to switch, purchasing at P^L forever must be at least as profitable for B as switching. That is, P^L must satisfy[22]

$$-I_B(1-\delta)\delta^T + (\alpha - c_B)\delta^T < \alpha - P^L, \tag{3a}$$

where the left hand side (LHS) of (3a) is the per period profitability of switching, and the right hand side (RHS) is the per period profitability of paying P^L forever.[23,24] The P^L

[22] Recall that by assumption the investment costs are not borne until the switch is operational. This is the reason for I_B being discounted.

[23] The buyer's calculus is made assuming that he can buy the alternative input at a price of α, so that α can be thought as his maximum willingness to pay for widgets. Notice that (3a) can be interpreted as a one period condition in the following way. Since the buyer can decide each period whether or not to vertically integrate, what is foregone this period by not vertically integrating is postponing integration by one period. The RHS of (3a) is the current period's surplus from taking price P^L and not vertically integrating this period. The LHS is the cost of delaying vertical integration by one period.

[24] Observe that dividing both sides of (3a) by $1-\delta$ we obtain that for B not to switch, the profitability of switching (in present value form) has to be less than the profitability of paying P^L forever (in present value form).

that makes (3a) an equality, P^L_{max}, leaves the buyer indifferent over switching.[25]

We might call P^L_{max} the "*Bain limit price*" in the sense of the traditional limit pricing models (e.g. Bain (1956), Modigliani (1958)), because it leaves the buyer indifferent between "entering" (switching) or not. Notice that P^L_{max} increases with average costs, the entry lag T, and with the rate of time preference δ, but that P^L_{max} is invariant to the level of the seller's sunk costs ($(1-\gamma)I$), but increases with the buyer's switching costs. By (2), $P_{max} < \alpha$.

Tradeoffs for S

For it to be profitable for S to sell at a price P^L instead of charging the monopoly price α for T periods and then exiting, P^L must satisfy:

$$P^L - c_S > (\alpha - c_S)(1-\delta^T) + \gamma I_S(1-\delta)\delta^T \tag{3b}$$

where the left hand side (LHS) of (3b) is the per period profitability of charging P^L forever, and the RHS is the per period profitability of charging the monopoly price for T periods and then exiting (see also footnote 23). The P^L that solves (3b) with equality, P^L_{min}, leaves the seller indifferent between charging that price forever, and charging the monopoly price for T periods and then selling his B-specific assets.[26]

P^L_{min} falls with the extent of specificity of the seller's investments, but increases with the entry lag, T. Thus, if sunk costs are so large that P^L_{min} is below long run average costs (LRAC), then if the equilibrium price was given by P^L_{min}, the original investment by S would have been unprofitable, in which case widgets would only have been produced, if at

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[25] In terms of the one period interpretation of (3a) discussed in the previous footnote, P^L_{max} just compensates the buyer for delaying vertical integration by one period.

[26] As with (3a), (3b) can be given a one period interpretation. If the seller charges P^L instead of α this period, he gives up (α - P^L) this period. If charging P^L delays the buyer's vertical integration by one period, the seller gains $(\alpha\text{-}c)\delta^T - (1\text{-}\delta)\gamma I_S\delta^T$, where the first term is the gain from being able to charge α at time T (because delaying vertical integration this period means that the buyer will not be integrated at time T), and the second term is the costs of scrapping the seller's recoverable assets one period later than time T. P^L_{min} exactly compensates the seller for the buyer postponing vertical integration by one period.

all, by a vertically integrated B. This is the Klein-Crawford-Alchian result. If the entry lag is large enough, however, P^L_{min}>LRAC, and independent production by S is feasible even if $P^L = P^L_{min}$.

For conditions (3a) and (3b) to hold, P^L must satisfy:

$$\alpha(1-\delta^T) + c_S\delta^T + \gamma(1-\delta)\delta^T I_S \le P^L \le \alpha(1-\delta^T) + c_B\delta^T + (1-\delta)\delta^T I_B. \qquad (3c)$$

The range of prices satisfied by (3c) are those for which neither B or S would do better by having B switch. By (1), there are P^L's that satisfy (3c), and by (2) such P^L's are less than α. Next, we show that there are market games with equilibria consisting of constant prices P^L satisfying (3c) and no switching.

3. Sequential Games

Intuitively, there must be market equilibria that do not involve switching. From S's perspective, given that there are alternatives more profitable than having B switch, charging a price below α and waiting to see whether B switches seems like an obvious strategy. The cost of such a strategy is that S loses the difference between α and the lower price he charges for one period. But as shown by (3b), there are prices below α for which this would be profitable, if B did not switch. Because of the prisoners' dilemma nature of the simultaneous move game, such an outcome cannot be a Nash equilibrium of that game. Therefore, we turn our attention to sequential move games.

We begin by describing two sequential move non-cooperative games: one in which P^L_{max} is a subgame perfect equilibrium, and another in which P^L_{min} is a subgame perfect equilibrium. Neither equilibrium involves switching. We will then show that bargaining games will support any price between P^L_{max} and P^L_{min} as subgame perfect equilibria.

Consider first a game of Markovian strategies,[27] where the seller quotes a price P^L which is valid as long as the buyer does not make a commitment to switch during that period, and where no bargaining is possible between S and B. If B does not make a commitment to switch, then B pays a price of α to S, since charging α then becomes a dominant strategy for S. Conditioned on S's offer, B decides whether or not to switch. This game, then, has S as a Stackelberg leader. Since no bargaining is allowed, S's offer is credible, and by (3a), B's best response to any price at or below P^L_{max} is to not switch. Given B's optimal decision rule, S's optimal strategy is to offer a contract price of P^L_{max}. This game, then, yields the "Bain limit price" as a subgame perfect equilibrium, with no vertical integration.

Consider now a game where B is the Stackelberg leader. In this game B offers to S not to commit to switch if S supplies one unit at a price P^L. If the seller does not accept this offer, then B switches and purchases from S, as in the previous game, at a price of α. Again, since no bargaining between S and B is allowed, B's offer is credible, and by (3b) S's best response to any contract price at or above P^L_{min} is to accept the contract. Given S's optimal decision rule, B's optimal strategy is to offer a contract price of P^L_{min}. Thus, this game, in which B is a Stackelberg leader, yields the "Klein-Crawford-Alchian price" as a subgame perfect equilibrium.

We have shown, then, that there are games that yield limit pricing and no switching as subgame perfect equilibria. These are models in which either the seller or the buyer have a first mover advantage, and no bargaining is permitted. The two games just described are extreme forms of bargaining games. In more general bargaining games, any P^L satisfying

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[27] This type of strategies relate current actions only to last period outcomes, implying that the optimal decision depends only on the node being played. When the strategy space is not restricted to Markovian strategies, then non-constant price strategies may arise. For example, the seller may choose a strategy that consists on charging α for, say, two periods, and some price below α for the next, say, five periods. If this pricing pattern is preferred by the buyer to vertical integration, it may also arise as an equilibrium. This pattern also involves limit pricing, since the average price, over time, will be below α.

(3c) could arise as a subgame perfect equilibrium. One example is the Nash bargaining solution, which results in an equilibrium limit price that is the average of the two reservation prices,[28]

$$P^L_{NASH} = \alpha - [\alpha - \frac{c_B + c_S}{2}]\delta^T + \delta^T(1-\delta)\frac{I_B + \gamma I_S}{2}. \qquad (4)$$

Notice that P^L_{Nash} increases with the time it takes to switch, T, but falls with the extent of sunkness of the seller's investment, and with the rate of time preference δ.

Define limit pricing equilibria as those equilibria featuring a price below α and no switching. Then, although limit pricing equilibria may involve prices above marginal costs, because of the inelastic demand assumption, there is no reduction in welfare,[29] and so limit pricing equilibria are efficient. Equilibria with switching are inefficient by assumption. In summary, we can state:

Proposition 1: Assuming: (a) a single buyer, and (b) switching is credible, then there are infinite horizon sequential games with subgame perfect limit pricing equilibria. Limit prices are in the range specified by (3c). These equilibria are efficient.

The result presented in Proposition 1 is in sharp contrast to the equilibrium that would arise if the buyer side was simply treated as a demand curve. In that case, S would charge the monopoly price for at least T periods. Instead, when B can make a credible threat to switch, all equilibria involve average long run prices below the monopoly price,

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[28] Since payoffs are linear in prices, the bargaining frontier is linear with a slope of -1. Observe that the no agreement outcome is given by vertical integration and monopoly pricing for T periods, implying a profit level for the buyer similar to that obtained from P^L_{max}, and a profit level for the seller similar to that obtained from P^L_{min}.

[29] In a model with a more general demand function, multiple part tariffs may arise, and the relevant limit price may take the form of a surcharge on inframarginal units.

either because of vertical switching following T periods of monopoly price, or because of limit pricing.

The role of sunk costs

Observe that a critical parameter determining the range of equilibrium limit prices is the extent of sunk investments ($(1-\gamma)I$). For example in the case of switching by vertical integration where B has access to the same technology as S, if there are no sunk costs ($\gamma=1$), only $P^L=P^L_{max}$ solves (3c). This is because in this case if the seller has no sunk costs, the buyer has no leverage over the seller. If $\gamma<1$, in the vertical integration case (i.e. with $I_B=I_S$, $c_S=c_B$) there is a range of equilibrium limit prices that satisfy (3c). In the case of general switching, I_B, I_S, c_S, c_B must be such that (1) holds. It is likely, for example, that $c_B>c_S$, if the new input is purchased, since c_B is then the market price of gadgets, while c_S is the marginal cost of widgets (which is less than average cost). In the "Bain limit pricing" model, P^L equals P^L_{max} and is independent of the level of sunk investments, but increases with long run average costs and the entry lag. If P^L is determined ala Klein-Crawford-Alchian, P^L equals P^L_{min} and falls with the amount of sunk costs that the buyer can expropriate from the seller.

If P^L is determined by a bargaining process, then the particular characteristics of B and S determining their relative bargaining power and the nature of the bargaining game will be critical. Since sunk costs provide what leverage the buyer has over the seller, and the entry lag is the leverage that the seller has over the buyer, we would expect that, in general, the limit price would be a decreasing function of sunk costs and an increasing function of the entry lag, as in the Nash bargaining solution.

Although the basic model here is quite simple, leaving aside the assumption of buyer-specific sunk costs and pricing, only two of the basic assumptions are critical to the basic results: that decisions are sequential, and that the buyer's decision to commit to switch is irreversible and immediately observable.[30] Both assumptions appear reasonable. It is unlikely to be rational for the buyer to make an irrevocable decision prior to knowing the price he has to pay. And a buyer can presumably make an irreversible decision by contract. The fact that the seller knows that the buyer can make an irreversible commitment is what gives the buyer leverage over the seller.

4. Variable Sunk Costs

A main result of the theory of the firm developed by Coase and Williamson is that technology and organizational form are related. Sellers whose investments are at risk have an incentive to choose technologies that reduce their exposure. As a consequence, equilibria without vertical integration of B and S may not be efficient. For example, it may result in a level of sunk investment that is lower, and a marginal production cost that is higher than optimal.[31] If technology is chosen unilaterally by S, the resulting equilibrium may require switching, even in games in which for an exogenously given γ, the equilibrium would involve limit pricing.[32] And if the buyer can make strategic decision *ex ante*, he may alter his switching opportunities in order to affect the *ex post* equilibrium. If S has not yet

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[30] This decision, instead of physical vertical integration, could be interpreted as a long term contract with an entrant.

[31] In our model this can be motivated in the following way. Let there be a tradeoff between sunkness ($(1-\gamma)$ in our model) and marginal costs, c, so that $c=c(\gamma)$, and let S determine the value of γ unilaterally (assume, for simplicity, the vertical integration case, so that $I_S=I_B$, $c_S=c_B$). Let γ^* represent the level of sunkness that minimizes operating costs (i.e., $c'(\gamma^*)=0$, with $c''(\gamma^*)<0$). Suppose that P^L is determined as the solution of a simple bargaining process that results in P^L being the average of the upper and lower bounds given in (3a) and (3b), i.e., $P^L = (1-\delta^T)\alpha + [c(\gamma^*)+c(\gamma)]\delta^T/2 + (1-\delta)\delta^T I(1+\gamma)/2$. Then total expected profits of the would-be monopolist are given by $V = [\alpha-(c(\gamma)+c(\gamma^*))/2](1-\delta^T)/(1-\delta) + I[\delta^T(1+\gamma)/2 - 1]$, and the first order condition, $V_\gamma=0$, is $c_\gamma = \delta^T I(1-\delta)/(1-\delta^T) > 0$. If c is monotone in γ, the equilibrium values of c and γ exceed c^* and γ^* respectively.

[32] If S has already entered with an inefficient technology, there may not be a limit price that satisfies (3c), and so the seller's profits are maximized by charging the monopoly price for T periods and exiting, forcing the buyer to vertically integrate. Observe, that for the limit price P^L to be an equilibrium, (3c) requires that $c(\gamma)<c(\gamma^*)+(1-\delta)I(1-\gamma)$, which may be violated by S's choice of technology. The incentives to vertically integration discussed here are analogous to those discussed in Klein, Crawford and Alchian (1978).

entered, the efficient outcome involves the buyer buying the innovation from the seller.[33]

III. Extensions.

The models we have presented above all involve a single buyer and a single seller, both with infinite horizons. In this section we show that limit price and no switching is a likely equilibrium also if we relax those two assumptions. To simplify the discussion, we develop this section for the vertical integration case. That is we assume that $I_B=I_S$ and $c_B=c_S$, and that B can vertically integrate physically or by contract. The results are easily shown to follow for the general switching model.

A. A Single Buyer, Finite Horizon Model

In a perfect information finite horizon game, the usual game-theoretic result is that there are only prisoners' dilemma-like subgame perfect equilibria. If that result would hold for the models considered here, all equilibria would involve vertical integration. In the type of games we have discussed, however, since the game is sequential and B's commitment decision is irreversible and observable, other outcomes are possible. In particular, in the finite horizon case, there are sequential games with subgame perfect equilibria involving no switching.

Let T+N be the length of the game and T+M be the minimum length of period necessary for switching to be profitable in the absence of a widget producer. Assuming away the integer constraint, M solves

$$-I(1-\delta)\delta^{T} + \delta^{T}(\alpha-c)(1-\delta^{M}) = 0. \tag{5}$$

If N<M, the unique equilibrium is for S to charge the monopoly price from the beginning, and B not to switch. If N>M, however, we show in the Appendix that there are

[33] The transaction price should at least equal the profits that independent production would provide the seller. There is, however, a joint gain equal to $[c(\gamma)-c(\gamma^*)]/(1-\delta)$ which will be shared by both the buyer and the seller.

finite horizon games with limit price equilibria. For example, P^L_{max} (P^L_{min}) is the unique subgame perfect equilibrium in games in which S (B) is allowed to give an offer that B (S) has to either accept or refuse. Other bargaining games yield prices between P^L_{max} and P^L_{min}. Thus,

Proposition 2: Assuming: (a) a single buyer, and (b) switching is credible, then there are sequential games with finite horizon larger than T+M, with limit price subgame perfect equilibria. The range of limit prices is that given by (3c), except for the period T+M+1 before the last where the lower bound is below that in (3c). (See details in the Appendix.) During the last T+M periods, the price is α.

B. A Multiple Buyers, Infinite Horizon Model

Since in this section we deal with multiple buyers, to make the analysis tractable we assume that the seller's sunk costs are market rather than customer-specific. As a consequence, buyers may have to act jointly to make credible commitments to switch. As in the previous section, for simplicity, we focus on the case of switching via vertical integration, physically or by contract. We show that most of the results of the single buyer-infinite horizon case still hold with multiple buyers, if buyers can contract, or if at least one buyer is large enough. When customers are of different sizes, we explore the implications of price discrimination. Here we find that price discrimination is not related to demand elasticities, but rather to the ability to switch. Furthermore, since switching is inefficient, price discrimination by deterring switching is socially efficient.

Assume that there are n buyers, each demanding s_i units of the good, with $\Sigma_i s_i=1$, and that vertically integration still requires a production capacity of 1 unit, enough to supply the whole market.[34]

1. Multiple Buyers with Contracting

Assume first that buyers have the ability to write long term contracts with any input supplier (including a vertically integrating buyer). Assume also that a buyer deciding to vertically integrate can contract in advance to supply his product to the remaining, non-integrated, buyers.[35] We analyze first the vertical integration subgame among the buyers. This subgame determines which buyer vertically integrates and the contract price at which he sells to the remaining non-integrated buyers. Buyers in this subgame make offers to each other consisting of a decision to vertically integrate and a long term contract price. These offers are contingent on all buyers signing the contract. Competition among buyers results in the profitability for the buyer that vertically integrates equalling that for the buyers that do not, so that if buyer i integrates it will sell $(1-s_i)$ units to the remaining n-1 buyers at average cost, each at a price of $[c+(1-\delta)I]$. It is easily seen that there is a limit price equilibrium with P^L specified by (3c).[36] Thus,

Proposition 3: Propositions 1 and 2 hold for the case of multiple buyers when all have the ability to write long term contracts.

2. Multiple Buyers without Contracting

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[34] The assumption of buyers' inelastic demands avoids potential raising rivals' costs' considerations for vertical integration, as discussed in Salop and Scheffman (1983), (1987) and Katz (1987).

[35] In this section, vertical integration can be interpreted as writing a long term contract with an independent entrant.

[36] For vertical integration not to be a profitable strategy for any buyer, the price charged by S (P^L) has to satisfy $0 \leq -I(1-\delta)\delta^T/n + (\alpha-c)\delta^T/n] \leq (\alpha-P^L)/n$, which is exactly condition (3a) developed for the case of a single buyer. P^L has to provide S with no lower profits than charging a price of α for T periods and then exiting. That is, $(\alpha-c)(1-\delta^T) + \gamma I(1-\delta)\delta^T \leq (P^L-c)$, which is exactly condition (3b) developed for the case of a single buyer.

We now show that when buyers cannot write long term contracts, as long as vertical integration is profitable at a minimum scale of I, there is a limit price equilibrium.

Assume first the case of identical buyers (i.e., $s_i=1/n$), and that in the absence of a widget producer, all can profitably vertical integrate. That is,

$$-I(1-\delta) + \frac{\alpha - c}{n} > 0. \qquad (6)$$

If $\gamma=0$, i.e., the seller has no recoverable assets, then once a buyer vertically integrates,[37] both share the remaining (n-1)/n units, at a price of c. But there is a basic externality in the entry decision. The buyer that vertically integrates bears the cost of the investment but by driving the price down to marginal cost provides all other buyers with a windfall. This subgame is similar to that in Dixit and Shapiro (1985). The full game has multiple subgame perfect limit price equilibria. The upper bound to the equilibrium limit prices increases with the number of buyers, and exceeds that of the limit price when there is a single buyer.

If $\gamma>0$, all equilibria in the buyers' vertical integration subgame involve more than one buyer vertically integrating. Observe that since the seller has recoverable assets the seller prefers to exit rather than sell at marginal cost. Thus, if a single buyer vertically integrates it becomes a monopolist, generating incentives for further vertical integration. These results are presented in Proposition 4, and are proved in the Appendix.

Proposition 4: Assuming: (a) multiple and identical buyers, (b) none able to write long term contracts, and (c) vertical integration is credible for all buyers, then there

[37] Because of the Bertrand assumption, which implies marginal cost pricing, the incumbent obtains zero net operating profits following entry. Thus, if $\gamma>0$ the incumbent will leave the market following entry. The incumbent's exit, however, implies that the entrant replaces the incumbent as the monopolist. Thus, to assure that the incumbent remains in the market we assume that $\gamma=0$. However, if the post-entry game provided the entrant with a positive net revenue in excess of its non-sunk investments, the assumption of $\gamma=0$ would not be needed.

are infinite horizon sequential games with limit pricing as subgame perfect equilibria. When the limit pricing equilibria exist, the upper bound to the equilibrium limit prices increases in n and exceeds that given by (3c). The lower bound is no lower than that in (3c).

3. Different Size Buyers

Consider now the case when buyers are of different sizes. In particular, suppose there is only one buyer, demanding $z<1$ units, for whom, in the absence of a market for widgets, it is profitable to vertically integrate, while vertical integration is not profitable for the remaining n-1 buyers, each demanding a share $s_i<z$. That is

$$-I(1-\delta)\delta^T + z(\alpha-c)\delta^T \geq 0 > -I(1-\delta)\delta^T + s_i(\alpha-c)\delta^T, \tag{7}$$

for $s_i<z$.

Thus, there is a critical value, z^*, for the market share of the large buyer that makes vertical integration profitable, with $z^* = I(1-\delta)/(\alpha-c)$. Assume first that $\gamma=0$. Then, in the same way as in previous sections, we can see that there are limit price equilibria with P^L given by[38,39]

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[38] Observe that the large buyer will prefer to pay a price P^L forever instead of vertically integrating only if

$$0 \leq -I(1-\delta)\delta^T + z(\alpha-c)\delta^T \leq z(\alpha-P^L). \tag{3a''}$$

Similarly, a seller with no recoverable assets will prefer to charge a price below α that precludes vertical integration, only if his profits must exceed those from charging a monopoly price. That is,

$$(\alpha-c)(1-\delta^T)/(1-\delta) \leq (P^L-c)/(1-\delta). \tag{3b''}$$

Thus, combining (3a") and (3b") we obtain (3c') in the text.

[39] Assume, for the moment, that P^L takes the value given by its upper bound in (3a'). For $z<z^*$ limit pricing will not develop, since the large buyer will obtain a negative surplus from vertical integration. At $z=z^*$, P^L is exactly α. For values larger than z^*, P^L is a decreasing function of z. Furthermore, as z converges to 1, P^L converges to the limit price specified in (3c) for the case of a single buyer. As long as the actual limit price is some function of its upper bound, this result will hold. However, at $z=z^*$, P^L may be less than α.

$$\alpha - (\alpha - c)\delta^T \leq P^L \leq \alpha - (\alpha - c)\delta^T + \frac{I(1-\delta)\delta^T}{z}. \qquad (3c')$$

When $\gamma>0$, however, the seller will leave the market following entry, thus providing the large buyer with a monopoly.[40] In this case, the vertical integration calculus for the large buyer is different. Now the large buyer's profits from vertical integration are larger, and are given by its own surplus plus that from all the small buyers. Hence, it will require a lower P^L so as not to vertically integrate. P^L is given by

$$-I(1-\delta)\delta^T + (\alpha - c)\delta^T \leq (\alpha - P^L), \qquad (8)$$

which is exactly the condition in the single buyer case given by (3a).[41] Thus, the limit price is lower than if S had no recoverable assets.

Assume now that the seller can discriminate. The seller will then charge α to all small buyers, but a lower limit price to the large buyer.[42] In particular, the lower bound for the limit price is given by

$$P^L_{\min} = \alpha - (\alpha - c)\frac{\delta^T}{z} + \gamma I \delta^T \frac{1-\delta}{z} < \alpha - (\alpha - c)\delta^T + \gamma I \delta^T (1-\delta), \qquad (3a')$$

where the right hand side represents $P^L_{\min}$ when the seller cannot price discriminate.[43] That is, if the seller could price discriminate, it would prefer to transfer to the large buyer up to all the profits from the smaller buyers rather than have the buyer vertically integrate.

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[40] While both the seller and the buyer have some recoverable assets, the buyer will always chose to stay, since, by assumption, its investment was profitable.

[41] As in the single buyer case, the vertically integrating buyer captures all the surplus.

[42] See Katz (1987) for an analysis of the welfare effects of third-degree price discrimination in intermediate goods industries.

[43] Observe that when the seller can price discriminate, he will prefer charging P^L forever only if $(\alpha\text{-c})(1\text{-z})/(1\text{-}\delta) + (P^L\text{-c})z/(1\text{-}\delta) \geq (\alpha\text{-c})(1\text{-}\delta^T)/(1\text{-}\delta) + \gamma I\delta^T(1\text{-}\delta)$. After rearranging terms we obtain the expression in the text.

Observe, however, that if we were modeling this industry treating buyers as simply demand curves, they would all be charged the same price, α, as their demands have the same reservation price. Once the differential abilities to threaten to vertically integrate are taken into account, however, price discrimination arises in equilibrium. Even if the buyers had downward sloping demand curves, price discrimination will not be necessarily related to elasticities, as the incentives to switch would depend on the relative magnitudes of consumer surplus in the independent or integrated organizational forms. Finally, since price discrimination is what deters duplicative investment, price discrimination in our framework is socially efficient.

Thus, we can state

> **Proposition 5:** Assuming: (a) multiple buyers, (b) none able to write long term contracts, (c) vertical integration is credible only for the largest buyer (with market share of at least $I(1-\delta)/(\alpha-c)$), and (d) the seller cannot price discriminate, then there are infinite horizon sequential games with limit pricing as subgame perfect equilibria. If there are no recoverable assets (i.e., $\gamma=0$), then the upper bound for the limit price falls with the market share of the large buyer. If, however, $\gamma>0$, the upper bound to the limit price is that given in (3c). If the seller can price discriminate, then the lower bound for the limit price is below that given in (3c).

IV. Implications for Antitrust Analysis under the Merger Guidelines

The Department of Justice's 1982 Merger Guidelines introduced a new approach to the antitrust analysis of market definition and entry barriers. Market definition is based on whether buyers would switch their purchases within a short period of time in sufficient volume to render a hypothetical anticompetitive price increase unprofitable. The Guidelines' barriers test is based on whether entry or its threat would prevent a merger-to-monopoly from profitably exercising significant market power for a period of more than two years. There are analytical problems with the *Guidelines*' barriers test which we will discuss momentarily.

There are a number of analytical and policy problems with the *Guidelines* market definition and barriers criteria. A significant shortcoming of the *Guidelines*, we believe, is they do not envisage a role for strategic buyers when buyers are captive for more than a short period of time. We have shown that even if buyers are captive for a considerable period of time, they may have strategies available to ameliorate apparent market power created by a merger of suppliers. Therefore, the market definition methodology adopted by the *Guidelines* may result in narrower markets than would be reflected by exercised market power.

The underlying intuition of the Guidelines' barriers criterion seems to be as follows. Suppose a merger-to-monopoly, and that entry takes two years. Then if price was raised to the monopoly level, entry would result within two years. But such a scenario is unlikely to occur. First, models featuring sunk costs as entry barriers show that if incumbents have sufficient sunk costs, entry may never occur, independent of the amount of time it would take to enter. Second, we have shown that if sellers have significant sunk costs, and buyers are the most likely entrants,[44] a merger-to-monopoly is not likely to lead to monopoly pricing followed by entry.

By (3a), P^L_{max} makes the buyer indifferent between paying the limit price in perpetuity and vertically integrating and paying the monopoly price for T periods. Thus a merger-to-monopoly could extract <u>at most</u> the equivalent of monopoly pricing for the period it would take to enter.[45] The actual value of the limit price depends, however, on the

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[44] Entry can take the form of vertical integration, contracting with entrants, or investing in switching costs.

[45] Formally, using (3a), the discounted value of the limit price minus average cost (AC),

relative bargaining strengths of the buyers and the seller, and the structure of the game. Thus, the limit price may generally be below P^L_{max}. Thus, for markets relevant to our strategic switching models, monopoly pricing for the duration of the entry lag provides an upper bound to the consumer welfare costs of a merger-to-monopoly. With customer or market-specific investments, buyers may have sufficient leverage to insure that little if any market power is exercised as a result of a merger of their suppliers. In general the Guidelines overestimate the welfare or consumer costs of a merger-to-monopoly.

To sum up, the length of the entry lag is critical in calculating the potential consumer welfare costs of an anticompetitive merger, since limit pricing results in a monopoly overcharge that is at most the equivalent of monopoly pricing until entry.

Bounds can be placed on the potential (percentage) price increase from a merger to monopoly. For example, if the limit price is given by P^L_{max}, then the monopoly overcharge is $(P^L_{max}\text{-}AC)/AC = (1\text{-}\delta^T)[(\alpha/AC)\text{-}1]$. Thus, if the annual rate of discount is 10% and if it takes two years to enter (T=2), then the price increase will be less than .17 times the monopoly mark-up. Consequently, if antitrust enforcement deters mergers that could result in a potential monopoly price increase of 5%, then, in fact, antitrust deters mergers that would bring a permanent price increase of less than .9%.

V. Final Comments.

This paper has developed an analysis of markets in which: (1) sellers have significant customer or market-specific investments; (2) buyers can make credible commitments to obtain alternative sources of supply; but (3) it takes an investment and time to effect a switch to an alternative source of supply. As explained in the introduction to this paper,

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i.e., the monopoly overcharge, is $(P^L_{max}\text{-}AC)/(1\text{-}\delta) = [P^L_{max}\text{-}(c + I(1\text{-}\delta))]/(1\text{-}\delta)=(1\text{-}\delta^T)(\alpha\text{-}c\text{-}I(1\text{-}\delta))/(1\text{-}\delta)$.

markets with these characteristics are common, since many markets are intermediate product markets in which suppliers have customer or market-specific investments and buyers may be the most likely "entrants," or where buyers can make credible commitments to switch to alternative inputs.

We have shown that in these markets the market power of sellers is significantly less than would be predicted models with unsophisticated buyers. Current prices and the switching decision are endogenously determined, with limit pricing being a likely equilibrium, even in the presence of full information. The limit price is predicted to increase with the amount of time it takes to enter, the number of buyers, and with the level of buyers' switching costs, but to <u>fall</u> with the level of sunk investments. Sunk costs, although representing a potential barrier to entry by independent entrants, are not a barrier to buyers making commitments to the use of alternative inputs or sources of supply. This paper, then, questions the standard prediction of an inverse relationship between market performance and sunk investments.[46] The paper also raises questions about the market definition and barriers criteria specified by the *Merger Guidelines.*

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[46] See Gilbert (1987) for a discussion of the welfare implications of specific assets in the framework of the modern theory of market structure.

APPENDIX

A. Proof of Proposition 2.

To prove the Proposition first observe that there is no subgame perfect equilibrium of the sequential game discussed in the text that involves vertical integration. Assume that period T+M before the last has arrived and the buyer is not vertically integrated. Then, the only equilibrium involves monopoly price from that period on. It is straightforward to show that if the seller has not vertically integrated up to period T+M+1 before the last, a price P will arise at that period that will make the buyer prefer not to vertically integrate. Such a price will arise independently of whether the seller or the buyer is the one to quote the price. Thus, given that the price for the period T+M+1 before the last is P, the buyer will not vertically integrate if

$$-I\delta^{T} + (\alpha - c)\delta^{T}\,\frac{1-\delta^{M+1}}{1-\delta} \leq \alpha - P,$$

or,

$$P_{\max}^{\tau+1} = \alpha - (\alpha - c)\delta^{T} + (1-\delta)I\delta^{T} = \alpha - (\alpha - c)\delta^{T+M} \geq P, \tag{A1}$$

where τ=T+M, and where the equality uses the definition of T+M given by

$$(\alpha - c)\delta^{T} - I(1-\delta)\delta^{T} = (\alpha - c)\delta^{T+M}. \tag{A2}$$

On the other hand, the seller would prefer to sell at a price P below the monopoly price, if so doing the buyer would not vertical integrate, only if

$$P - c + (\alpha - c)(1-\delta^{T+M})\,\frac{\delta}{1-\delta} \geq (\alpha - c)\,\frac{1-\delta^{T}}{1-\delta} + \gamma I\delta^{T},$$

or,

$$P_{\min}^{\tau+1} = \alpha - (\alpha-c)\delta^{T} + (\gamma-\delta)I\delta^{T} = \alpha - (\alpha-c)\delta^{T+M} - (1-\gamma)\delta^{T} \leq P, \qquad (A3)$$

where the equality uses again the definition of T+M.

Thus, for P to be profitable for both the buyer and the seller, it has to satisfy (A1) and (A3) simultaneously. Since $\gamma<1$, there always exists a P such that (A1) and (A3) hold. If the seller is the one that gives the price offer, then it will offer P_{max} as long as the buyer does not vertically integrate. If, instead, the buyer is the one that gives price offers, it would offer to pay not to vertically integrate if the price does not exceed P_{min}.

Similarly, it can be shown that if the buyer did not vertical integrate at period T+M+2 before the last, then there exists a price less than α that will deter the buyer from vertically integrating at that time. To determine the range of prices that can arise, assume first that if the buyer does not vertical integrate, then next period's price will be such that the buyer will remain indifferent between integrating or not (i.e. the boundary in (A1)). Then prices are given by

$$P_{\max}^{\tau+2} = \alpha - (\alpha-c)\delta^{T+M} = \alpha - (\alpha-c)\delta^{T} + I(1-\delta)\delta^{T}. \qquad (A4a)$$

If, instead, the next period's price is expected to be such that the seller will remain indifferent between charging the monopoly price or a limit price, then $P^{\tau+2}$ is given by

$$P_{\min}^{\tau+2} = \alpha - (\alpha-c)\delta^{T} + \gamma I\delta^{T}(1-\delta). \qquad (A4b)$$

Thus, if the limit price is such that the buyer is indifferent between vertically integrating and not, then $P^{T+2}_{max} = P^{T+1}_{max}$. And, similarly, it can be shown that $P^{\tau+2}_{max}=P^{\tau+1}_{max}$, for all τ. That is, the limit price is a constant and equals the upper bound in (3c). If, instead, the limit price is set at the reservation level of the seller, then it can be shown that for k>2, the limit price is given by

$$P_{\min}^{\tau+k} = P_{\min}^{\tau+2} = c + (\alpha-c)(1-\delta^{T}) + \gamma I\delta^{T}(1-\delta). \qquad (A5)$$

To show (A5), solve first for $P_{\min}^{\tau+3}$. While tedious, it can be shown that $P_{\min}^{\tau+3}=P_{\min}^{\tau+2}$ using a method similar to the derivation of (A3). Thus, for k=3, (A5) holds. Assume now, that at T+M+k periods before the last the seller expects the future limit prices to remain constant until T+M+1 periods before the last when the price will be given by the lower bound in (A3). Thus, the limit price P that leaves the seller indifferent between charging P for k periods or the monopoly price α for T periods is given by

$$(\alpha-c)\frac{1-\delta^{T}}{1-\delta} + \gamma I\delta^{T} = (P-c)\frac{1-\delta^{k-1}}{1-\delta} + \delta^{k-1}(P^{T+M+1}-c) + \delta^{k}(\alpha-c)\frac{1-\delta^{T+M}}{1-\delta},$$

which after solving for P confirms (A5). Thus, if the bargaining game between the buyer and the seller is such that the seller is always left indifferent between charging the monopoly or the limit price, then the limit price is a constant (equal to the lower bound in (3c)) until T+M+1 periods before the last. At T+M+1 periods before the last the price falls to the lower bound of (A3), and from T+M periods before the last to the end the price is the monopoly price, α.

Therefore, the range of feasible limit prices in the finite horizon model is the same as in the infinite horizon one, except for the period T+M+1 before the last, proving the proposition.

B. Proof of Proposition 4:

Let us first analyze the case of γ=0. We show first that the upper bound to the limit price is given by

$$0 < -I\delta^{T} + (\alpha-c)\frac{\delta^{T}}{n(1-\delta)} \le \frac{\alpha-P^{L}}{n(1-\delta)},$$

or

$$P^L \leq \alpha - (\alpha - c)\delta^T + nI\delta^T(1-\delta). \qquad (B1)$$

Consider the game that develops between buyers when facing monopoly pricing. If a buyer expects someone else to vertically integrate its profits from not vertically integrating are simply

$$\delta^T \frac{\alpha - c}{n(1-\delta)}$$

which exceed those if it would vertically integrate. Thus, every buyer prefers someone else to vertical integrate. This game has N equilibria involving pure strategies, and one symmetric mixed strategy equilibrium. The pure strategies equilibria consist of any of the N buyers vertically integrating. The mixed strategy equilibrium is such that all buyers are indifferent between vertically integrating and not, and where each chooses a probability p of integration such that the others will be indifferent between vertically integrating and not. In either type of equilibrium, all buyers prefer not to vertically integrate if the price charged satisfies (B1). Observe that the upper bound to the limit price is substantially above the upper bound given by (3a).

The condition for the seller to prefer to charge P^L, rather than α, depends on the nature of buyers' strategies. If buyers play mixed strategies, then the probability of each vertically integrating (p) is determined by

$$-I\delta^T + (\alpha - c)\frac{\delta^T}{n(1-\delta)} - p(\alpha - c)\frac{\delta^T}{n(1-\delta)} + (1-p)\delta^{T+1}[-I + \frac{\alpha - c}{n(1-\delta)}],$$

or

$$p - 1 - \frac{1}{\frac{\alpha - c}{nI} + \delta}. \qquad (B2)$$

and S prefers to charge P^L only if

$$\frac{P^L-c}{1-\delta} \geq (\alpha-c)\frac{1-\frac{\delta^T\pi}{1-\delta+\delta\pi}}{1-\delta},$$

or

$$P^L \geq c + (\alpha-c)[1-\frac{\delta^T\pi}{1-\delta+\delta\pi}], \tag{B3}$$

where

$$\pi=\sum_{i=1}^{n}\binom{n}{i}p^i(1-p)^{n-i}$$

is the probability of at least one firm vertically integrating. Thus, in the mixed strategy equilibrium, P^L has to satisfy

$$c + (\alpha-c)[1-\frac{\delta^T\pi}{1-\delta+\delta\pi}] \leq P^L \leq c + (\alpha-c)(1-\delta^T) + (1-\delta)\delta^T nI. \tag{B4}$$

Since $\pi/(1-\delta+\delta\pi)<1$, the LHS of (B4) exceeds the lower bound of the limit price for the single buyer case when γ=0. Thus, since there is a positive probability that no buyers will vertically integrate, (B4) implies that there many not be an equilibrium with limit pricing. This result, however, does not follow if buyers play pure strategies. In this case the seller will prefer to charge a limit price of P^L only if

$$\frac{P^L-c}{1-\delta} \geq (\alpha-c)\frac{1-\delta^T}{1-\delta},$$

which is exactly equation (3b) when $\gamma=0$. Thus, P^L is given by

$$(1-\delta^T)\alpha + c\delta^T \leq P^L \leq \alpha(1-\delta^T) + c\delta^T + (1-\delta)\delta^T nI \tag{B5}$$

Comparing (B4) and (B5), observe that the upper bound to the limit price is the same, and it increases with n. The lower bound in (B4) is above that in (B5) which equals the lower bound in the single buyer case, showing the proposition when the seller has no recoverable assets.

When the seller has recoverable assets ($\gamma>0$) the set of equilibria in the buyers' subgame is expanded. There are now $\binom{n}{2}$ pure strategy equilibria, and n symmetric mixed strategy equilibria. The pure strategy equilibria differ in which two firms vertically integrating. Since a single firm vertically integrating obtains a monopoly, such a configuration cannot be an equilibrium to the subgame. But, if two firms are vertically integrating, no other firm will like to do so. Each of the mixed strategy equilibria now involves one firm choosing to vertically integrate with probability 1, and the remaining n-1 choosing to vertically integrate with probability given by (B2). Since now the probability of one firm vertically integrating is one, the calculus for the seller is the same as for the case of a single buyer. Thus, the lower bound for the limit price is given by (3b). The upper bound is still given by (B1) which exceeds (3a). Thus, proving the proposition.

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