STRATEGIC FIRM BEHAVIOR AND ENTRY DETERRENCE: THREE ESSAYS

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A Thesis Submitted in Partial Fulfillment of The Requirements for the Degree of Doctor of Philosophy

 in

The Faculty of Graduate Studies (Department of Economics)

We accept this thesis as conforming tø the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

August 1993

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ABSTRACT

This thesis consists of three independent chapters on entry deterrence. The first two chapters consider the use of contracts as a barrier to entry, while the final chapter examines the possibility of firms expanding their product lines to deter entry in a vertical differentiation model. In Chapter 1, the role of exclusive dealing contracts in the liner shipping industry is investigated. It is shown that if the entrant is capacity-constrained, exclusive dealing contracts can be an effective entry barrier, even if the entrant has a lower cost. Chapter 2 considers an industry with two stages of production. It is shown that an upstream incumbent is able to deter the entry of a more efficient producer by establishing long-term contractual relations with downstream firms, provided the downstream firms are in direct competition against each other. Chapter 3 considers the question of entry deterrence in a one-dimensional market where goods are differentiated by quality. It is shown that an incumbent firm may decide to produce several products solely for the purpose of deterring entry. Again, it is possible that a lower-cost entrant is deterred. In all three chapters, the welfare consequence is clear: social welfare is lower, since more efficient entrants are excluded from the market.

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ACKNOWLEDGEMENT

In the course of completing this dissertation, I have incurred an enormous debt to the many people who have helped in various ways. In particular, I thank my research supervisor Hugh Neary for his comments on earlier versions, and his support and encouragement. Without his help, this dissertation would not have been completed for many more months to come. I am also grateful to my dissertation committee members, Mukesh Eswaran, Trevor Heaver, and Margaret Slade. Their helpful comments and suggestions have greatly improved the substance as well as the presentation of the material. I also thank Ken Hendricks, Tae Oum, Scott Taylor, and Bill Waters for their comments on an earlier version, and John Cragg and Bill Schworm for their advice and pointers on completing a dissertation. I have also benefited from discussions and comments from ECON 640 workshop participants. Finally, I thank my wife, Lian Oi, for her forbearance and support.

INTRODUCTION

An important question in industrial organization is whether incumbent firms are able to profitably exclude the entry of other firms, since entry barriers are the main source of monopoly and oligopoly power. Incumbent firms have little or no power over prices when entry barriers are nonexistent. By erecting entry barriers, incumbent firms often earn supranormal profits. Social welfare is usually lower in comparison to the free-entry case. The question also carries important legal implications, since the courts in many instances have to decide whether certain practices by incumbent firms restrict entry and hence limit competition in a particular industry. Among well-known cases in the United States are *Standard Oil* of 1911, *Alcoa* of 1941, and *United Shoe Machinery* of 1953.¹

Following Bain (1956), we define an entry barrier as anything that allows incumbent firms to earn supranormal profits without the threat of entry. Broadly speaking, there are two forces interacting in creating entry barriers: the structural features of markets and the behavior of incumbent firms. Bain identified four features of market structure that enable incumbent firms to erect entry barriers. They are: economies of scale, absolute cost advantages, productdifferentiation advantages, and capital requirements. In addition, Bain also suggested three kinds of behavioral responses by incumbent firms in the face of an entry threat:

- (i) Blockaded entry The incumbent firms behave as if there is no threat of entry. No entry occurs, because the market is not attractive enough for potential entrants.
- (ii) Deterred entry Entry cannot be blockaded. The incumbent firms alter their behavior to successfully thwart entry.
- (iii) Accommodated entry Entry occurs, because it is more costly for the incumbent firms ¹For a more detailed discussion of these and other cases, see Scherer (1980), Chapters 20 and 21.

to erect entry barriers than simply to allow entry.

Bain's ideas were formalized in a game theoretic context by Spence (1977), Dixit (1979, 1980), and Milgrom and Roberts (1982). The Spence-Dixit model says that firms compete through the accumulation of production capacity in the long run. An incumbency advantage leads the incumbent firm to accumulate a large capacity (and hence to charge a low price) in order to deter or limit entry. The Milgrom-Roberts model, on the other hand, is based on the asymmetry of information between the incumbent firms and entrants. The incumbent firms charge a low price to convey the information that either demand or their own marginal cost is low, thus signaling low profitability for potential entrants.

More recently, it has also been suggested that contractual arrangements (e.g., exclusive dealing contracts) between incumbent firms and customers in oligopolistic markets can serve as a barrier to entry. (See, for examples, Aghion and Bolton 1987, and Rasmusen et al. 1991.) Unlike the cases of capacity and prices, however, the idea of contracts as a barrier to entry appears to be considerably more controversial. In the antitrust literature, a school of thought that is often referred to as the Chicago School holds that firms establish contractual relations purely for efficiency reasons. (See, for examples, Bork 1978, Posner 1976, Marvel 1982 and Ornstein 1989.) These contractual arrangements, it is argued, simply cannot deter the entry of more efficient (i.e., lower-cost) entrants, the reason being that it is not in the best interest of the customers to limit competition for the incumbent firms. It is therefore not likely that the customers will agree to these arrangements, unless they are sufficiently compensated. To successfully deter lower-cost entrants, the incumbent firms need to compensate the customers for their loss of alternative and less costly sources of supply. However, this cannot be profitable for the incumbent firms given that they are less efficient. Thus, in the case of linear pricing, the incumbent firms must price at or lower than potential entrants' marginal costs, but this cannot be profitable for the incumbent firms given that their costs are higher (Bork,

1978).

However, in industrial organization, the anticompetitive effects of contractual arrangements in oligopolistic markets remain a concern among many economists. Comanor and Frech (1985), Krattenmaker and Salop (1986), and Mathewson and Winter (1987) show that exclusive dealing arrangements between a manufacturer and dealers may reduce the competitiveness of rival manufacturers or even eliminate the rivals altogether from the markets. Mathewson and Winter further show that such arrangements can have a welfare-enhancing property, since wholesale prices may be lower under exclusive dealing. However, as pointed out by Bernheim and Whinston (1992), the result is restricted to the case of linear pricing. The possibility of firms using two-part franchise contracts to avoid the problem of double marginalization is not considered in these studies.

Aghion and Bolton (1987) and Rasmusen et al. (1991) show that, under certain institutional settings, a monopolist seller is able to erect entry barriers through signing exclusive dealing agreements with customers. Rasmusen et al. assume the existence of a minimum efficient scale of production, such that an entrant will need a minimum number of customers, say x, in order for entry to be worthwhile. Thus, the incumbent monopolist needs only to sign up enough customers so that there are less than x customers for the entrant. In particular, Rasmusen et al. show that all customers entering the agreement is a Nash equilibrium.

Aghion and Bolton, on the other hand, consider a type of contract that consists of two elements: a contract price and liquidated damages, the latter are to be levied on the buyer if a breach of contract occurs. Entry is uncertain in the model, with the probability of entry depending on the liquidated damages agreed upon between the seller and buyer. A marginally more efficient entrant will find it unprofitable to induce the buyer to breach the contract. In contrast, a very efficient entrant may find it profitable to offer a sufficiently low price so that the buyer is fully compensated for breaching the contract. The liquidated damages thus act as an entry fee, which is divided between the seller and buyer. The authors show that, by setting the liquidated damages optimally, the seller can exclude the entry of some, though not all, lower-cost entrants.

This thesis consists of three independent chapters, namely

- (1) "Exclusive Dealing Contracts as a Barrier to Entry in Liner Shipping,"
- (2) "Long-term Vertical Contracts and Entry Deterrence," and
- (3) "Quality Differentiation and Strategic Product Line Expansion."

The first two chapters consider the question of entry deterrence through contracts along the same line as Aghion and Bolton, and Rasmusen et al. The third chapter considers product line expansion as an entry barrier in a vertical differentiation model. These chapters are summarized as follows.

Chapter 1 considers the role of exclusive dealing contracts, known as loyalty contracts, in the liner shipping industry. A salient feature of the industry is the existence of cartellike associations known as liner conferences. In many trade routes, conferences face severe competition from independent lines as well as tramps. The latter are in the ship chartering business, but often enter the liner market when there is empty space left after securing a major cargo. To defend their market share, conferences often offer shippers (i.e., customers) loyalty contracts, which essentially guarantee a lower price in return for shippers' 'loyalty' in not using nonconference lines. Since a conference usually consists of several members who are the well-established lines in the business, it enjoys a distinct advantage in size as compared to independent lines and tramps. In the model, we assume that the conferences do not face capacity constraints as independent lines and tramps do.

To analyse the competitive effects of loyalty contracts, we consider a two-stage game. There are three players: a conference, an entrant who is capacity constrained, and a shipper. The entrant is assumed to be more efficient, i.e., to have a lower cost, than the conference. In the

first stage, the conference offers the shipper a loyalty contract, which specifies a price and contains a clause that states that the shipper will not ship through nonconference lines. If the shipper accepts the contract, production takes place in the second stage and no entry occurs. On the other hand, entry occurs in the second stage if the contract is rejected. The conference and entrant then play a price game in the second stage, and production takes place after prices are announced. It is shown that, under these circumstances, loyalty contracts may represent an effective entry barrier—the entrant is excluded from the industry despite its lower cost. Clearly, the outcome is not socially efficient. This result is in sharp contrast to the Chicago School argument that such contracts cannot be effective in deterring more efficient entrants.

Critical to the entry determine result in Chapter 1 is the assumption that the entrant is capacity-constrained. In Chapter 2, we relax this assumption and examine the case where no such constraint exists. The central question in Chapter 2 is whether firms in a vertical relationship are able to deter entry by entering into long-term contracts. We consider a twostage game. In stage 1, an upstream monopolist offers a long-term contract to each of two downstream firms. If the contract is accepted by both downstream firms, it is implemented in stage 2, and no entry occurs. On the other hand, if the contract is rejected, the upstream monopolist then faces a potential entrant, who must decide whether to invest in some research and development activities. If the entrant invests in the R & D and succeeds, it will be able to displace the monopolist as the sole upstream supplier. The probability that this occurs is exogenously given as $0 < \alpha < 1$, which is known to all parties. Throughout, we allow firms to use two-part franchise contracts in order to avoid the problem of double marginalization. The main conclusion of this chapter is that entry deterrence is not possible when the two downstream firms are not in competition against each other (e.g., they operate in unrelated downstream product markets). However, entry deterrence is a likely outcome if the two downstream firms are in direct competition against each other. The downstream firms in this

case are willing to sign the long-term contract to avoid playing a Prisoner's Dilemma game in stage 2. Social welfare is lower in this case, since the less efficient upstream monopolist is allowed to continue to operate instead of being displaced, with probability α , by a more efficient entrant.

Chapter 3 considers the question of entry deterrence in a one-dimensional market where goods are differentiated in quality. Specifically, we examine whether incumbent firms in this market are able to expand their product lines strategically for the purpose of entry deterrence. In the model, firms must decide how many products to introduce, as well as the price for each product. A sunk cost is incurred for each quality a firm chooses to produce. Firms then compete in prices, given their quality choices. We assume that firms are not able to alter their capacity choices once the sunk cost is incurred. Thus the sunk costs enable firms to credibly commit to a particular product quality. We show that a protected monopolist produces only a single good, even if there are consumers who are not served by the monopolist. In a duopoly where each duopolist produces a single good, firms choose the maximum degree of differentiation to minimize price competition. Further, neither firm has any incentive to expand its product line in the single-good duopoly equilibrium. However, if one firm enters the market first, then it may wish strategically to expand its product line to deter potential entrants who have a lower sunk cost. We also examine the case of technological advance which enables firms to introduce higher-quality products than previously possible. We show that, when compared to a monopolist who faces the threat of entry, a protected monopolist is less willing to introduce a new product. Also, if given the exclusive right to the new technology, the high-quality producer in a duopoly has less incentive to make use of the new technology as compared to the low-quality producer.

Chapter 1

Exclusive Dealing Contracts As a Barrier to Entry in Liner Shipping

1.1 Introduction

This paper considers whether loyalty contracts, a form of exclusive dealing contracts widely used in liner shipping, can deter lower cost entrants who are capacity-constrained. The question of whether the use of these contracts is socially efficient is also considered.

These issues have concerned governments for many decades. As early as 1906, the British government appointed a royal commission (the Royal Commission on Shipping Rings) to investigate, among other matters, whether the practice of deferred rebates (a popular type of loyalty contracts at the time) was detrimental to colonial trade. The Commission, however, was unable to reach a consensus and two reports were issued. The majority reports, signed by eleven commissioners, concluded that the practice of deferred rebates did not create excessive market power for the shipping conferences.¹ The minority report, signed by five commissioners, stated that the practice created an artificial barrier to entry and thus gave conferences too much market power.²

Some fifty years later, another landmark case occurred in the United States. The Japan-

¹A shipping conference is a cartel-like association of shipping lines. See Section 1.2 below.

²Royal Commission on Shipping Rings (1909), vol.1 p.37 and pp.95-114.

Atlantic and Gulf Freight Conference filed a proposed dual rate system, another form of exclusive dealing contract widely used in the United States, with the Federal Maritime Board in 1952. The Board was in favor of the proposal, but an independent line, Isbrandtsen, joined by the United States Department of Justice and Department of Agriculture, protested formally. A hearing was held, but the parties involved were unable to reach an agreement. The case then went before the United States Supreme Court in 1958 and the Court ruled in favor of Isbrandtsen on the ground that the dual rate contracts employed by the conference stifled outside competition.³

This and other similar rulings have been criticized by many economists associated with the Chicago School. See, for examples, Bork (1978), Posner (1981), and Ornstein (1989). These authors argue that contractual arrangements between firms cannot have any anticompetitive effects, rather they are adopted for efficiency reasons. Many industrial organization economists, however, do not share this view. The purpose of this paper is to show that, under plausible conditions pertaining to the shipping industry, liner conferences can effectively and profitably use loyalty contracts to limit entry of smaller lines and tramps.

The plan of this paper is as follows. Section 1.2 gives a brief account of the shipping industry. Section 1.3 briefly reviews the literature on exclusive dealing contracts in the areas of shipping, antitrust and industrial organization. A formal model and the main results are presented in Section 1.4. Some remarks and discussion of the results are contained in Section 1.5. Section 1.6 concludes the paper.

³Federal Maritime Board v. Isbrandtsen Co., 356 U.S. 481 (1958). See McGee (1960), pp.252-60 for a summary.

1.2 The Shipping Industry

Broadly speaking, the shipping industry consists of two distinct markets: liner and tramp shipping. Liner companies provide regular shipping services between designated ports according to fixed schedules. The commodities liners transport are usually manufactured and semimanufactured goods. These cargoes are typically originated by many shippers at several ports and destined for many consignees at several ports. Tramp shipping, in contrast, provides vessel services on a time or trip chartered basis. There is no regular schedule nor fixed route. The commodities transported by tramp ships are usually grains and other low-valued goods in shipload quantity, originated by one or a few shippers.

A salient feature of liner shipping is the existence of cartel-like associations known as liner conferences.⁴ The primary objective of conferences is to limit competition between member lines. This is usually achieved through setting common freight rates and other terms of carriage for all member lines. Sometimes conferences also allocate output among members and divide revenues from joint operations. There are usually two conferences on a given trade route, one for each direction of trade. Most conferences have less than ten members, although there are some conferences with as many as fifty members. However, not all liner companies are members of conferences. In some routes, independent and conference lines coexist.

Conferences face competition from independent lines and tramps on many trade routes. The latter often enter the liner market if there is empty space left after securing a major cargo. The independents and tramps usually have limited capacities, smaller fleet sizes and provide less frequent and lower quality of services. Many liner conferences defend their market share by signing a form of exclusive dealing contract known as loyalty contract with shippers (i.e., customers). Broadly, loyalty contracts are of two types: deferred rebate and dual rate. Under the deferred rebate system, shippers who use conference services exclusively for *two* successive

⁴See Heaver (1991) for an account of some of the issues relating to liner conferences.

periods receive a rebate for the first period at the end of the second period. This practice is prohibited by the United States Shipping Act of 1916 for all international trade involving the United States. The dual rate contract, on the other hand, give shippers a discount of 10% to 20% off "noncontract" rates. In return, shippers agree not to ship through nonconference lines. Note that these are contracts between a conference and shippers, so that shippers who sign the contract may use the services of *any* member lines without violating the terms of contract. In the absence of enforcement costs, the two forms of loyalty contracts are identical (McGee, 1960, pp.233-5).

1.3 Related Literature

Numerous economists, legal professionals and shipping researchers have investigated whether loyalty contracts represent an artificial barrier to entry into liner shipping. However, opinions remain at least as divided as in the days of the Royal Commission at the turn of the century. The following is a brief survey of some of their studies.

McGee (1960, pp.249–50) believes that loyalty contracts are the most important device which liner conferences use to deter entry. He observes that in numerous occasions the discount rates of dual rate contracts rose as competition from independent lines and tramps became more intense. Furthermore, no loyalty arrangements exist for certain commodity groups for which the tramps pose no challenge whatsoever. Bennathan and Walters (1969, pp.39–40) argue that loyalty contracts raise the "strategic scale of entry" in that an entrant has to offer at least some of the shippers a full substitute for the services of the conference. More recently, Sjostrom (1988) argues that a conference can profitably exclude a lower cost entrant who is constrained in the frequency of services it can offer. His argument, however, is flawed.⁵

⁵With reference to Figure 1 of Sjostrom (1988, p. 343), it is not true that the conference can always profitably exclude a lower cost entrant. When the conference offers a lower price in the contract, it applies to all units supplied, not just to those at the margin, as claimed by Sjostrom (1988). Further, the equilibrium on which the comparative static exercises are performed is neither unique nor subgame perfect.

In contrast, Sletmo and Williams (1981, pp.209–10) and Davies (1986) do not think that loyalty contracts are effective in deterring entry of independent lines or tramps. They point to the fact that there have been frequent entry and exit of lines in the industry. In particular, Davies (1986) believes that the liner market is close to being perfectly contestable.

In the antitrust literature, exclusive dealing contracts are often regarded as ineffective in deterring lower-cost entrants (see, for examples, Bork, 1978, Chapter 15; Posner, 1981; Ornstein, 1989). The reason being that in order to induce customers to sign a loyalty contract, the incumbent firm must compensate the customers for what they would otherwise have gotten from the entrant. To do this when the entrant has a lower cost must necessarily result in losses for the incumbent, and is thus inconsistent with profit maximizing behavior. In fact, many authors believe that exclusive dealing contracts are socially efficient in that they help to define property rights (Marvel, 1982), or reduce transaction costs and avoid free-rider problems (Ornstein, 1989). Consequently, they advocate that the legal status of exclusive dealing contracts be changed from rule of reason to per se legal.

In industrial organization, however, many economists have challenged this view. Comanor and Frech (1985), Kranttenmaker and Salop (1986), and Mathewson and Winter (1987) show that exclusive dealing arrangements between a manufacturer and its dealers may injure the competitiveness of rival manufacturers.⁶ Mathewson and Winter further show that, in some cases, such arrangements may enhance social welfare. However, Bernheim and Whinston (1992) show that this result depends critically on the assumption that firms do not use two-part franchise contracts to eliminate double marginalization.

On the question of entry deterrence, Aghion and Bolton (1987) show that exclusive dealing contracts with liquidated damages can reduce the probability of entry of some lower-cost entrants, although it does not preclude entry completely. Central to this result is their

⁶However, Schwartz (1987) points out that the equilibrium outcomes obtained by Comanor and Frech are not subgame perfect.

assumption that the incumbent firm and the buyer do not observe the potential entrant's cost, they know only its distribution function. Furthermore, there is a strictly positive probability that the entrant's cost is higher than that of the incumbent, in which case no entry will occur. The buyer is willing to accept a contract that charges a price lower than the monopoly price precisely because there is a probability that no entry occurs. The result does not hold for the case where all potential entrants have lower cost, nor for the case where a lower-cost entrant will appear for certain.

Rasmusen et al. (1991) show that if there exists a minimum efficient scale of production, exclusive dealing contracts can be profitable and effective in deterring entry. The intuition is as follows. Suppose there are 10 customers, and the entrant needs to serve at least 3 in order to reach the minimum efficient scale. The incumbent firm can deter entry by locking up at least eight customers. If customers behave noncooperatively, then the outcome "all customers signing the contract" is clearly a Nash equilibrium. Implicit in their formulation is the assumption that the entrant is unable to offer similar contracts to the customers.

1.4 The Model

Consider a two-stage model. There are three players: a conference, a potential entrant who has a lower cost but is capacity constrained, and a shipper. The conference is assumed to behave like a dominant firm. ⁷ The issues of how members of a cartel set prices and divide profits are avoided. In the first stage, the conference offers the shipper a loyalty contract, which specifies a price and contains a clause which states that the shipper will not ship through non-conference lines. If the shipper accepts the contract, production takes place in the second stage and no entry occurs. On the other hand, entry occurs if the contract is

⁷This assumption effectively requires the conference to behave in such a way as to maximize profits for all its member lines. However, not all writers agree that this is an appropriate assumption for liner conferences. See, for example, Sletmo and Williams (1981).

rejected, and the conference and entrant play a price subgame in the second stage. Production takes place after prices are announced. Information is perfect and there is no uncertainty.⁸ The timing of the game is depicted in Figure 1.1.



Figure 1.1: Timing of game

The shipper produces a single output x, which is produced at zero cost but has to be shipped to the market at a per unit shipping cost of p. The shipper is assumed to be a price taker in the input market. The shipper's demand for shipping services is⁹

$$q(p) = a - bp. \tag{1.1}$$

The inverse demand function is p(q) = (a - q)/b.

The capacities of the conference and the entrant are denoted as K_c and K_e , respectively.

⁸If the conference is prohibited from offering the loyalty contract, then the game consists only of the second stage; since, as shown later, both the conference and the entrant supply positive levels of output in equilibrium, entry deterrence is not possible.

⁹This demand function is appropriate, for example, if the demand for the final product x is linear and the market is characterized by oligopolistic competition between sellers who compete in quantities. Specifically, suppose the demand for the final product is $p_x = h_0 - h_1 \sum_i x_i$, where x_i is the quantity supplied by firm *i*. Then, if firms compete in quantities, the input demand by the shipper is of the form in (1.1).

Capacity of each firm is exogenously given and cannot be changed. Each firm i is assumed to produce at a constant marginal cost, denoted α_i , i = c, e, as long as output is less than capacity. Formally, the cost function for firm i is

$$C_i = \begin{cases} \alpha_i q_i & \text{if } q_i \leq K_i \\ \infty & \text{otherwise.} \end{cases}$$

For simplicity, let $\alpha_e = 0$. This assumption does not affect the results that follow since it merely shifts the origin of α_c .

The conference is assumed to face no capacity constraint. The entrant, on the other hand, has a small capacity such that it would not be able to supply the monopoly output had all incumbents exited the market.¹⁰ Note that the monopoly output for the entrant is $q_e^m \equiv \arg \max_q qp(q) = a/2$. The capacity assumption is stated below.

Assumption 1.1: $K_c \ge a$, $K_e < a/2$.

It follows then $K_c > K_e$, and that only the conference is in a position to offer a loyalty contract. It is further assumed that the conference has a higher cost, although not so high as to render it uncompetitive against the entrant. Specifically, the conference's unit cost is no more than $p(K_e) = (a - K_e)/b$, the highest price at which the entrant can sell all its capacity. This is stated in assumption 1.2.

Assumption 1.2: $0 < \alpha_c < (a - K_e)/b$.

This assumption ensures that if entry is deterred, it is not because the conference is more efficient. As in Deneckere and Kovenock (1990), strategies which involve a firm pricing below its marginal cost will not be considered since these are weakly dominated strategies.

Because the entrant is capacity constrained, it is necessary to derive the residual demand the

¹⁰This is a realistic assumption for the liner shipping industry if capacity is interpreted as frequency of services over, say, a year. On most trade routes, independent lines and tramps are capable of providing far less frequent services than conferences because of their limited fleet sizes. Further remarks about this assumption can be found in Section 1.5.

conference faces when it is undercut. For this purpose, the efficient rationing rule is used. That is, the shipper is assumed to buy from the low-price firm first. If the low-price firm cannot supply all her demand, she then buys from the high-price firm. If the conference and the entrant charge the same price p and the entrant is not capacity constrained, the entrant supplies $\lambda(a - bp)$ and the conference supplies $(1 - \lambda)(a - bp)$, where $\lambda \in [0, 1]$ is fixed exogenously. The payoff function for firm i, i = c, e is given below.

$$\Pi_{i} = \begin{cases} L_{i}(p_{i}) \equiv (p_{i} - \alpha_{i}) \min(K_{i}, a - bp_{i}) & \text{if } p_{i} < p_{j} \\ T_{i}(p_{i}) \equiv (p_{i} - \alpha_{i})S_{i} & \text{if } p_{i} = p_{j} \\ H_{i}(p_{i}) \equiv (p_{i} - \alpha_{i}) \max(0, a - K_{j} - bp_{i}) & \text{if } p_{i} > p_{j}. \end{cases}$$

where

$$S_e = \min(K_e, \ \lambda(a - bp)), \tag{1.2}$$

$$S_c = \max(a - K_e - bp, (1 - \lambda)(a - bp)).$$
 (1.3)

Define

$$p_i^H = \arg \max_{p_i} H_i(p_i)$$

 $H_i^* = H_i(p_i^H)$
 $p_i^I = \min\{p: H_i^* = L_i(p)\}$

In words, p_i^H is the optimal price for firm *i* if it is to be the high price firm; the profit it gets is H_i^* . Next, p_i^I is such that firm *i* is indifferent between being the low price firm charging p_i^I and the high price firm earning H_i^* . Further, let $p_i^H = 0$ if $H_i = 0$. It can be easily verified that

$$p_c^H = \frac{1}{2b}(a - K_e + b\alpha_c), \tag{1.4}$$

which, after substitutions, gives

$$H_c^* = \frac{1}{4b}(a - K_e - b\alpha_c)^2,$$
(1.5)

 and

$$p_c^I = \frac{1}{2b} \left[(a + b\alpha_c) - \sqrt{2(a - b\alpha_c)K_e - K_e^2} \right].$$
(1.6)

Note that the expression in the square root in (1.6) is positive since by Assumption 1.2, $K_e < a - b\alpha_c$. Furthermore, $p_c^H > \alpha_c$ due to Assumption 1.2.

Notice that $p_e^H = H_e^* = p_e^I = 0$. That is, if the entrant is the high-price firm, it earns nothing since the conference will supply the whole market.

A subgame perfect equilibrium is sought, in which strategies constitute a Nash equilibrium for each subgame. As usual, the logic of backward induction is employed to solve the game.

Under a similar framework, Sjostrom (1988) argues that, in equilibrium, the entrant supplies all its capacity by charging its marginal cost, while the conference acts as a dominant firm by supplying the residual demand. This is, however, not an equilibrium for the price subgame. Consequently, the results he obtains from comparative static exercises are not valid. Proposition 1.1 states that

Proposition 1.1 Given Assumptions 1.1 and 1.2, there does not exist a pure-strategy equilibrium for the price subgame.

Proof: Suppose not, i.e., suppose there exists a pure-strategy equilibrium (p_c^*, p_e^*) . First, I show that $p_i^* \ge \alpha_c$ for i = c, e. Since pricing below marginal costs is ruled out by assumption, $p_c^* \ge \alpha_c$. Thus it remains to show that $p_e^* \ge \alpha_c$. Suppose the contrary, $p_e^* < \alpha_c$. Then, by Assumption 1.2, $q_e = K_e$, and this implies $q_c = a - K_e - bp_c$. Profit maximization by the conference requires that $p_c^* = p_c^H > \alpha_c$. But if $p_c^* > \alpha_c$, then $p_e^* < \alpha_c$ is not optimal, a contradiction.

Next, consider three cases: $p_e^* > p_c^*$, $p_e^* < p_c^*$, and $p_e^* = p_c^*$.

Case 1: $p_e^* > p_c^*$.

In this case the conference supplies the whole market since it is the low-price firm. That is, $q_c = a - bp_c^*$ and $q_e = 0$, which means that the entrant makes zero profit. But if the entrant undercuts the conference slightly by charging $(p_c^* - \varepsilon)$, ε arbitrarily small, it gets a profit of $(p_c^* - \varepsilon) \min(K_e, a - b(p_c^* - \varepsilon)) > 0$, a contradiction.

Case 2: $p_e^* < p_c^*$.

In this case the entrant charges the lower price, thus it either sells up to capacity or supplies the whole market, i.e., $q_e = \min(K_e, a - bp_e^*)$. Consider two cases. First, suppose the entrant is capacity constrained, i.e., $q_e = K_e$. Then $p_e^* \leq (a - K_e)/b$. Further, it must be true that $p_e^* < p_c^H$. Suppose not, then $p_c^* > p_e^* \geq p_c^H$. But in equilibrium, the highest price the conference charges is p_c^H , a contradiction. Thus $p_e^* < p_c^H$, but then there exists a price $p \in (p_e^*, p_c^H)$ such that $\Pi_e(p) \equiv pK_e > p_e^*K_e \equiv \Pi_e^*$, which contradicts the hypothesis that p_e^* is optimal. Next, suppose the entrant is not capacity constrained, i.e., $q_e = a - bp_e^*$. This implies $p_e^* \geq (a - K_e)/b > \alpha_c$, where the latter inequality follows from Assumption 1.2. Since the entrant is not capacity constrained, the conference makes no sales and earns zero profit. However, by undercutting the entrant slightly, the conference can make a strictly positive profit. This again contradicts equilibrium.

Case 3: $p_e^* = p_c^* = p^*$.

In this case firm *i* gets to supply S_i , i = c, e, as given in (1.2) and (1.3). If $p^* = \alpha_c$, the conference makes zero profit, but by raising the price to p_c^H , it gets $(p_c^H - \alpha_c)(a - K_e - bp_c^H) > 0$, a contradiction. If $p^* > \alpha_c$, then at least one firm has an incentive to undercut its rival. Suppose $\lambda = 0$, then the entrant is making zero profit, but by undercutting slightly it can makes a strictly positive profit. If $\lambda > 0$, then the conference has an incentive to undercut, since by charging p^* it supplies $S_c < a - bp^*$ while by undercutting slightly it gets to supply the whole market. This contradicts the hypothesis that p^* is optimal.

This non-existence result is driven by the assumption that the entrant has a limited capacity. Without this capacity constraint, the standard Bertrand result obtains; that is, a purestrategy equilibrium exists in the form of $p_c^* = p_e^* = \alpha_c$, with the entrant displacing the conference as the sole supplier. However, this equilibrium breaks down when the entrant is capacity-constrained. To see this, suppose the entrant charges the price $p_e = \alpha_c$. The conference then faces a residual demand and the optimal response is to charge $p_c^H > \alpha_c$. But if this is the case, the entrant, who is charging $p_e = \alpha_c$, will want to charge a price that is just below p_c^H . Thus, any pair of prices with $p_e = \alpha_c$ is not an equilibrium. Further, the conference has an incentive to undercut the entrant if the entrant charges any price that is above α_c . Note that the entrant makes no sales if it is undercut. Thus, any pair of prices that are both above α_c cannot be an equilibrium. There is, therefore, no pure-strategy equilibrium for the price subgame.

Since there does not exist a pure-strategy equilibrium, it is necessary to look for mixedstrategy equilibria. A mixed strategy for firm *i* is a distribution function G_i with a support $[\underline{p}_i, \overline{p}_i]$, where $\overline{p}_i \geq \underline{p}_i$. A mixed-strategy equilibrium is defined as a pair of distribution functions (G_i^*, G_j^*) such that

$$\Pi_i(G_i^*, G_j^*) \ge \Pi_i(G_i, G_j^*) \quad \forall \quad G_i, \ i = c, e,$$

where $\Pi_i(G_i, G_j)$ is the expected profit of firm *i* when a pair of mixed strategies (G_i, G_j) is played. A mixed-strategy equilibrium in this context may be interpreted as a situation in which firms randomly hold sales, as in Varian (1980). Casual empirical observations indicate that freight rates in the liner shipping market are indeed quite volatile, particularly when there is new entry. (See, for example, Stopford, 1988.) Thus a mixed-strategy equilibrium appears to be an appropriate description.

Proposition 1.2 gives the supports of the two firms' strategies and their corresponding equilibrium profits for the price subgame.

Proposition 1.2 In a mixed strategy equilibrium, the conference and the entrant share a common support $[p_c^I, p_c^H]$, with their respective equilibrium profits as H_c^* and $L_e(p_c^I)$.

Given the two firms' supports and equilibrium profits, Proposition 1.3 establishes the mixed strategy equilibrium.

Proposition 1.3 Given Assumptions 1.1 and 1.2, a unique mixed-strategy equilibrium for the price subgame is given by the following distribution functions:

where $\tilde{G}_c(p) = (p - p_c^I)/p$.

Proof: It is straightforward to show that $G_c(\cdot)$ and $G_e(\cdot)$ are increasing functions, with $G_i(p_c^I) = 0, G_i(p_c^H) = 1, i = c, e$. Further, both functions are right continuous on $[p_c^I, p_c^H]$. Thus, (G_c, G_e) are distribution functions. Next, given G_e , the conference's profit from charging a price p is

$$\Pi_{c}(p) = G_{e}(p)[(p - \alpha_{c})(a - K_{e} - bp)] + (1 - G_{e}(p))(p - \alpha_{c})(a - bp),$$

which, after substituting in G_e , simplifies to the equilibrium profit of the conference. Similarly, given G_c , noting that the entrant is capacity constrained, i.e., $K_e < (a - bp)$ for all $p \in [p_c^I, p_c^H]$, the profit of the entrant is

$$\Pi_{e}(p) = G_{c}(p) \ (0) + (1 - G_{c}(p))pK_{e},$$

which simplifies to the equilibrium profit of the entrant. Thus (G_c, G_e) are indeed a pair of equilibrium strategies. Finally, the equilibrium is unique since (\tilde{G}_c, G_e) uniquely solve the

¹¹Deneckere and Kovenock (1990) give a complete characterization of the capacity-constrained price game when firms' marginal costs differ. They show that the supports of firms' strategies are not necessarily the same and that each firm's support is not necessarily connected. These cases occur when the high-cost firm has a small capacity. Kreps and Scheikman (1983) and Osborne and Pitchik (1986) give results pertaining to cases in which firms' marginal costs are the same.

following equations

$$\begin{aligned} H_c^* &= G_e(p)[(p - \alpha_c)(a - K_e - bp)] + (1 - G_e(p))(p - \alpha_c)(a - bp), \\ L_e(p_c^I) &= (1 - \tilde{G}_c(p))pK_e. \quad \P \end{aligned}$$

Note that the conference's equilibrium strategy, $G_c(p)$, has a mass point at p_c^H . That is, the conference charges the price p_c^H with a strictly positive probability, which implies that the conference is more likely to be undercut in equilibrium. This result is hardly surprising since the conference can still earn a strictly positive profit H_c^* if it is undercut, whereas the entrant gets nothing if it is the high-price firm. Thus, the entrant will tend to be more aggressive in setting its price.

Given the solution of the price subgame in the second stage, it is straightforward to solve the full game. Note that for any given pair of prices (p_c, p_e) , the average price (weighted by quantities) the shipper pays is

$$A_p = \frac{q_c p_c + q_e p_e}{q_c + q_e} = \frac{(a - q_e - bp_c)p_c + q_e p_e}{a - bp_c},$$

where

$$q_e = \begin{cases} 0 & \text{if } p_e > p_c \\ \min(K_e, \ \lambda(a - bp)) & \text{if } p_e = p_c = p \\ K_e & \text{if } p_e < p_c. \end{cases}$$

Note that if $p_e < p_c$, then $q_e = K_e$ for all $p_e \in [p_c^I, p_c^H]$.

Thus, given the mixed-strategy equilibrium of the price subgame, the expected price the shipper pays is obtained by integrating over all possible pairs of prices, i.e.,

$$E_{p} = \int_{p_{c}^{l}}^{p_{c}^{H}} \int_{p_{c}^{l}}^{p_{c}^{H}} A_{p} \tilde{G}_{c}'(p_{c}) G_{e}'(p_{e}) dp_{c} dp_{e} + \int_{p_{c}^{l}}^{p_{c}^{H}} \Pr[p_{c} = p_{c}^{H}] G_{e}'(p_{e}) \frac{K_{e} p_{e} + (a - K_{e} - bp_{c}^{H}) p_{c}^{H}}{a - bp_{c}^{H}} dp_{e}.$$
(1.7)

Now, if the conference can find a price at which it can make more profit, and yet is lower than the price that the shipper who does not sign a contract expects to pay, then the conference can exclude the lower cost entrant. That is, suppose there exists a price \tilde{p} such that

$$\tilde{p} \leq E_p \quad \text{and} \quad \Pi_c(\tilde{p}) > H_c^*.$$

Then the conference can profitably exclude a lower-cost entrant by offering a loyalty contract that charges \tilde{p} . Proposition 1.4 shows that this is always possible.

Proposition 1.4 Given Assumptions 1.1 and 1.2, there always exists a price \tilde{p} such that the conference can profitably exclude the potential entrant.

Proof: Note that the lowest price the shipper pays in the mixed strategy equilibrium is p_c^I , which occurs with a probability of strictly less than one. Thus, from the definition of E_p in (1.7) above, it is obvious that $E_p > p_c^I$. This implies that there exists a price $p_c^I < \tilde{p} \leq E_p$. Further, $\Pi_c(\tilde{p}) = (\tilde{p} - \alpha_c)(a - b\tilde{p})$, and note that by definition, p_c^I is the price which solves the equation $(p - \alpha_c)(a - bp) = H_c^*$. Since $p_c^I < \tilde{p} < p_c^m$, where p_c^m is the monopoly price for the conference, it follows then $\Pi_c(\tilde{p}) > H_c^*$. Thus, the conference earns a higher profit by offering the shipper a loyalty contract with a price \tilde{p} . It is to the advantage of the shipper to accept the contract. Therefore, entry is deterred.

Intuitively, if the shipper rejects the contract, the conference and entrant play their respective mixed strategies, and prices will likely be high since the conference's equilibrium strategy calls for charging p_c^H with a strictly positive probability. Hence, the shipper is willing to accept the contract. The conference, on the other hand, is willing to offer such a contract because it would otherwise face a residual demand and charge a high price p_c^H but supply a small quantity. If it offers a contract, it captures the whole market, although at a lower price. Proposition 1.4 shows that the latter is always more profitable.

1.5 Discussion

The equilibrium for the full game involves the conference offering a loyalty contract with a price \tilde{p} and the shipper accepting the contract. By signing a loyalty contract, both the conference and the shipper gain, at the expense of the entrant. This result may appear to rely heavily on the assumption of a single shipper. However, if one regards capacities of firms as the frequency of services over a period of time, then the result holds for n identical shippers. Each shipper will prefer to sign the contract with the conference.

This result does not depend on the type of competition assumed in the second stage. In fact, the same result holds if competition in the second stage is Cournot rather than Bertrand. This case is analysed in Appendix 1B. The intuition is as follows. Under the Cournot assumption, firms supply different quantities (due to different marginal costs), but charge the same price. Competition is less intense, and both firms earn strictly positive profit at this price. The conference can therefore offer a loyalty contract supplying all the shipper's demand at a slightly lower price. In effect the conference achieves a discrete jump in revenue by charging a slightly lower price. This means that the conference earns a higher profit by offering the contract. The entrant, although having a lower cost, is again deterred due to its limited capacity.

The equilibrium outcome, however, is not socially efficient, since the shipping service is provided at a total cost of $\tilde{C} = \alpha_c(a - b\tilde{p})$, not the lowest possible. A more efficient outcome is $q_e = K_e$ and $q_c = a - K_e - b\tilde{p}$, with a total cost of $C^* = \alpha_c(a - K_e - b\tilde{p}) < \tilde{C}$. Nonetheless, the outcome is socially more efficient than that under monopoly, since the contract price is lower than the monopoly price. The presence of a potential entrant, as predicted by the contestable market hypothesis, exerts a downward pressure on price. The entrant's capacity constraint, however, prevents it from completely disciplining the conference. Instead, the conference exploits this 'weakness' of the entrant by introducing a loyalty contract system to exclude the entrant. Therefore, the market fails to be contestable because of the entrant's capacity constraint.

In part, the entrant is unable to reap the efficiency gain because, according to the rules of the game, the entrant does not get to move if the shipper accepts the contract. This can be interpreted as saying that there is no way in which the entrant can credibly commit to charging a low price before it enters the market. The no-entry result is weakened if precommitment by the entrant is possible. To see this, consider a slightly modified version of the game. Suppose that the shipper, having accepted the contract, is allowed to breach it at no cost; and that the entrant can commit to charging its marginal cost, i.e., $p_e = 0$. Whether the entrant will default obviously depends on the contract price \tilde{p} .

To decide what contract price to offer, the conference has to anticipate what will happen if the shipper breaches the contract. Since in that event the entrant is committed to charging $p_e = 0$, the best response of the conference is to charge p_c^H , which gives a profit of H_c^* . The (weighted) average price the shipper pays is then

$$A_{p}^{l} = \frac{p_{c}^{H}(a - K_{e} - bp_{c}^{H})}{a - bp_{c}^{H}}.$$
(1.8)

(The superscript "l" is used to indicate that this is the lowest possible average price the shipper pays.)

If on the other hand, the conference and the shipper sign a loyalty contract at an agreed price of \tilde{p} , then the conference's profit is $\tilde{\Pi}_c(\tilde{p}) = (\tilde{p} - \alpha_c)(a - b\tilde{p})$. In order to induce the shipper not to default, the contract price must be less than the average price in (1.8). Assume, for the moment, that $\alpha_c < A_p^l$, so that the conference can find a contract price \tilde{p} such that $\alpha_c < \tilde{p} \leq A_p^l$.¹² However, for the conference to offer such a contract, it must be able to earn a higher profit than H_c^* . The highest price the conference may charge is $\tilde{p} = A_p^l$, which gives

¹²Note that, a priori, A_p^l need not be greater than α_c . It will be shown later that $A_p^l > \alpha_c$ whenever the conference can profitably deter entry.

a profit of $\tilde{\Pi}_c(A_p^l)$.¹³ Therefore, a contract will be offered if

$$\widetilde{\Pi}_c(A_p^l) = (A_p^l - \alpha_c)(a - bA_p^l) \ge H_c^*.$$
(1.9)

If this inequality holds, it also ensures that $A_p^l > \alpha_c$. To see this, note that by definition, $A_p^l < p_c^H$, thus $a - bA_p^l > a - bp_c^H > 0$. Since $H_c^* > 0$, this implies that if the inequality in (1.9) holds, then $A_p^l > \alpha_c$.

After substitutions and some algebraic manipulations, the entry deterrence condition in (1.9)simplifies to¹⁴

$$4aK_e(a - K_e + b\alpha_c) \le (a - K_e - b\alpha_c)(a + K_e - b\alpha_c)^2$$

$$(1.10)$$

The inequality in (1.10) is depicted in Figure 1.2 in (α_c, K_e) space, with a = 2 and b = 1. The shaded region represents combinations of α_c and K_e where a contract is offered (and thus entry is deterred). Note that entry is likely to be deterred if the cost disadvantage of the conference is small, or the entrant's capacity is low, or both. Entry deterrence is therefore only optimal for the conference for some values of K_e and α_c .

It is worth noting that the above entry deterrence condition is derived under the extreme assumptions that the shipper is allowed to breach the contract without paying any damages, and that the entrant is committed to charging the lowest possible price (i.e., its own marginal cost). Both assumptions tend to reduce the feasibility and profitability of offering an exclusive dealing contract by the conference. Hence, entry deterrence is least likely under these circumstances.

Central to the entry deterrence results is the assumption that the entrant is capacity-constrained. Absent this capacity constraint, the standard Bertrand result applies. That is, the low-cost entrant simply displaces the conference, and loyalty contracts cannot be an effective entry barrier. This is in essence the argument of the Chicago School. However, an entrant

¹³Since $0 < A_p^l < p_c^H < p_c^m$, the conference's profit function $\tilde{\Pi}_c$ is thus increasing over the interval $[0, A_p^l]$. ¹⁴See Appendix 1C for the derivation.



Figure 1.2: Graphical representation of entry deterrence condition, with a = 2, b = 1

who has a limited capacity is not able to displace the conference. The entrant's small capacity means that the shipper cannot satisfy all her demand through the entrant (at a relatively low price), and must also use the conference's services (at a relatively high price). This results in a high average price, hence a low surplus for the shipper. As a result, the conference is able to compensate the shipper for her loss of a more efficient but low-capacity supplier. It is at this point that the Chicago School argument breaks down. Loyalty contracts indeed represent an effective entry barrier against low-capacity entrants.

Why, then, does the entrant have a limited capacity? Is there not an incentive for the entrant to increase its capacity? Two responses can be offered. First, this capacity assumption is a realistic one for the shipping industry if capacity is interpreted as the frequency of services over, say, a year. Note that a conference consists of several members who are usually the well-established lines in the business. Not surprisingly, on most trade routes independent lines and tramps are capable of providing far less frequent services than conferences due to limited fleet sizes. It is therefore unreasonable, from a practical viewpoint, to expect an independent line or a tramp ship to be able to match the capacity of the conference.

Second, on a theoretical note, the imperfection of capital markets may justify the capacity assumption. Fudenberg and Tirole (1986), Poitevin (1989), and Bolton and Scharfstein (1990) show that it is more difficult for an entrant to obtain financing if the capital market is characterized by asymmetric information. Because of this imperfection, an incumbent firm is able to prey on a financially constrained rival by inflicting losses on the rival.¹⁵ The same argument can be applied to show why the entrant has a limited capacity and is unable to increase that capacity.

1.6 Conclusion

This paper shows that loyalty contracts can be effective barriers to entry when the entrant has a limited capacity. This result does not depend on the assumption of Bertrand competition (and hence the nonexistence of pure-strategy equilibrium). A weaker result is obtained if precommitment by the entrant is possible. The resulting equilibrium is not socially efficient, since a lower-cost entrant is unable to enter the market. Central to this result is the capacity constraint of the entrant, which enables the conference to stay in the market. The ensuing price (or quantity) competition results in a high average price, hence a lower surplus for the shipper. This in turn allows the conference to compensate the shipper for her loss of an alternative supplier.

Without the capacity constraint, the standard Bertrand result applies: a more efficient entrant simply displaces the conference. Exclusive dealing contract is therefore not an effective entry barrier. The Chicago School argument is thus valid in this case. The use of exclusive dealing contracts cannot possibly cause any efficiency loss. However, this argument breaks down when the entrant is capacity-constrained. Casual observations about the shipping industry

¹⁵This is often referred to as the 'long-purse' story of predation in industrial organization.

suggest that, as compared to the Chicago School argument, the present model seems more convincing. In fact, conferences openly admitted that the main purpose of loyalty contracts was to exclude entry of smaller entrants. Mr. Sutherland, an executive of a liner company, testified before the Royal Commission on Shipping Rings (1909) that,

To put the matter quite clearly and openly, the conference system and the rebates exclude fairly what you might call the casual competition. Without the rebate system, you are liable to have a state of *chaos*; with the rebate system, that casual competition which would throw things into a state of chaos is excluded. (Cited in McGee, 1960, p.243; emphasis added.)

Presumably, by 'chaos,' Mr. Sutherland referred to the volatility of freight rates when there was entry. Clearly, the practice of rebate system (a form of exclusive dealing) has an adverse effect on the competitiveness of 'casual competitor' such as tramps. Therefore, we conclude that the Chicago School's position of letting all exclusive dealing contracts be per se legal in liner shipping is questionable, if not unwarranted.

Chapter 2

Vertical Contracts and Entry Deterrence

2.1 Introduction

Firms in a vertical relationship often enter into various forms of contractual arrangements broadly known as vertical control or vertical restraints. These arrangements range from a simple supply contract to a complex vertical merger (i.e., vertical integration) between two or more firms. Broadly, there are two strands of literature on vertical control in industrial organization. The first focuses on the control problem of a monopoly or monopsony, who wishes to influence the actions of firms at other stages of production. For example, a manufacturer may like to impose restrictions on retailers' choices of price, output, location and so on (see, for example, Mathewson and Winter, 1984). The welfare effect of these restrictions is generally ambiguous. (See the surveys by Katz, 1989; and Perry, 1989.)

More recently, many studies have examined whether vertical integration can lead to the foreclosure of competition in upstream or downstream markets when these markets are characterized by oligopolistic competition. (See Salinger, 1988; Hart and Tirole, 1990, Ordover, et al., 1990; and Bolton and Whinston, 1991, among others.) These studies show that it is possible for vertical integration to lead to anticompetitive foreclosure, and social welfare is generally lower.

Little, however, has been said in the literature regarding the possibility of an incumbent firm deterring more efficient entrants through some forms of vertical control. This paper examines whether an upstream monopolist is able to deter the entry of more efficient entrants into the upstream market through establishing contractual relationships with its downstream customers. We show that entry deterrence is possible if the downstream firms are competing against each other in an imperfectly competitive product market. This is, however, not true if the downstream firms are *not* in direct competition against each other (e.g., they operate in unrelated product markets).

The paper is organized as follows. Section 2.2 reviews the relevant literature. Section 2.3 outlines the basic setting of the model and considers the simple case where the downstream firms are not in direct competition. The case of Cournot competition between downstream firms is considered in Section 2.4. The results are discussed in Section 2.5. Some concluding remarks are contained in Section 2.6.

2.2 Related Literature

In the antitrust literature, it is widely believed that vertical contractual arrangements are made mainly for efficiency reasons (see, for example, Marvel, 1982). In particular, a school of thought that is often referred to as the Chicago School holds that these practices cannot have any anti-competitive effects. Among the chief proponents are Bork (1978) and Posner (1976, 1981). These authors argue that a downstream firm, for example, is unlikely to want to participate in schemes that will limit entry in the upstream market. This is because by making the upstream market less competitive, the downstream firm loses alternative and perhaps less costly sources of supply. Thus, for an upstream producer to successfully implement such schemes, it must compensate the downstream firm for its loss. However, this cannot be profitable for the upstream producer if it is less efficient than potential entrants whom it
wishes to exclude. Based on these arguments, Posner (1981) calls for the courts to treat all vertical restraints as per se legal.

In industrial organization, however, the anticompetitive effect of vertical contractual arrangements in oligopolistic markets remain a concern. For examples, Comanor and Frech (1985), Kranttenmaker and Salop (1986), and Mathewson and Winter (1987), among others, have shown that firms in imperfectly competitive markets can use exclusive dealing contracts to reduce the competitiveness of rivals or even eliminate rivals altogether.

On the question of entry deterrence, recent contributions by Aghion and Bolton (1987) and Rasmusen et al. (1991) show that, under certain institutional settings, a monopolist seller is able to deter entry through signing exclusive dealing contracts with customers. Aghion and Bolton consider a particular type of contract that contains two elements: a contract price and liquidated damages to be levied on the customer if a breach of contract occurs. In the model, entry is uncertain, with the probability of entry depending on the liquidated damages agreed upon between the seller and buyer. A marginally more efficient entrant may be unable to set a price attractive enough for the buyer to breach the contract. On the other hand, a very efficient entrant may find it profitable to offer the buyer a sufficiently low price that the buyer is fully compensated in breaching the contract. In this way, liquidated damages act as an entry fee, which is divided between the seller and buyer. The authors show that, by setting the liquidated damages optimally, the seller can exclude the entry of some, though not all, lower-cost entrants.

On the other hand, Rasmusen et al. assume the existence of a minimum efficient scale of production such that an entrant will need a minimum number of customers, say x, in order for entry to be worthwhile. To deter entry, the incumbent therefore need only sign up enough customers through contracts so that there are less than x customers for the entrant. In fact, Rasmusen et al. show that all customers signing the contract with the incumbent is a Nash

equilibrium.

This paper considers the use of supply contracts as a device for entry deterrence. These contracts take a simple form: they commit downstream firms to acquire all their requirements of a certain input from the upstream supplier.¹ Unlike the contracts considered by Aghion and Bolton, no liquidated damages are specified. Further, the use of two-part franchise contracts is permitted, i.e., the contract may contain a fixed fee as well as a per-unit charge. It is worth noting that, in the simple environment considered below, there is no substantive difference between signing a supply contract and outright vertical merger. The analysis below requires little modification if the latter possibility is considered.

This paper differs from Aghion and Bolton, and Rasmusen et al. in one important aspect: downstream firms are in direct competition against each other. It is this downstream competition which enables the upstream incumbent to use contracts as barriers to entry.

2.3 Basic Setting

An upstream monopolist, denoted U, supplies an input z to two downstream firms, 1 and 2. For concreteness, we refer to all upstream firms as producers and all downstream firms as retailers. Producer U holds an exclusive right (e.g., a patent) to a technology that is necessary to produce the input. Assume, for simplicity, that this is the only factor of production for the two retailers, who share a production technology which turns one unit of z into one unit of final product. The upstream monopolist faces a potential entrant, denoted E, who has to decide whether to invest in research and development. If producer E invests and the R & D is successful, it will be able to supply the input to retailers 1 and 2 at a lower cost. In effect, the entrant is in a position to displace the incumbent as the sole upstream supplier.

¹In the antitrust literature, these contracts are known as requirements contracts. They do not differ from exclusive dealing contracts in the present context. Under the antitrust laws, these contracts are not illegal, rather they are subject to the rule of reason. That is, these practices will be decided on a case-by-case basis by the courts. For greater detail, see Blair and Kaserman (1983), Chapter 9.

The probability that producer E succeeds in the R & D is exogenously given as $0 < \alpha < 1$, which is known to all parties.

Consider the following hypothetical example. The upstream monopolist is a utility company, that supplies the energy requirements of two nearby factories. There exists an alternative source of energy which, if successfully developed, will be able to meet the energy requirements of the two factories at a lower cost. There is, however, a risk involved in developing this alternative source. In other words, success is not assured when the R & D investment is made. The questions of interest are: Is there any incentive for the upstream monopolist to establish a contractual relationship with firms 1 and 2 so that the entrant is discouraged from investing in R & D? Will the downstream firms accept such a contract?

It is assumed that the upstream monopolist is prohibited from discriminating between downstream retailers. In other words, if a contract is offered, it must be made available to both retailers. This assumption rules out the possibility that the upstream producer can create a monopoly in the downstream market by contracting with only one retailer. It is also assumed that all firms are risk neutral.

Given that the industry structure consists of successive oligopolies, the problem of double marginalization may arise if only linear pricing is considered (Spengler, 1950).² We assume that firms are sophisticated enough to recognize and avoid this problem through nonlinear pricing. For the present purpose, it suffices to allow the use of two-part tariffs, so that elimination of double marginalization is not a motive for signing contracts. That is, firms may negotiate contracts that contain a fixed fee and a constant per-unit charge. In the event that no contract is signed, firms are also free to negotiate two-part tariffs on spot transactions.³ It is easy to show that such a pricing scheme maximizes the combined profits

²Unless, of course, the downstream market is characterized by Bertrand competition.

³It goes without saying that linear contracts are a special case of two-part tariffs, with the fixed fee being set at zero.

of the upstream and downstream firms.⁴

Consider a two-stage game. In stage 1, producer U offers retailer i (i=1,2) a supply contract, which specifies a wholesale price w and a fixed fee f. If both retailers accept the contract, it is implemented in stage 2, and no entry will occur, regardless of whether producer E invests in R & D. If neither retailers accept the contract, two possibilities arise in stage 2. Either entry occurs or it does not. Entry does not occur if producer E fails in its R & D effort, which occurs with probability $1 - \alpha$. There are then three firms in the industry: producer U upstream, and retailers 1 and 2 downstream, and they bargain over a two-part tariff on spot transactions. We do not specify the bargaining process, although we assume that the bargaining outcome is efficient; that is, firms will not agree on an inferior outcome when an outcome is available in which they can all be made better off. The joint profit to be divided is therefore the amount an integrated monopoly would earn. Note that each firm's share of the joint profit is unknown, since it depends on the firms' bargaining power, which is left unspecified. However, the possibility that the upstream producer appropriates all of the joint profit through the fixed fee is not ruled out.

On the other hand, entry occurs if producer E invests in R & D and succeeds, which occurs with probability α . In this event, there are four firms in the industry: producers U and E upstream, and retailers 1 and 2 downstream. We assume throughout that retailers 1 and 2, being in the same downstream market, do not engage in direct bargaining between themselves. The same assumption also applies for producers U and E.⁵ There are four possibilities in this case: either producer U or E sells to both retailers 1 and 2, or each producer sells to a different retailer.⁶ The bargaining issues involved are complex, since

 $^{^{4}}$ For a clear exposition of the problem of double marginalization and ways to overcome it, see Tirole (1988), pp.174–177.

⁵This assumption is made for practical reason, since it is illegal in most cases for firms in the same market to attempt to divide the market among themselves.

⁶We rule out the possibility that both producers selling to a single retailer. Since producer E is more efficient, it is unlikely that a retailer would find it advantageous to acquire its input from both producers.

not only are the producers competing for customers downstream, but also the retailers are choosing suppliers upstream. To avoid these bargaining issues, we proceed by letting the two retailers choose, simultaneously, their respective upstream supplier. That is, retailers 1 and 2 play a one-shot game in choosing, non-cooperatively whether to acquire their inputs from producer U or E. Henceforth we will refer to this game as the 'Choose a Supplier' game. The detail of this game can be found in Section 2.4.

For simplicity, we rule out the possibility that one of the retailers, say retailer *i*, agrees to, while retailer j ($j \neq i$), rejects, the contract. In effect, we assume that there is no incentive for a retailer to hold out by not signing if the other retailer has agreed to sign the contract. Ideally, this should constitute part of the equilibrium outcome of the model. However, more structure is needed to analyse this possibility; for example, one must specify what happens to the retailer who holds out if no entry occurs in stage 2. Obviously, different specifications could lead to vastly different results. We therefore assume that there are ways by which the parties to the contract can avoid such opportunistic behavior. For example, the parties may be able to agree that the contract is void unless both retailers enter the agreement. Further discussion of this assumption is deferred until Section 2.5.

The timing of the game is illustrated in Figure 2.1.

Consider first the simple case where retailers 1 and 2 are not in direct competition against each other in the downstream product market. They may, for example, be located in geographically separated regions or operate in unrelated markets. Assuming that they are identical in every other aspect, there is then no loss of generality in considering a representative retailer, say retailer k. Proposition 2.1 shows that signing a contract in stage 1 *cannot* be part of a subgame perfect equilibrium.

Proposition 2.1 Suppose that the retailers do not compete against each other in the down-



Figure 2.1: Timing of game

stream product market. Then, there does not exist a subgame perfect equilibrium in which the upstream monopolist and the retailers sign a contract.

Proof: Consider first stage 2. Suppose no contract is signed in stage 1. Then, in the event that no entry occurs, only firms U and k are in the industry. This is the case of successive monopolies, and total profit is maximized through the use of two-part tariffs. Let Π^* denote the total profit, and $R_k \geq 0$ be retailer k's share of the total profit. Thus, the payoff to producer U is $\Pi^* - R_k$. Next, suppose entry occurs in the upstream market. Then, there are two producers competing for a single buyer in the downstream market. This competition for buyer causes the more efficient entrant to offer a wholesale price and fixed fee combination that gives a profit of $\Pi^* + \epsilon$ to firm k, where $\epsilon > 0$ is some arbitrarily small amount, and the incumbent makes no sales. Let $\hat{\Pi}$ denotes the total profit to be shared between firms E and k. Note that by supposition, $\hat{\Pi} > \Pi^*$. The payoffs to firms k and E are, respectively, $\Pi^* + \epsilon$ and $\hat{\Pi} - (\Pi^* + \epsilon)$.⁷

In stage 1, retailer k's expected profit for not signing the contract is a weighted sum of its gains in stage 2 under the two cases considered above, i.e.,

$$(1-\alpha)R_k + \alpha(\Pi^* + \epsilon).$$

Similarly, if a contract is not signed, the expected profit for producer U in stage 2 is

$$(1-\alpha)(\Pi^* - R_k) + \alpha \cdot (0) = (1-\alpha)(\Pi^* - R_k).$$

Suppose, contrary to the hypothesis, that a contract is signed. Let R_k^c be retailer k's share of the total profit, Π^* . Then, the payoffs to producer U is $\Pi^* - R_k^c$. Hence, for the contract to be offered by producer U, it must be true that

$$\Pi^* - R_k^c \ge (1 - \alpha)(\Pi^* - R_k),$$

⁷Alternatively, suppose that firms E and k engage in a noncooperative bargaining game, in which retailer k holds the outside option of dealing with producer U instead. Assuming that players have a common discount factor which approaches unity, then the payoffs for firms k and E are, respectively, Π^* and $\hat{\Pi} - \Pi^*$. See Osborne and Rubinstein, (1990), pp.54-63.

which, after rearranging terms, simplifies to

$$R_k^c \le (1-\alpha)R_k + \alpha \Pi^*. \tag{2.1}$$

However, for the same contract to be acceptable to retailer k, it must also be true that

$$R_k^c \ge (1 - \alpha)R_k + \alpha(\Pi^* + \epsilon).$$

which contradicts (2.1).

The intuition behind Proposition 2.1 is as follows. Suppose no contract is signed in stage 1. Since the entrant has a lower cost, the retailer is assured of at least $\Pi^* + \alpha$ in the event that entry occurs in stage 2. If no entry occurs, the joint profit between the monopolist incumbent and retailer is Π^* . Hence, the sum of the incumbent and retailer's expected profits is *at least* Π^* plus some small amount in stage 2. However, in stage 1, the total profit to be divided between the incumbent and retailer through a contract is *at most* Π^* . Clearly, by not signing the contract, either the incumbent or the retailer can be made better off without making the other worse off. Therefore, a contract cannot be part of an equilibrium.

This result is in sharp contrast to that of Aghion and Bolton, who show that it is possible for the upstream producer to deter lower-cost entrants through contracts. Their model, however, contains an important feature. The contract they consider contains two components: a contract price and liquidated damages, the latter are to be paid by the retailer if a breach of contract occurs. Thus, it is possible for the retailer to breach the contract by paying the agreed liquidated damages. By setting the liquidated damages, the incumbent in effect imposes an entry fee that the entrant must pay in order to trade with the retailer. This entry fee is set in the same way a monopoly would set its price. Thus, a very efficient entrant (as compared to the incumbent) is willing to pay the liquidated damages on behalf of the retailer to induce the retailer to breach the contract. On the other hand, a marginally more efficient entrant is not willing to do so. Hence, the incumbent is able to exclude some, but not all entrants. For comparison, we may interpret the contract in this paper as one which, once signed, is prohibitively costly to breach. In effect, the 'liquidated damages' in this case are large as compared to the benefit of the contract, and do not accrue to the incumbent.⁸ It can be shown that, given this modification, the result of Aghion and Bolton no longer holds. However, while this interpretation is possible, we emphasize that the present model does not focus on an alternative specification of the liquidated damages assumption in the Aghion-Bolton model.

2.4 Cournot Competition in the Downstream Market

In this section, we consider Cournot (quantity) competition between retailers 1 and 2 in the downstream product market. The case of Bertrand (price) competition when the final products are differentiated is considered in Appendix 2B. It is shown there that the qualitative nature of the results remains unchanged. We do not consider the case of homogeneous-good Bertrand competition because, by definition, the retailers earn zero profit in all cases. The retailers are therefore indifferent between signing and not signing a contract.

For simplicity, we assume that the final product is homogeneous and the retailers face linear demand of the form

$$p = 1 - (q_1 + q_2), \tag{2.2}$$

where p denotes the price and q_i denotes the quantity of retailer i, i = 1, 2.

Let w_i and f_i be, respectively, the wholesale price and fixed fee facing retailer i, i = 1, 2. Note that, by the no-discrimination assumption, $w_i = w$ and $f_i = f$ if both retailers acquire their inputs from the same producer.

⁸For example, one can think of liquidated damages as litigation costs, most of which go to the lawyers.

The decision problem of retailer i is to maximize its share of the total profit,

$$R_{i} = \max_{q_{i}} (p - w_{i})q_{i} - f_{i}.$$
(2.3)

The first-order condition gives rise to the reaction function for retailer i, i = 1, 2:

$$q_i(q_j) = \frac{1}{2}(1 - q_j - w_i), \ j \neq i.$$

Solving the two reaction functions gives the optimal quantity supplied by each retailer,

$$q_i^* = \frac{1}{3}(1 - 2w_i + w_j), \quad i = 1, 2, \ j \neq i.$$
(2.4)

Substituting (2.4) into (2.3) gives the Cournot profit for retailer i, i = 1, 2:

$$R_i = \frac{1}{9}(1 - 2w_i + w_j)^2 - f_i.$$
(2.5)

Consider next the upstream market, where we assume that the production is characterized by constant marginal cost. Let c_u and c_e denote, respectively, the marginal costs of producers U and E, if producer E succeeds in the R & D. Assumption 2.1 states that the entrant is a more efficient producer, and that the marginal costs are not too high in relation to demand.

Assumption 2.1: $c_e < c_u < 1$.

We now proceed to analyse various possible market configurations in stage 2 of the game. Recall that if entry occurs in stage 2, there are four firms in the industry: producers U and E upstream, and retailers 1 and 2 downstream. There are four possible market configurations: either both retailers buy from the same producer, or each retailer buys from a different producer. In order to derive the equilibrium market configuration(s), we examine each possible configuration in turn.

Case 1: Both retailers acquire their inputs from producer U.

We denote this case as $\{U-1-2\}$. The decision problem facing producer U is

$$S_u = \max_{w_i} \left(w_i - c_u \right) (q_1^* + q_2^*) + (f_1 + f_2).$$
(2.6)

Since we do not allow producer U to discriminate between retailers, we have $w_i = w$ and $f_i = f$ (i = 1, 2), which imply that, from (2.4),

$$q_i^* = \frac{1}{3}(1-w) = q^*, \quad i = 1, 2,$$

and from (2.5),

$$R_i = \frac{1}{9}(1-w)^2 - f = R, \quad i = 1, 2.$$

Hence (2.6) reduces to

$$S_u = \max_w (w - c_u)(2q^*) + 2f,$$

which, after substituting q^* and f, becomes

$$S_u = \max_w \frac{2}{3}(w - c_u)(1 - w) + 2\left[\frac{1}{9}(1 - w)^2 - R\right].$$
 (2.7)

Note that the objective function in (2.7) is strictly concave, thus a global maximum exists and the unique solution is given by,

$$w^* = \frac{1}{4}(1+3c_u). \tag{2.8}$$

Substituting (2.8) into (2.7) gives the maximum total profit, denoted $\Pi_u^* (\equiv S_u + 2R)$, to be divided among the three firms,

$$\Pi_u^* = \frac{1}{4} (1 - c_u)^2.$$
(2.9)

It is worth noting that Π_u^* is the same as the monopoly profit of an integrated monopolist. Because the use of two-part tariffs is allowed there is no double marginalization. Producer U, being the sole upstream supplier, is able to set the wholesale price w^* such that the retail price and quantity are identical to those under an integrated monopolist.

Case 2: Both retailers acquire their inputs from producer E.

This case is denoted $\{E-1-2\}$. The above results apply, with appropriate changes in labels, to this case. In particular, the maximum total profit to be divided among firms E, 1, and 2 is given by,

$$\Pi_e^* = \frac{1}{4} (1 - c_e)^2.$$
(2.10)

Case 3: Each retailer acquires input from a different producer.

We denote this case as $\{U\text{-}i, E\text{-}j\}$ $(i, j = 1, 2, i \neq j)$. Note that the retailers' decision problems remain the same as before. Thus, retailer *i*'s optimal output and profit are given, respectively, by (2.4) and (2.5). However, the decision problems facing producers U and Eare quite different. In particular, each has an incentive to expand the market share of its downstream ally at the expense of the other downstream firm. To this end, producers Uand E may find it desirable to charge a negative price, i.e., give a per-unit subsidy to their respective downstream allies. Formally, for a given $w_i \in \mathbf{R}$, firm E's decision problem is given by,

$$S_e = \max_{w_j} (w_j - c_e)(q_j^*) + f_j$$
subject to $w_j \le \frac{1}{2}(w_i + 1),$

$$(2.11)$$

where the constraint ensures that q_j^* , the quantity supplied to and sold by retailer j, is nonnegative. The decision problem of producer U is similarly given, with the subscripts i and jinterchanged and c_e replaced by c_u . Define

$$\Pi_{u-i} \equiv S_u + R_i \text{ and}$$
$$\Pi_{e-j} \equiv S_e + R_j.$$

In words, Π_{u-i} and Π_{e-j} are the total profits for the alliances *U-i* and *E-j*, respectively. Presumably, these profits are divided according to some bargaining process, which is left unspecified. Proposition 2.2 states the equilibrium prices charged by the two producers and the respective total profits for the two alliances.⁹

Proposition 2.2 (i) If $c_u \leq \frac{1}{3}(2c_e+1)$, the equilibrium upstream prices are

$$w_i^* = \frac{1}{5}(8c_u - 2c_e - 1)$$
 and $w_j^* = \frac{1}{5}(8c_e - 2c_u - 1),$ (2.12)

⁹The analysis in Proposition 2.2 assumes that each retailer sets its output price by taking its own as well as its rival's wholesale prices as given. Implicitly, it is assumed that each retailer believes that the wholesale prices alter the rival's marginal costs in a credible manner.

and the equilibrium total profits are

$$\Pi_{u-i}^* = \frac{2}{25}(1 - 3c_u + 2c_e)^2 \quad and \quad \Pi_{e-j}^* = \frac{2}{25}(1 - 3c_e + 2c_u)^2.$$
(2.13)

(ii) If $c_u > \frac{1}{3}(2c_e + 1)$, the equilibrium upstream prices are

$$w_i^o = \frac{1}{3}(2c_e + 1)$$
 and $w_j^o = \frac{1}{3}(4c_e - 1),$ (2.14)

and the equilibrium total profits are

$$\Pi^{\circ}_{u-i} = 0 \quad and \quad \Pi^{\circ}_{e-j} = \frac{2}{9}(1 - c_e)^2.$$
(2.15)

Proof: See Appendix 2A.

It should be noted that in case (i), producer U's cost is not too high, thus its downstream ally is able to compete against its rival in the product market. This is, however, no longer true in case (ii), where producer U's cost is so high that the optimal choice is to charge a price which results in no sales and zero profit for its downstream ally.¹⁰ To illustrate, we rewrite the total profit function for the alliance U-i as (after substituting q_i^* and f_i),

$$\Pi_{u-i}(w_i) = \frac{1}{9}(1 - 2w_i + w_j)(1 + w_i + w_j - 3c_u).$$

Hence, for a given w_j , $\prod_{u-i}(w_i) \leq 0$ if and only if $w_i \leq 3c_u - w_j - 1$, or the constraint binds, i.e., $w_i = \frac{1}{2}(1+w_j)$, or both. In case (i) of Proposition 2.2, we have $3c_u - w_j - 1 < \frac{1}{2}(1+w_j)$ (which, after rearranging terms, simplifies to $c_u < \frac{1}{2}(w_j + 1)$), while the reverse holds in case (ii). These two cases are illustrated in Figure 2.2.

Note also that in both cases (i) and (ii), total industry profit (i.e., $\Pi_{u-i} + \Pi_{e-j}$) is less than that under an integrated monopoly. This is due to the Cournot competition between retailers, which results in a partial dissipation of profits.

We are now in a position to analyse the game. Consider first stage 2. Suppose no contract is signed between firms U and i (i = 1, 2) in stage 1. Then, two possibilities exist in stage 2:

¹⁰If exit is costless, this can be interpreted as both firms U and i exiting the market.



Figure 2.2: Firm U's objective function under cases (i) and (ii)

either entry occurs or it does not. If entry does not occur, there are three firms in the industry: producer U upstream and retailers 1 and 2 downstream. Since the use of two-part tariffs is allowed, producer U simply charges a wholesale price which results in maximum total profit, Π_u^* , for all three firms. This profit is then divided through the use of a fixed fee, which is presumably set through a bargaining process between the three firms. Let \tilde{R} be retailer i's (i = 1, 2) share of the total profit. Thus, producer U's share is $\Pi_u^* - 2\tilde{R}$.

Next, consider the event that entry occurs. There are then four firms in the industry: producers U and E upstream, and retailers 1 and 2 downstream, and there are four possible market configurations: $\{U-1-2\}, \{U-1, E-2\}, \{U-2, E-1\}, \text{ and } \{E-1-2\}$. As mentioned earlier, to avoid the bargaining issues involving four firms, we let retailers 1 and 2 play a one-shot game in choosing, non-cooperatively, whether to acquire their inputs from producers U or E. We refer to this game as the 'Choose a Supplier' game. Since producer E is more efficient, it appears that the only reasonable equilibrium market configuration is $\{E-1-2\}$. It will be shown later that this is indeed the case.

In addition, we seek to establish an upper bound on the two retailers' equilibrium payoffs, while leaving the bargaining process unspecified. For this purpose, we let all bargaining power reside with the retailers in the other three market configurations. That is, we assume that all profits go to the two retailers in each of the market configurations $\{U-1-2\}$ and $\{U-i, E-j\}$ $(i \neq j)$. We show in Section 2.5 that this assumption is not crucial to the result that follows. Specifically, the result remains valid as long as the bargaining position of the two retailers is not weaker in the case $\{U-i, E-j\}$ $(i \neq j)$ than in the case $\{U-1-2\}$.

Given the above assumptions, suppose producer E offers the payoffs (G, G) to retailers 1 and 2. The question, then, is how large must G be in order for both retailers to choose E as their upstream supplier. To answer this, we examine the normal form of the 'Choose a Supplier' game, which is depicted in Figure 2.3.



Figure 2.3: Normal form of the 'Choose a Supplier' game

In Figure 2.3, the first entry to each cell is the payoff to retailer 1, while the second entry is

the payoff to retailer 2. The matrix is constructed as follows. The top left-hand corner of the matrix applies if both retailers choose producer U as their upstream supplier—the market configuration is $\{U\text{-}1\text{-}2\}$. From the previous analysis, the joint profit is Π_u^* , as given in (2.9). Since, by supposition, all bargaining power resides with the two retailers, they thus divide the joint profit equally among themselves, leaving zero profit for producer U. On the other hand, if retailer 1 chooses producer E while retailer 2 chooses producer U as their respective upstream suppliers, then the lower left-hand corner of the matrix is relevant. The market configuration is $\{U\text{-}2, E\text{-}1\}$, and from the previous analysis, the joint profits for the alliances U-2 and E-1 are, respectively, $\Pi_{u\text{-}2}$ and $\Pi_{e\text{-}1}$, which are given in Proposition 2.2. The upper right-hand corner of the matrix is constructed in a similar manner. However, when both retailers choose producer E as their upstream supplier, their share of total profit is G each. In what follows, we show that 2G is strictly less than the total profit, Π_e^* , despite the fact that the retailers get all the profits in each of the other market configurations.

Referring to Figure 2.3, from the perspective of retailer 1, if retailer 2 chooses U, retailer 1 is better off by choosing E if and only if

$$\Pi_{e-1} > \frac{1}{2} \Pi_u^*.$$

On the other hand, if firm 2 chooses E, retailer 1 is better off by choosing E if and only if

$$G > \prod_{u-1}$$
.

Similarly, from the perspective of retailer 2, choosing E is always optimal regardless of what retailer 1 does if and only if the following inequalities hold:

$$\begin{split} \Pi_{e^{-2}} &> \quad \frac{1}{2}\Pi_u^*, \quad \text{and} \\ G &> \quad \Pi_{u^{-2}}. \end{split}$$

However, since $\Pi_{u-1} = \Pi_{u-2}$ and $\Pi_{e-1} = \Pi_{e-2}$, the four inequalities above can be summarized

$$\Pi_{e-i} > \frac{1}{2} \Pi_u^*, \ i = 1, 2, \text{ and}$$
 (2.16)

$$G > \Pi_{u-i}, \ i = 1, 2.$$
 (2.17)

Proposition 2.3 states the condition under which 'both retailers 1 and 2 choosing E' is a unique Nash equilibrium outcome.

Proposition 2.3 For the 'Choose a Supplier' game in Figure 2.3, producer E can ensure that the outcome (E, E) is a unique Nash equilibrium outcome by setting $G > \prod_{u-i}$, i.e.,

$$G = \begin{cases} \frac{2}{25}(1 - 3c_u + 2c_e)^2 + \epsilon & \text{if } c_u \leq \frac{1}{3}(2c_e + 1), \\ \epsilon & \text{otherwise,} \end{cases}$$
(2.18)

where $\epsilon > 0$ is arbitrarily small, if the following condition holds:

$$c_u > \frac{1}{13}(12c_e + 1). \tag{2.19}$$

Proof: See Appendix 2A.

The condition in (2.19) is depicted in Figure 2.4. It will be shown later that the same condition also ensures that signing a contract is a unique subgame perfect equilibrium for the whole game.

The intuition behind Proposition 2.3 is as follows. If c_u is large as compared to c_e , i.e., (2.19) holds, suppose retailer j chooses U, retailer i's payoff for choosing U, $\frac{1}{2}\Pi_u^*$, is low. Retailer iis better off by choosing E. This is no longer the case if c_u is close to c_e . In particular, imagine that $c_u = c_e$, then $\Pi_{u-i} = \Pi_{e-j}$, and we have $\frac{1}{2}\Pi_u^* > \Pi_{e-j}$ since the monopoly profit is always greater than the sum of duopoly profits. Thus, condition (2.16) is never satisfied. However, when c_e is lower than c_u such that (2.19) holds, a retailer who associates itself with the lowcost producer E gains a substantial advantage in the downstream product market. Given that its wholesale price is lower, its downstream market share is larger, and consequently its



Figure 2.4: Condition for (E, E) as a Nash equilibrium outcome

duopoly profit is greater than half of the monopoly profit. For this reason, if (2.19) holds, the 'Choose a Supplier' game is simply a standard Prisoner's Dilemma. Note that the maximum that G need attain is

$$\frac{2}{25}(1-3c_u+2c_e)^2+\epsilon < \frac{2}{25}(1-3c_u+2c_u)^2 = \frac{2}{25}(1-c_u)^2 < \frac{1}{2}\Pi_u^*,$$

Thus, the payoff under (E,E) is strictly less than that under (U, U) for each retailer. Hence, we have

$$G < \frac{1}{2} \Pi_u^*. \tag{2.20}$$

In other words, both retailers would like to 'cooperate' by choosing U, however, because of (2.20), each is better off by 'defecting' to E if the other retailer chooses U. Hence, by both choosing E, the two retailers actually end up with the worst possible outcome. This result also makes signing a contract in stage 1 attractive for retailers 1 and 2, as stated in Proposition 2.4. **Proposition 2.4** Suppose $c_u > \frac{1}{13}(12c_e + 1)$. Then, in the unique subgame perfect equilibrium, producer U and retailer i (i = 1, 2) sign a contract.

Proof: Suppose no contract is signed in stage 1. Then, given $c_u > \frac{1}{13}(12c_e + 1)$, retailer *i*'s (i = 1, 2) expected profit for not signing the contract is,

$$(1-\alpha)\tilde{R}+\alpha G.$$

Similarly, producer U's expected profit is

$$(1-\alpha)(\Pi_u^* - 2\tilde{R}) + \alpha (0) = (1-\alpha)(\Pi_u^* - 2\tilde{R}).$$

To show that there exists a contract which can make firms U, 1 and 2 better off, it suffices to show that the sum of their expected profits when no contract is signed is strictly less than the total profit when a contract is signed. Note that if a contract is signed, the total profit is Π_u^* , as given in (2.9). The sum of firms U, 1 and 2's expected profits when no contract is signed is,

$$2[(1-\alpha)\tilde{R} + \alpha G] + (1-\alpha)(\Pi_u^* - 2\tilde{R}) = 2\alpha G + (1-\alpha)\Pi_u^*$$

= $\Pi_u^* - 2\alpha(\frac{1}{2}\Pi_u^* - G)$
< $\Pi_u^*,$

where the last inequality follows from (2.20). Hence, by signing a contract, firms U, 1 and 2 can divide the total profit in such a way that all parties to the contract are made better off. \P

The result is a direct consequence of Proposition 2.3, which says that, in the event that entry occurs, competition between the two retailers results in the worst possible outcome for each firm. Therefore, both retailers are willing to sign the contract in stage 1 to avoid the 'choose a supplier' game in stage 2. As a consequence, entry is deterred. Central to the result is the assumption that the two retailers are not able to collude in choosing a supplier in the event

that entry occurs. If the retailers are able to cooperate in choosing a supplier, they effectively act as a single firm in the input market. Hence the result in Proposition 2.1 applies, that is, a contract in stage 1 cannot be an equilibrium outcome, and entry cannot be deterred. It should, however, be noted that any such arrangements which permit the retailers to collude in the input market are likely to run afoul of the antitrust laws.

It should be noted that if the condition depicted in Figure 2.4 is violated, i.e., if $c_u \leq \frac{1}{13}(12c_e + 1)$, there are then two Nash equilibria, (U, U) and (E, E), for the 'Choose a Supplier' game (if G remains as in Proposition 2.3). It is unclear, a priori, which is a more likely equilibrium outcome, neither is it clear what is an appropriate value for G. However, suppose it is possible for the retailers to communicate their choices before the 'Choose a Supplier' game begins. For example, suppose retailer 1 is able to communicate its choice to retailer 2 before the game begins. This then enables the retailers to coordinate their choices by choosing the outcome which gives the highest payoffs to both firms. In this case, producer E has an incentive to set $G > \frac{1}{2} \prod_u^*$ to ensure that (E, E) is the equilibrium outcome. It is then straightforward to show that Proposition 2.4 no longer obtains; that is, no contract will be signed in stage 1. Thus, the condition depicted in Figure 2.4 represents the necessary as well as the sufficient condition for Proposition 2.4.¹¹

2.5 Discussion

We show that a contract is likely to be an equilibrium outcome of the game if the retailers are competing against each other in the product market. This result is contingent on the assumption that the entrant has no means of making a credible offer to the downstream firms in stage 1. Suppose, instead, that such a possibility exists. Specifically, we allow the

¹¹Note that as long as the condition depicted in Figure 2.4 is satisfied, Proposition 2.4 remains valid even if communication between players is allowed. This is because the incentive for each player to 'defect' remains unchanged.

entrant to offer a cash payment M to each downstream firm it it refuses to sign the contract in stage 1. Proposition 2.5 states that the retailers then no longer have any incentive to sign the contracts.

Proposition 2.5 Given that $c_u > \frac{1}{13}(12c_e + 1)$, suppose that the entrant offers each retailer a payment M in stage 1. Then, in the unique subgame perfect equilibrium, no contract is signed in stage 1, instead the entrant's offer is accepted by both retailers.

Proof: Consider stage 2. If entry occurs, retailers 1 and 2 then play the 'Choose a Supplier' game in Figure 2.3, and the resulting payoff for each firm is G. On the other hand, if no entry occurs, each retailer gets, as before, \tilde{R} . Let $M = \alpha(\frac{1}{2}\Pi_u^* - G)$. The expected profit for each retailer for not signing the contract is thus

$$M + \alpha G + (1 - \alpha)\tilde{R} = \alpha \frac{1}{2}\Pi_u^* + (1 - \alpha)\tilde{R}.$$

The expected profit for producer U remains as before, which is given by

$$(1-\alpha)(\Pi_u^* - 2\tilde{R}).$$

Suppose, contrary to the hypothesis, producer U and retailer i (i = 1, 2) sign a contract. Let R^c be retailer *i*'s share of the total profit. Hence producer U's share is $\Pi_u^* - 2R^c$. For this contract to be acceptable to retailer *i*, it must be the case that

$$R^{c} > \alpha \frac{1}{2} \Pi_{u}^{*} + (1 - \alpha) \tilde{R}.$$
(2.21)

Further, for the contract to be acceptable to producer U, it must also be the case that

$$\Pi_u^* - 2R^c \ge (1 - \alpha)(\Pi_u^* - 2\tilde{R}),$$

which, after rearranging terms, reduces to

$$R^c \le \alpha \frac{1}{2} \Pi_u^* + (1 - \alpha) \tilde{R}.$$

The contradicts (2.21). To verify that the entrant is willing to pay retailer *i* the amount M, we note that the entrant's expected profit is $\alpha(\prod_e^* - 2G) - 2M > 0$ if neither retailer signs the contract in stage 1. Hence the entrant is strictly better off by inducing the retailers not to sign the contracts.

Proposition 2.5 reflects the fact that the entrant has much to gain due to its lower cost if it successfully enters the market. Hence it is willing to pay the necessary amount to induce the retailers not to sign the contracts.

Note that in constructing the 'Choose a Supplier' game, we assume that all profits go to the two retailers in each of the market configurations $\{U-1-2\}$ and $\{U-i, E-j\}$ $(i \neq j)$. We show now that this assumption can be relaxed without affecting the results. Proposition 2.4 continues to hold as long as the retailers' bargaining power (measured in terms of profit shares) under $\{U-i, E-j\}$ is greater than or equal to that under $\{U-1-2\}$. Note that each retailer is bargaining with a different producer in the former, while the two retailers are bargaining against a single upstream firm in the latter. Hence, each retailer is likely to be in a stronger bargaining position in the former case.

To see that the result remains unchanged, suppose that the retailers' share of profits is $\lambda \in (0, 1]$ in each of the market configurations $\{U\text{-}1\text{-}2\}$ and $\{U\text{-}i, E\text{-}j\}$ $(i \neq j)$. Then in the 'Choose a Supplier' game in Figure 2.3, the payoffs under (U, U) become $(\frac{\lambda}{2}\Pi_u^*, \frac{\lambda}{2}\Pi_u^*)$, and the payoffs under (E, U) are $(\lambda \Pi_{e^{-1}}, \lambda \Pi_{u^{-2}})$, and similarly for the case (U, E). With an appropriate choice of G, and if condition (2.19) holds, then the unique Nash equilibrium remains (E, E), which means that Proposition 2.4 remains valid. It is easy to see that condition (2.19) can be further relaxed if the retailers' share of profits is less than λ under (U, U). In particular, suppose the retailers' share of profit is zero under (U, U), $(S_{e^{-1}}, S_{u^{-2}})$ under (E, U), and $(S_{u^{-1}}, S_{e^{-2}})$ under (U, E), where $S_{k^{-i}} \geq 0$, k = e, u, i = 1, 2. Then, by setting $G = S_{u^{-i}} + \epsilon$, conditions (2.16) and (2.17) is satisfied for all values of c_u and c_e . That

is, producer E can always ensure that (E, E) is the only Nash equilibrium.

In Section 2.3, we ruled out the possibility that one of the retailers, say retailer *i*, rejects the contract while retailer $j, j \neq i$, signs the contract. We justify this assumption by assuming that firms U, 1 and 2 are able to agree that the contracts are void unless both retailers enter the agreements. Alternatively, we may assume that if the entrant decides to invest in R & D, it has to invest an amount *I*. This amount is large enough so that the entrant's expected return net of the investment cost is positive if and only if there are two customers downstream, i.e., in the event that both retailers reject the contracts. Therefore, if retailer *i* is the only customer downstream, the entrant will not invest in the R & D. There is then no incentive for retailer *i* to hold out if retailer *j* has signed the contract since no entry will occur anyway. Note that the investment cost does not affect the entrant's decision in stage 2 of the game, since the amount is already sunk by then. Hence all results in Section 2.3 remain valid.

2.6 Conclusion

This paper shows that it is possible for an upstream monopolist to use supply contracts as a barrier to entry if retailers are in competition against each other in the downstream product market. Social welfare in this case is lower, since the inefficient incumbent is allowed to continue to operate instead of being displaced, with probability α , by more efficient entrants. In view of this, we believe that the proposal by the 'Chicago School' of making vertical contracts per se legal is unwarranted. However, the other extreme of making these contracts per se illegal is also indefensible, since there can be substantial efficiency gains. For example, these contracts may reduce supply uncertainties for retailers or protect specific assets from opportunistic behavior, as in Marvel (1982). Therefore, rule of reason is the only sensible position on the legal status of vertical contracts seems to be the rule of reason.

Chapter 3

Quality Differentiation and Strategic Product Line Expansion

3.1 Introduction

Most firms produce several rather than a single product. In many industries, it is not uncommon to find a small number of firms supplying a large number of products.¹ In many cases these multiproduct firms do not begin with a full spectrum; instead, some products are added while others are dropped over time. IBM, for example, first established itself in the mainframe computer market, later expanded into the mini and personal computer markets. There are, however, few studies in industrial organization that focus on the product line decisions of firms. In most product differentiation models, for example, it is often assumed that each firm produces only a single product.

The conventional explanation for multiproduct firms is that there are economies of scope in producing several products jointly. This is, however, not the only reason that firms produce multiple products. For example, some firms introduce lower-quality products that are more costly to produce. For example, Intel, the maker of microprocessors for personal computers, unveiled the 486SX processor shortly after it introduced the 486DX processor. The 486SX is

¹Indeed, this is listed as one of the awkward facts of product differentiation in the real world by Eaton and Lipsey (1989), p.726.

identical to the 486DX except that the floating point processor in the 486SX has been turned off (*PC Magazine*, December 31, 1991). In other words, the 486SX is a crippled version of the 486DX, and it is more costly to produce. The same phenomenon is observed in the computer software industry, where it is common to find software publishers introduce 'light' versions of their main products. Clearly economies of scope do not provide a satisfactory account for such phenomena.

This paper examines the strategic motive behind firms' product line decisions in the context of a vertically differentiatied product market. Unlike some previous studies (e.g., Brander and Eaton, 1984; and Bhatt, 1987), which fix the number of potential products and the degrees of substitutability among products, the number of potential products is infinite in the present framework, and firms are free to choose the degrees of differentiation among products. The questions we seek to answer are: Can an incumbent firm expand its product line strategically so as to pre-empt its rivals? What are the optimal number of products for firms to bring to the market? What are the equilibrium market structures under different assumptions of the model? Can an incumbent firm deter a more efficient entrant? How do firms adjust their product lines when a change in technology makes introducing higher-quality products possible?

This paper is organized as follows. A review of the related literature is found in Section 3.2. Section 3.3 outlines the basic model, while Section 3.4 considers the question of entry deterrence by an incumbent monopolist. Section 3.5 extends the analysis to consider firms' product line decisions when technological advances make the introduction of higher-quality products possible.

3.2 Related Literature

Previous studies of multiproduct firms tend to fall into one of two categories. The first consists of studies which focus on cost factors (i.e., economies of scope) as the main reason that firms produce several products. A recent survey of the literature can be found in Panzar (1989). Studies in the second category consider whether a firm can gain a strategic advantage in the market by supplying several products. Examples are Schmalensee (1978), Brander and Eaton (1984), Bhatt (1987), Bonanno (1987), and Shaked and Sutton (1990).

It has been suggested in the literature that firms competing in oligopolistic markets tend to produce close substitutes (Spence, 1976; Schmalensee, 1978). This phenomenon is termed product segmentation by Brander and Eaton (1984). In contrast to a segmented market, an interlaced market is one in which each firm produces products that are less closely related. In a model with two firms, two markets and four possible products, Brander and Eaton find that if firms enter the market sequentially, market segmentation (as opposed to market interlacing) is indeed the likely outcome. Not surprisingly, a segmented market structure gives rise to higher prices and profits for both firms than an interlaced one because competition is less intense. In contrast, Bhatt (1987), in a model with two firms, two markets and six possible products, finds that an interlaced market structure is the likely outcome, although firms would prefer a segmented market. A feature of Bhatt's model is that each firm occupies an established market to begin with. Thus regardless of what the other firm does, each firm is strictly better off by invading the other firm's market. In other words, producing distant substitutes is a dominant strategy for both firms.

Schmalensee (1978), Eaton and Lipsey (1979), and Bonanno (1987) consider the issue of entry deterrence using a Hotelling-type spatial model. The central result is that monopoly persists. The incumbent firm maintains its monopoly position by crowding the product space. Bonanno (1987) further shows that in some cases, entry deterrence need not be achieved through product proliferation; rather, it is sometimes possible for the incumbent firm to deter entry by strategically locating its products.

In a more general setting, Shaked and Sutton (1990) examine oligopolistic firms' decisions regarding the number of products to produce. They argue that there are two opposing effects when a new product is introduced. The expansion effect measures the degree to which total demand is increased by introducing a new product; and the competition effect measures the effect on profit due to more intense competition because of the new product. Using these measures, they are able to completely characterize the two-good case. The result is then applied to a linear demand schedule model. They find that, contrary to previous studies, entry deterrence is not necessarily the optimal strategy for the incumbent. For example, for the three-good case, there exists an equilibrium in which two firms each offers a single product. As they point out, the model is considerably less tractable as the number of products goes beyond three.

More recently, Donnenfeld and Weber (1992) consider a model of non-simultaneous entry into an industry where firms compete in a vertically differentiated product market. There are three firms in the model, each producing a single product. The authors show that the first two firms to enter the market supply the highest- and the lowest-quality product, whereas the third firm chooses an intermediate quality and earns a higher profit than the incumbent who supplies the lowest-quality product. A notable feature of the model is that firms do not incur any sunk cost in choosing a particular quality to produce. This assumption enables the authors to obtain comparative static results through differentiations. Thus, for example, the authors show that firms' equilibrium profits increase as the quality spectrum is increased exogenously. This result is obtained through taking the first derivatives of firms' profit functions with respect to the range of quality spectrum. Clearly, this exercise is meaningful only if firms are able to adjust their quality choices costlessly in response to any exogenous (and infinitesimally small) changes in the environment. However, as is pointed out later, this raises the question of whether quality choices represent a credible commitment by firms to minimize price competition.

3.3 Basic Model

Consider a one-dimensional market where goods differ in quality. Each consumer buys at most one unit of the good with the most preferred quality, given prices. There are N consumers, each is assumed to have an indirect utility function of the form²

$$V = \begin{cases} \theta s - p & \text{if the consumer buys a good of quality } s \text{ at price } p, \\ 0 & \text{if the consumer buys nothing,} \end{cases}$$
(3.1)

where θ is a taste parameter, it represents consumers' willingness to tradeoff quality against price (i.e., preference intensity); and is assumed distributed uniformly on the unit interval $[\theta_0 - 1, \theta_0]$, where $\theta_0 > 1$. Without loss of generality, normalize N = 1 (e.g., one million). Let $F(\theta)$ denote the cumulative distribution function, i.e., $F(\theta) = \theta - (\theta_0 - 1)$. In what follows, θ will be referred to as the consumer's characteristic. The quality of goods, s, is assumed to lie in a bounded interval, $s \in [1, \overline{s}]$, where $\overline{s} > 1$. Let $l = \overline{s} - 1$ denote the length of the quality spectrum. Note that the representation of consumer preference (3.1) differ from that of Shaked and Sutton (1982, 1983), who assume that consumers differ in incomes rather than tastes. However, as pointed out by Tirole (1988, p.96), a simple transformation of (3.1) yields

$$\tilde{V} = \begin{cases} s - (1/\theta) p & \text{if the consumer buys a good of quality } s \text{ at price } p, \\ 0 & \text{if the consumer buys nothing,} \end{cases}$$

which says that all consumers derive the same utility from consuming a good of quality s but have different marginal rates of substitution between income and quality $(1/\theta)$, due to different income levels. Thus, a higher θ corresponds to a lower marginal utility of income,

²This particular form of utility function is used in previous studies of vertical differentiation by Tirole (1988), Donnenfeld and Weber (1992), and Motta (1993), among others.

and hence a higher income level. Under this interpretation, the preference representation here is analogous to that of Shaked and Sutton.

Two features of the preference representation in (3.1) are worth emphasizing. First, goods with higher quality are preferred by all consumers at the same price; and second, a consumer with higher θ is willing to pay more for a higher quality good. Thus, this preference representation is different from horizontal differentiation, where some consumers strictly prefer product x while others strictly prefer product y even if both products are sold at the same price.

There are two potential firms in the market: firms A and B. A firm may choose to produce one or several products of different qualities in the interval $[1, \overline{s}]$. A sunk cost $K_i > 0$ is incurred for each quality firm i plans to produce. It is worth noting that firm i incurs the same sunk cost K_i for each quality it chooses to produce. There are no other costs of production.³ Note that there are neither economies nor diseconomies of scope in jointly producing several products of different qualities. It is assumed that firms cannot alter the quality level of their products once a choice is made (i.e., after the sunk cost K_i is incurred). This is the case, for example, if it is prohibitively costly to retool plants and equipment to produce products of a different quality.⁴

Consider first the case of a monopolist who faces no threat of entry. In what follows it will be referred to as a protected monopolist. The monopolist has to decide the number of products to produce, the quality of each product, and then set a price for each product.

Proposition 3.1 A protected monopolist produces only one product; and its optimal quality choice is \overline{s} , the highest quality level.

 $^{^{3}}$ We deliberately keep the cost structure as simple as possible so as to focus on the strategic effects of product line expansion.

⁴This assumption receives much emphasis in Prescott and Visscher (1977), who argue that in many instances it is more reasonable to model firms as making once-and-for-all location decisions (quality choices in the present context).

Proof: See Appendix 3A.

The highest-quality product is supplied at the monopoly price $p^m = \frac{1}{2}\theta_0 \overline{s}$. The monopolist will not produce more than one product even if the market is not covered, i.e., there are some consumers who do not buy any product at all. Formally, this occurs when $\theta_0 < 2$, i.e., when θ_0 is small. Note that we restrict the distribution of θ on a unit interval, thus a small θ_0 corresponds to the case where consumers' valuations of the products differ greatly in relative terms. It is evident from the proof that the result is true even if the sunk cost is zero. This result is due primarily to the particular form of consumer preference, which does not permit the monopolist to extract surplus by offering a low-end and a high-end product. If a low-end product is introduced, it attracts customers away from the high-end product. Given the preference representation in (3.1) as well as the distribution assumption of θ , the loss from the high-end product strictly dominates the gain from the low-end product and as a result, the monopolist's overall profit is lower.

This result is similar to that obtained by Stokey (1979), who considers the intertemporal pricing problem of a durable goods monopolist. In her model, consumers differ in their valuations of a single infinitely durable good, which all consumers prefer to consume earlier rather than later. The monopolist has an opportunity to price discriminate by gradually lowering its price over time, thus inducing high-valuation consumers to buy earlier, and at a higher price, than low-valuation consumers. However, Stokey proves that, for a particular class of utility function (to which the specification in (3.1) belongs), the optimal amount of intertemporal price discrimination is no price discrimination at all. That is, the monopolist simply sets a price in the first period and does not lower the price over time. The reason is simple. Given this particular form of consumer preference, the price cuts necessary to attract a wider market induce too many buyers to postpone their purchases, thus making price discrimination unprofitable. By renaming the durable good at different dates as goods of different qualities, it can be seen that the present model closely resembles that of Stokey.

Proposition 3.1 also states that the monopolist will always choose to produce the highestquality product. This is in fact true for any firm which enters the market first. By producing the highest quality, a firm can charge a higher price since consumers with higher θ are willing to pay more. For this reason, products of different qualities enter firms' profit function in a nonsymmetric fashion in this model. This is in contrast to Shaked and Sutton (1990), who assume that all products are symmetric as far as firms' profits are concerned.

Note that the first-best outcome involves the provision of the highest-quality good at zero price (the marginal cost), and every consumer buys one unit of the product. Thus the number and quality of products under monopoly coincide with the social optimum. The price, however, is greater than the marginal cost; furthermore, for some values of θ_0 , not every consumer buys the good.

Suppose now the monopolist faces a potential entrant. Does the monopolist have an incentive to deter entry by producing more than one product? To answer this question, it is necessary to consider the duopoly case: Two firms, A and B, play a three-stage game. Suppose, for now, that each firm produces only one product. Firm A chooses a quality level, s_A in stage 1; in stage 2, firm B decides on a product quality, s_B , given firm A's choice. The two firms then compete in prices in stage 3.⁵

Three assumptions are made.

Assumption 3.1: $\frac{8}{7} < \theta_0 < 2$. Assumption 3.2: $\overline{s} \leq \frac{2\theta_0 - 1}{2 - \theta_0}$. Assumption 3.3: $K_B > \frac{1}{9} \cdot \frac{(2 - \theta_0)^2}{4(2 - \theta_0)^2 + 1}$.

Assumptions 3.1 and 3.2 are made so that every consumer buys a unit of one of the products.

 $^{{}^{5}}$ It will be shown later that, if given a chance to introduce another product in stage 3, neither firm has an incentive to do so.

The first inequality in Assumption 3.1 places a lower bound on consumers' preference intensity θ_0 to avoid cases where some consumers do not buy either of the products; the second inequality ensures that consumers' preference intensity is not so high that all consumers demand the highest-quality product. Assumption 3.2 imposes an upper bound on the highest possible quality to ensure that the market is sufficiently competitive so that equilibrium prices are low enough for every consumer to buy one of the products. Assumption 3.3 puts a lower bound on the sunk cost of firm B so that it is possible (though it may not be profitable) for firm A to deter entry by introducing a finite number of products in the market.⁶

Proposition 3.2 states a well-known maximum differentiation result.⁷

Proposition 3.2 Given Assumptions 3.1–3.3, and if $K_B < \frac{l}{9} \cdot (2-\theta_0)^2$, firms A and B choose to supply, respectively, the highest- and the lowest-quality products in a unique subgame perfect equilibrium; that is, $s_A^* = \overline{s}$ and $s_B^* = 1$.

Proof: Consider the third-stage price subgame, given firms' quality choices (s_A, s_B) . There are two possibilities: either $s_A > s_B$ or $s_A < s_B$.⁸ Assuming, for now, that $s_A > s_B$. Let θ_A be the consumer who is indifferent between buying from firms A and B. That is,

$$\theta_A = \frac{p_A - p_B}{s_A - s_B}$$

The demand for s_A is

$$Q_A = 1 - F(\theta_A) = \theta_0 - \theta_A,$$

and the demand for s_B is

$$Q_B = F(\theta_A) = \theta_A - (\theta_0 - 1).$$

⁶Without a lower bound on the entrant's sunk cost K_B , entry deterrence through product proliferation is not possible when K_B approaches zero.

⁷See Shaked and Sutton (1982). The formulation here follows that of Tirole (1988, pp.296-7). Note that the result does not hold if the market is not covered, see Choi and Shin (1992).

⁸The third possibility, namely $s_A = s_B$ is ignored since it is never optimal for firms to choose the same quality.

Each firm maximizes revenue $p_iQ_i - K_i$, i = A, B. The first-order conditions give rise to the following reaction functions:

$$p_A(p_B) = \frac{1}{2} [\theta_0(s_A - s_B) + p_B]$$
(3.2)

$$p_B(p_A) = \frac{1}{2} [p_A - (\theta_0 - 1)(s_A - s_B)]$$
(3.3)

Solving (3.2) and (3.3) yields the following optimal prices, expressed as functions of $s \equiv [s_A, s_B]$:

$$p_A(s) = \frac{1}{3}(1+\theta_0)(s_A - s_B) \tag{3.4}$$

$$p_B(s) = \frac{1}{3}(2-\theta_0)(s_A - s_B) \tag{3.5}$$

Substituting (3.4) and (3.5) into firms' revenue functions yields the following 'reduced-form' profit functions:

$$\Pi_A(s) = \frac{1}{9}(1+\theta_0)^2(s_A - s_B) - K_A$$
(3.6)

$$\Pi_B(s) = \frac{1}{9}(2-\theta_0)^2(s_A - s_B) - K_B$$
(3.7)

Note that Assumption 3.1 ensures that firm B's price and market share are strictly positive. Thus, in stage 2, firm B chooses the optimal quality to maximize (3.7), which yields $s_B^* = 1$. Similarly, in stage 1, firm A's optimal quality choice is $s_A^* = \overline{s}$.

To show that every consumer buys one of the products, it suffices to show that the consumer with the lowest preference intensity, $(\theta_0 - 1)$, buys a unit from firm *B*. The utility of this consumer is $(\theta_0 - 1)$ if she buys from firm *B*, the price she pays is

$$p_B^* = \frac{l}{3}(2 - \theta_0) < \theta_0 - 1$$

where the latter inequality follows from Assumption 3.2.

The maximum gross profits of firms A and B are, respectively,

$$\Pi_{A}^{d} = \frac{l}{9}(1+\theta_{0})^{2}, \text{ and}$$
 (3.8)

$$\Pi_B^d = \frac{l}{9} (2 - \theta_0)^2.$$
 (3.9)

Note that

$$\Pi_A^d > \Pi_B^d > K_B. \tag{3.10}$$

The first inequality follows from the fact that $\theta_0 > 1$, and the second inequality is true by supposition. Since firm A is to move first, it can choose to produce the low- or high-quality product. That is, it effectively faces a choice of the gross profits in (3.8) and (3.9). Thus, by the inequality in (3.10), firm A's choice of $s_A = \overline{s}$ is indeed optimal. This establishes that $s_A = \overline{s}$ and $s_B = 1$ constitute a unique subgame perfect equilibrium. ¶

Note that the inequality $K_B < \frac{l}{9} \cdot (2 - \theta_0)^2$ is necessary so that firm B finds it worthwhile to enter the market, otherwise, firm B's entry is blockaded and firm A becomes a natural monopolist.

This maximum differentiation result comes from the fact that, when setting prices in stage 3, firms are not able to costlessly alter their quality choices given that the sunk costs have already been incurred. This allows firms to credibly commit themselves to the quality choices which result in the least competition in prices. In other words, firms choose the two extreme quality levels to minimize price competition in stage 3. Note that the same result is obtained by Donnenfeld and Weber (1992, Proposition 1). In their model, however, firms incur no sunk cost when making product quality choices. It is unclear, then, how firms could credibly commit to their quality choices to minimize price competition.

We next show that, in the duopoly equilibrium stated in Proposition 3.2, neither firm A nor B has any incentive to introduce another product. That is, suppose we add another stage to the game: in stage 4, each firm is given an opportunity to introduce another product. Proposition 3.3 shows that neither firm has an incentive to do so.

Proposition 3.3 Given that firms A and B supply, respectively, the highest- and the lowestquality products in stage 3, in a Nash equilibrium of the subgame in stage 4, neither firm has an incentive to expand its product line.

Proof: There are two existing products in the market, Q_A and Q_B , with quality levels $s_A = \overline{s}$ and $s_B = 1$. Note that both firms A and B have incurred the necessary sunk cost for the production of these products.

Consider first the incentive of firm A to introduce another product. Suppose firm A decides to introduce a second product, denoted Q_A^o , with quality $s_A^o < \overline{s}$. There are now three products in the market: Q_A, Q_A^o , and Q_B . Refer to Figure 3.1. Define θ_1 as the characteristic of the consumer who is indifferent between buying quality Q_A and Q_A^o . Let θ_2 be similarly defined. Let p_A, p_A^o , and p_B denote the prices of products s_A, s_A^o , and s_B , respectively. Then,



Figure 3.1: Firm A introduces a second product

$$heta_1 = rac{p_A - p_A^o}{s_A - s_A^o} \ \ \, ext{and} \ \ \, heta_2 = rac{p_A^o - p_B}{s_A^o - s_B}.$$

The demands for the three products are

$$Q_A = 1 - F(\theta_1) = \theta_0 - \theta_1,$$

$$Q_A^o = F(\theta_1) - F(\theta_2) = \theta_1 - \theta_2 \text{ and,}$$

$$Q_B = F(\theta_2) = \theta_2 - (\theta_0 - 1).$$

The decision problems of firms A and B are, respectively,

$$\max_{p_A, p_A^o} p_A Q_A + p_A^o Q_A^o - K_A,$$

and

 $\max_{p_B} p_B Q_B.$

Solving these two maximization problems yields the following optimal prices:

$$p_A^* = \frac{1}{2}\theta_0(s_A - s_A^o) + \frac{1}{3}(\theta_0 + 1)(s_A^o - s_B),$$

$$p_A^{o*} = \frac{1}{3}(\theta_0 + 1)(s_A^o - s_B), \text{ and }$$

$$p_B^* = \frac{1}{3}(2 - \theta_0)(s_A^o - s_B).$$

Substituting these prices into the profit function of firm A, and noting that $s_A = \overline{s}$ and $s_B = 1$, we have

$$\Pi_A(s_A^o) = \frac{1}{4}\theta_0^2(\overline{s} - s_A^o) + \frac{1}{9}(\theta_0 + 1)^2(s_A^o - 1) - K_A.$$
(3.11)

However, by differentiating the profit function with respect to s_A^o , we get

$$\begin{array}{rcl} \frac{\partial \Pi_A}{\partial s^o_A} &=& \frac{1}{9}(\theta_0+1)^2-\frac{1}{4}\theta_0^2 \\ &=& \frac{1}{36}(2-\theta_0)(2+5\theta_0) \,>\, 0. \end{array}$$

Hence, firm A's profit is strictly increasing in s_A^o , which means that it is maximized by setting $s_A^o = s_A = \overline{s}$. Hence, there is no incentive for firm A to introduce a second product, since $K_A > 0$.

Consider next the incentive of firm B to introduce another product. Suppose firm B decides to introduce a second product, denoted Q_B° . The quality of this product is $s_B^{\circ} > s_B$. There are now three products in the market: Q_A, Q_B° , and Q_B . Refer to Figure 3.2. Define θ_1 as the characteristic of the consumer who is indifferent between buying Q_A and Q_B° . Let θ_2 be similarly defined. Let p_A, p_B° , and p_B be, respectively, the prices of Q_A, Q_B° , and Q_B . Then,



Figure 3.2: Firm B introduces a second product

$$\theta_1 = \frac{p_A - p_B^o}{s_A - s_B^o}$$
 and $\theta_2 = \frac{p_B^o - p_B}{s_B^o - s_B}$.
The demands for the three products are

$$Q_A = 1 - F(\theta_1) = \theta_0 - \theta_1,$$

$$Q_B^o = F(\theta_1) - F(\theta_2) = \theta_1 - \theta_2, \text{ and}$$

$$Q_B = F(\theta_2) = \theta_2 - (\theta_0 - 1)$$

The decision problem of firms A and B are, respectively,

$$\max_{p_A} p_A Q_A,$$

and

$$\max_{\substack{p_B^o, p_B}} p_B^o Q_B^o + p_B Q_B - K_B$$
(3.12)
subject to $Q_B \ge 0$,

where the constraint in (3.12) requires firm B to supply non-negative quantity of Q_B . It will be shown later that this constraint binds at the solution to firm B's problem. We solve these two maximization problems by first ignoring firm B's constraint; and the resulting optimal prices are

$$p_A^* = \frac{1}{3}(\theta_0 + 1)(s_A - s_B^0),$$

$$p_B^{o*} = \frac{1}{3}(2 - \theta_0)(s_A - s_B^o), \text{ and }$$

$$p_B^* = \frac{1}{3}(2 - \theta_0)(s_A - s_B^o) - \frac{1}{2}(\theta_0 - 1)(s_B^o - s_B).$$

It is straightforward to show that, at these prices, $Q_B < 0$, which violates the constraint in (3.12). Thus, the optimal quantity of Q_B supplied by firm B is constrained at $Q_B^* = 0$. The 'reduced-form' profit function of firm B is then

$$\Pi_B(s_B^{\circ}) = \frac{1}{9}(2-\theta_0)^2(s_A - s_B^{\circ}) - K_B.$$

Hence, firm B maximizes its profit by setting $s_B^o = s_B = 1$. Therefore, firm B has no incentive to expand its product line either.

The intuition behind this result is as follows. Given that each firm is occupying one end of the quality spectrum, a firm introducing a second product can only choose a quality level in between the two existing qualities. As such, although the new product expands the firm's overall market share, it also attracts some consumers away from its existing product. Proposition 3.3 shows that the overall effect on the firm's profit is negative. In the language of Shaked and Sutton (1990), the competition effect dominates the expansion effect, hence the firm's profitability is adversely affected. Thus, unlike the result obtained by Bhatt (1987), neither firms find it profitable to introduce a second product. This result also implies that if the duopolists were to simultaneously choose the number of products to bring to the market, each would choose to supply a single product.⁹ Note that this equilibrium is not necessarily unique. In particular, there may exist an equilibrium in which each firm simultaneously chooses to introduce another product. Regrettably, the algebra in this case is intractable, and we are not able to obtain any result. Note, however, that if each firm is restricted to supplying a single product, then the equilibrium stated in Proposition 3.2 is unique.

3.4 Entry Deterrence

Suppose now an incumbent monopolist, firm A, faces a potential entrant, firm B. The question is: Does the incumbent have any incentive to deter entry by expanding its product line? Put differently, is the resulting market structure a two-good monopoly or a duopoly with each firm producing a single good?

Consider again a three-stage game similar to the one above, except now the incumbent has already established a product, Q_{A1} , with quality $s_{A1} = \overline{s}$ in the market.¹⁰ In stage 1, the incumbent decides whether to introduce a second product, denoted by Q_{A2} . In stage 2, the

⁹It is assumed that both duopolists have decided to enter the market, thus the option of not producing, i.e., choosing zero product, is ruled out.

¹⁰It will become clear later that this specification is equivalent to letting the incumbent choose the two products' quality levels in stage 1. The analysis below is greatly simplified by fixing s_{A1} .

potential entrant decides whether to enter the market and if it does enter, makes a quality choice, taking into account the incumbent's choice in stage 1. If the entrant enters the market, the two firms compete in prices in stage 3. The game ends if the entrant does not enter.

There are two issues that need to be addressed. First, is it feasible to deter entry by introducing two products? Second, can the incumbent increase its net profit by deterring entry? That is, does the incumbent has an incentive to deter entry? Proposition 3.4 states that the monopolist can always deter entry by introducing two products in the market.

Proposition 3.4 Given Assumptions 3.1–3.3, a monopolist incumbent can always deter entry by introducing two products, with quality choices $s_{A1} = \overline{s}$ and

- (a) $s_{A2} = 1$ if $K_B \ge \frac{l}{36}$, or
- (b) $\overline{s} 36K_B < s_{A2} < 1 + \frac{9K_B}{(2-\theta_0)^2}$ if $K_B < \frac{l}{36}$.

Further, the monopolist maximizes profit by setting $Q_{A2} = 0$, i.e., the monopolist incurs the sunk cost for the second product but does not carry out any production.

Proof: See Appendix 3A.

From Propositions 3.1 and 3.2, and in view of Proposition 3.4, it is clear that regardless of whether the entrant enters or not, the incumbent always chooses to produce the highest quality, \overline{s} . There is therefore no loss of generality in setting $s_{A1} = \overline{s}$ and only letting firm Achoose s_{A2} in stage 1.

Judd (1985) argues that, if exit costs are low, it may not be credible for the incumbent to deter entry through product proliferation. The reason being that, if the entrant enters one of the product markets, intense post-entry competition in this market will adversely affect the profitability of the incumbent's other products. Therefore, the incumbent is better off by exiting this market if exit costs are not prohibitive. Unlike Judd, we rule out the possibility of exit by either firm. Specifically, we assume that exit costs are so high that exit is not an option for the incumbent. Besides the obvious costs of shutting down factories and laying off or relocating workers, there are many other reasons why this may be so. For example, by exiting the market, the incumbent may suffer a loss of reputation if building a reputation of toughness is desirable. (See Kreps and Wilson, 1982; and Milgrom and Roberts, 1982b). Alternatively, if product quality is not observable by consumers, by withdrawing the product in question, the incumbent may signal a low quality for all its other products. See Choi and Scarpa (1992).

Consider next the incentive of the incumbent to deter entry. If entry is deterred, the incumbent becomes a two-good monopolist, its profit is maximized by setting $Q_{A2} = 0$. In other words, the monopolist maintains some form of "excess capacity" to deter entry—it incurs the sunk cost for Q_{A2} but does not carry out any production.¹¹ The intuition behind this result is exactly the same as that for Proposition 3.1. The resulting net profit for the monopolist is

$$\Pi_A^m = \frac{1}{4}\overline{s}\theta_0^2 - 2K_A.$$
 (3.13)

On the other hand, if entry is allowed, the incumbent earns the duopoly profit

$$\Pi_A^d = \frac{l}{9} (1 + \theta_0)^2 - K_A.$$
(3.14)

Thus, entry determine is profitable if and only if $\Pi_A^m \ge \Pi_A^d$. That is, if

$$\frac{1}{4}\overline{s}\theta_0^2 - \frac{l}{9}(1+\theta_0)^2 \ge K_A \tag{3.15}$$

The right-hand side is the cost of entry deterrence, and the left-hand side represents the benefit in terms of an increase in profit. Thus, the condition in (3.15) simply states that for entry deterrence to be profitable, the benefit must outweight the cost. The inequality in (3.15) is illustrated in Figure 3.3 below, for three different values of \overline{s} , namely, $\overline{s} = 1.5$, $\overline{s} = 3$ and $\overline{s} = 5$. The shaded regions represent combinations of θ_0 and K_A such that the incumbent has an incentive to deter entry.

¹¹If, however, there exists a minimum efficient scale of production, the optimal quantity of Q_{A2} may well be strictly positive. This is the case, for example, if the average cost curve is U-shaped and the cost is very large when output is small.



Figure 3.3: Incentive of incumbent to deter entry

It is immediately clear from Figure 3.3 that entry deterrence is not necessarily optimal for the incumbent. In particular, when its sunk cost K_A is high and the preference intensity θ_0 is low, the incumbent is usually better off by allowing entry. This is because a high sunk cost makes entry deterrence costly, while a low preference intensity makes monopolizing the market less attractive. However, the condition under which the incumbent has no incentive to deter entry does not imply that entry will necessarily occur. Define

$$K^* \equiv \frac{1}{4}\overline{s}\theta_0^2 - \frac{l}{9}(1+\theta_0)^2.$$

Proposition 3.5 states the conditions for different equilibrium market outcomes.

Proposition 3.5 Given Assumptions 3.1-3.3, the following market structures are possible: (i) If $K_B \geq \frac{l}{9}(2 - \theta_0)^2$, entry is blockaded; the incumbent is a natural monopoly.

- (ii) If $K_B < \frac{l}{9}(2-\theta_0)^2$, two possibilities exist:
 - (a) If $K_A \leq K^*$, the incumbent is a two-good monopoly, i.e., entry is deterred.
 - (b) If $K_A > K^*$, the incumbent and the entrant each produce a single product, i.e., entry is accommodated.

Proof: (i) Note that from the proof of Proposition 3.2, firm B's gross profit is

$$\Pi_B^d = \frac{l}{9}(2 - \theta_0)^2.$$

Thus, entry is blockaded if $\frac{l}{9}(2-\theta_0)^2 \leq K_B$.

(ii) Given that $K_B < \frac{l}{9}(2-\theta_0)^2$, firm B enters if firm A does not pursue any entry deterrence strategy. However, from previous discussion, entry deterrence is profitable if and only if (3.15) holds; i.e., $K^* \ge K_A$. This proves (ii)(a). On the other hand, entry is accommodated if $K^* < K_A$, which is (ii)(b).

Note that the equilibrium market structure is a duopoly only if the incumbent's sunk cost is high while that of the entrant is low. Specifically, the entrant's sunk cost must be strictly lower than that of the incumbent. To see this, we first establish Lemma 3.1.

Lemma 3.1:
$$K^* > \frac{l}{9}(2-\theta_0)^2$$
.

Proof: See Appendix 3A.

By Proposition 3.5 and Lemma 3.1, it can be easily shown that the equilibrium market structure is a duopoly if the following inequalities hold:

$$K_B < \frac{l}{9}(2 - \theta_0)^2 < K^* < K_A.$$

That is, entry can only occur in the event that firm B has a strictly lower sunk cost. Propositions 3.5 and Lemma 3.1 can also be used to partition the (K_A, K_B) space into three zones which correspond to the different market structures. This is illustrated in Figure 3.4.

It is worth noting that if $K_A = K_B$, entry deterrence is always profitable, and hence monopoly persists. This result is consistent with that obtained under horizontal differentiation models, e.g., Schmalensee (1978), Eaton and Lipsey (1979), and Bonanno (1987), among others. Intuitively, if the entrant can earn a positive net profit by introducing a new product, the incumbent can always mimic the entrant and do strictly better. This is because when a new



Figure 3.4: Equilibrium market structures

product is introduced, it affects the demand and hence the profitability of the incumbent's product. The entrant will not take this negative 'external effect' into account whereas the incumbent will. Hence the incumbent can do strictly better than the entrant. In other words, the net profit of a two-good monopoly is always greater than the sum of the duopoly profits, i.e., $\Pi_A^m > \Pi_A^d + \Pi_B^d$. The incumbent therefore has more of an incentive to deter entry than the entrant has to enter. This also explains why the entrant needs to have a strictly lower sunk cost in order to enter the market. The welfare implication is clear. Social welfare suffers since exclusion of a more efficient entrant, i.e., one with a lower sunk cost, is possible.

3.5 Technological Advances

Suppose, due to an (exogenous) improvement in technology, the range of quality increases to, say, $[1, \overline{s} + \alpha]$, where $\alpha > 0$ is some constant. The questions of interest are: Under what condition will a protected monopolist introduce a new product? What if the monopolist is

unprotected, i.e., facing a potential entrant who has the same access to the new technology? Next, in the context of a single-good duopoly, how does the firm which produces the high-end product before the technological advance reposition its product line if it has the exclusive right to the new technology? What if this right belongs to the firm that produces the low-end product before the technological advance?

These questions are of interest because quality spectra never remain the same in the real world. Technological advances frequently redefine the best available product quality in many industries. For example, a 24-pin dot-matrix printer was regarded as the high end product in the early 1980s. Along came laser technology, which pushed all dot-matrix printers to the low end of the product spectrum. Similar examples abound in other industries.

Consider first the case of a monopoly. Suppose a protected monopolist is producing an existing product of quality \overline{s} . Given the technological advance, the monopolist has to decide whether to introduce a new product by incurring the sunk cost K. It follows from Proposition 3.1 that, if a new product is introduced, its quality level is set optimally at $\overline{s} + \alpha$; and the output of its existing product is set to zero. The monopolist's net earning in the next period is

$$\Pi^N = \frac{1}{4}(\overline{s} + \alpha)\theta_0^2 - K.$$
(3.16)

On the other hand, if the monopolist does nothing with the new technology, it continues to earn $\frac{1}{4}\overline{s}\theta_0^2$ in the next period.¹² Hence, the protected monopolist will introduce a new product if and only if

$$\Pi^N \ge \frac{1}{4}\overline{s}\theta_0^2. \tag{3.17}$$

Consider next the unprotected monopolist, who is facing a potential entrant who has the same access to the new technology. We assume that the incumbent enjoys an advantage in

 $^{^{12}}$ Note that the sunk cost has already been incurred, thus it does not appear in the monopolist's next-period profit.

that the new technology is available to the incumbent first. In other words, the entrant is able to enter the market only if the incumbent decides not to introduce a new product. As before, if the incumbent introduces a new product, it incurs the sunk cost K, and earns the net profit Π^N in (3.16). On the other hand, if the incumbent does not introduce a new product, the new technology will then be employed by the entrant. The market then becomes a duopoly with each firm producing a single product. To ensure that every consumer buys a unit of one of the products in the duopoly case, we assume that Assumptions 3.1 and 3.2 continue to hold with the new technology. In particular, we re-state Assumption 3.2 as follows.

Assumption 3.4:
$$\alpha \leq \frac{2\theta_0 - 1}{2 - \theta_0} - \overline{s}.$$

The product quality of the incumbent is fixed at \overline{s} , while that of the entrant is optimally set at $\overline{s} + \alpha$. The latter follows directly from Proposition 3.2, which states that firms in a duopoly maximize profits through maximum quality differentiation. Here the incumbent becomes a supplier of low-end products, and from Proposition 3.2, its profit is

$$\frac{\alpha}{9}(2-\theta_0)^2.$$
 (3.18)

Hence, the unprotected monopolist will introduce a new product if and only if

$$\Pi^N \ge \frac{\alpha}{9} (2 - \theta_0)^2. \tag{3.19}$$

Proposition 3.6 states that a protected monopolist has less incentive to introduce a new product.

Proposition 3.6 Given the technological advance described above, a protected monopolist has less incentive to introduce a new product than a monopolist who faces the threat of entry.

Proof: We show that, for a new product to be introduced, it needs to generate a higher profit (i.e., a higher Π^N) for the protected monopolist. That is, by comparing (3.17) and (3.19),

we need to show that

$$\frac{1}{4}\overline{s}\theta_0^2 > \frac{\alpha}{9}(2-\theta_0)^2.$$
(3.20)

To derive this inequality, we note that

$$\frac{1}{4}\overline{s}\theta_0^2 - \frac{\alpha}{9}(2-\theta_0)^2 = \frac{1}{36}[9\overline{s}\theta_0^2 - 4\alpha(2-\theta_0)^2].$$

By making use of Assumption 3.4, and after rearranging terms, we have

$$\frac{1}{4}\overline{s}\theta_0^2 - \frac{\alpha}{9}(2-\theta_0)^2 > \frac{1}{36}[(13\theta_0^2 - 16\theta_0 + 16)\overline{s} + (8\theta_0^2 - 20\theta_0 + 8)].$$
(3.21)

But the term $(13\theta_0^2 - 16\theta_0 + 16)$ is strictly positive,¹³ and since $\overline{s} > 1$, by setting $\overline{s} = 1$ at the right-hand side of (3.21), we have

$$\frac{1}{4}\overline{s}\theta_0^2 - \frac{\alpha}{9}(2-\theta_0)^2 > \frac{1}{12}(7\theta_0^2 - 12\theta_0 + 8) > 0 \quad \forall \ \theta_0.$$

Hence the inequality in (3.20) obtains.

The result is hardly surprising. A protected monopolist gains less from introducing a new product since it merely displaces the monopolist's existing product. On the other hand, an unprotected monopolist not only has to take into account the benefits of introducing a new product, it must also consider what will happen if it does not introduce a new product while the entrant does. It is therefore not surprising that the unprotected monopolist has more incentive to introduce a new product. This result seems to be supported by some casual empirical observations. Intel, for example, has recently decided to quicken the pace of product developments through developing two rather than one microprocessor generation at once. This is primarily in response to the challenge posed by recent entrants such as Advanced Micro Devices Inc. and Cyrix Corp. (*Business Week*, June 1, 1992).

We consider next the case of a single-good duopoly. Assuming that, before the technological advance, firms A and B are producing, respectively, the high- and low-end products, i.e.,

¹³It can be easily shown that $\min_{\theta}(13\theta_0^2 - 16\theta_0 + 16) > 0$.

 $s_A = \overline{s}$ and $s_B = 1$. For the purpose of comparison, let $K_A = K_B = K$. We further assume that the new technology is proprietary in nature, that is, one of the two firms has an exclusive right to the technology. Proposition 3.7 states the conditions under which each firm is willing to introduce a new product if it holds the exclusive right.

Proposition 3.7 Given the technological advance described above,

(i) suppose firm A has the exclusive right to the new technology, it will introduce a new product if and only if

$$\alpha \ge \frac{4K}{\theta_0^2}.\tag{3.22}$$

(ii) Suppose firm B has the exclusive right to the new technology, it will introduce a new product if

$$\alpha > \frac{9K}{(\theta_0 + 1)^2}.$$
(3.23)

Proof: See Appendix 3A.

Note that (3.22) represents the necessary and sufficient condition for firm A to introduce a new product, whereas (3.23) is only a necessary condition for firm B. The latter is derived by establishing a lower bound on firm B's profit when a new product is introduced. The sufficient condition is more complex and not needed for the result that follows. The next proposition states that firm A has less incentive to introduce a new product.

Proposition 3.8 The firm producing the high-end product (firm A) before the technological advance has less incentive to introduce a new product as compared to the firm which is producing the low-end product (firm B).

Proof: Referring to (3.22) and (3.23), we need to show that (3.22) is a more stringent condition. In other words, there exists some values of α for which firm B would introduce a new

product whereas firm A would not, i.e.,

$$\frac{4K}{\theta_0^2} > \frac{9K}{(\theta_0 + 1)^2}.$$
(3.24)

To show this, we note that

$$\frac{4K}{\theta_0^2} - \frac{9K}{(\theta_0 + 1)^2} = \frac{K}{\theta_0^2(1 + \theta_0)^2}(2 - \theta_0)(2 + 5\theta_0),$$

which is strictly positive for all relevant values of θ_0 . Hence the inequality in (3.24) obtains.

The intuition is simple. For firm A, the high-quality producer before the technological advance, introducing a new product draws customers away from its existing product. On the contrary, for firm B, introducing a new product primarily draws customers away from its rival. Clearly, then, firm B has more incentive to introduce a new product. The result suggests that low-quality producers are willing to invest more in bringing new products to the market. In contrast, high-quality producers are more inclined to maintain their existing product lines. Consequently, there is a tendency for firms to 'leap-frog' each other in introducing new products. This is indeed a common phenomenon in the real world. For example, Epson, once a prominent dot-matrix printer manufacturer, has been relegated to also-run status since the introduction of laser printer technology. Another example is the emergence of Japanese automakers, who were for years regarded as low-quality producers, into high-quality luxury-car markets.

3.6 Conclusion

In the context of a vertically differentiation model, we show that a monopolist produces no more than one product. The monopolist's choice the number and quality of product coincide with the social optimum. In the case of a duopoly, if product quality represents a credible commitment, firms choose the maximum degree of product differentiation to minimize price competition. Furthermore, neither firm has any incentive to expand its product line in a Nash equilibrium. However, if a firm enters the market first, it may wish to expand its product line solely for the purpose of deterring later entrants. This result is consistent with that obtained under the horizontal differentiation literature, e.g., Schmalensee (1978), Eaton and Lipsey (1979) and Bonanno (1987). We also show that entry deterrence is possible even though the entrant is more efficient (i.e., has a lower sunk cost).

In the event of a technological advance, we show that a protected monopolist is less willing to expand its product line. This implies that, if firms are to bid for the right to the new technology, a protected monopolist is not willing to offer more than an unprotected monopolist. This is in marked contrast to the Schumpeterian notion that unchallenged monopolies are a necessary breeding ground for innovations (and hence new products). Likewise, when compared to a low-quality producer, a high-quality producer has less incentive to introduce a new product if given the exclusive right to a new technology. The implication of this result is that we are more likely to observe interlaced product markets rather than segmented ones.

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Appendix 1

Appendix 1A Proof of Proposition 1.2

This appendix contains six lemmata which establish Proposition 1.2. A more general version of the capacity-constrained price game when firms' marginal costs differ is discussed in Deneckere and Kovenock (1990). They show that in a mixed strategy equilibrium, firms' supports do not necessarily be the same and they may not be connected. These possibilities, however, are ruled out by Assumptions 1.1 and 1.2 in this paper. These assumptions also greatly simplify the proof.

Throughout this Appendix, (Π_c, Π_e) is used to denote, respectively, the equilibrium profits of the conference and entrant. The support of each firm's strategy is denoted $[\underline{p}_i, \overline{p}_i]$, i = c, e. It is worth noting that in a mixed-strategy equilibrium each firm randomizes in such a way that keeps the other firm indifferent among its strategies. Formally, if $P', P'' \in [\underline{p}_i, \overline{p}_i]$, then $\Pi_i(P', G_j) = \Pi_i(P'', G_j)$. This fact is used repeatedly in the proofs below.

Lemma 1.1 Suppose $\overline{p}_c = \overline{p}_e = \overline{p}$. Then in equilibrium at most one firm has a mass point at \overline{p} .

Proof: By Proposition 1.1 there does not exist a pure strategy equilibrium. Thus, only mixed

strategy equilibria need to be considered. By assumption,

$$\underline{p}_i \ge \alpha_i. \tag{A1.1}$$

Further, the upper bound of a mixed strategy equilibrium is strictly greater than the lower bound, i.e.,

$$\overline{p} > \underline{p}_i. \tag{A1.2}$$

Combining (A1.1) and (A1.2) gives

$$\overline{p} > \alpha_i. \tag{A1.3}$$

Suppose, contrary to the hypothesis, both firms have a mass point at \overline{p} . Then, by (A1.3), both firms make positive profit at \overline{p} . However, by reducing the price slightly, one of the firm would get a strictly higher profit by avoiding the probability of a tie. This contradicts equilibrium.

Lemma 1.2 There exists a firm $i \in \{c, e\}$ such that $\Pi_i = H_i^*$.

Proof: Suppose, without loss of generality, $\overline{p}_i \geq \overline{p}_j$. Consider first $\overline{p}_i > \overline{p}_j$. Since $G_j(\overline{p}_j) = 1$, by charging \overline{p}_i , firm *i* gets for certain $\Pi_i = H_i(\overline{p}_i) \leq H_i^*$, by definition of H_i^* . But (G_i, G_j) is a pair of equilibrium strategy, so $\Pi_i(\overline{p}_i) \geq H_i^*$. Thus $\Pi_i(\overline{p}_i) = H_i^*$. Next, consider $\overline{p}_i = \overline{p}_j = \overline{p}$. By Lemma 1.1, at most one firm has a mass point at \overline{p} . Suppose firm *j* has no mass point at \overline{p} . Then, $\Pi_i(\overline{p}) = H_i(\overline{p}) \leq H_i^*$. But, again, $\Pi_i(\overline{p}) \geq H_i^*$, which implies $\Pi_i = H_i^*$.

Lemma 1.3 $\Pi_c = H_c^*, \ \Pi_e > H_e^*.$

Proof: Since a firm is at worst undercut by its rival in playing its mixed strategy, in equilibrium $\Pi_i \geq H_i^*$, i = c, e. Suppose a strict inequality holds for the conference, i.e., $\Pi_c > H_c^*$, then by Lemma 1.2, $\Pi_e = H_e^* = 0$. But note that $\underline{p}_c \geq \alpha_c$ by assumption. By charging a price $p \in (0, \alpha_c)$, the entrant earns a strictly higher profit. Thus, $\Pi_e = H_e^*$ cannot be the equilibrium profit. Therefore $\Pi_e > H_e^*$ in equilibrium, and by Lemma 1.2, $\Pi_c = H_c^*$.

Lemma 1.4 (i) $\overline{p}_c \geq \overline{p}_e$, (ii) $\overline{p}_c = p_c^H$, $\overline{p}_e \leq p_c^H$.

Proof: (i) Suppose not, i.e., $\overline{p}_c < \overline{p}_e$. Then, by charging \overline{p}_e , the entrant gets for certain $\Pi_e = 0$. But this contradicts Lemma 1.3, which states that $\Pi_e > H_e^* = 0$. (ii) Suppose $\overline{p}_c > \overline{p}_e$. Then $\Pi_c = H_c$. But from Lemma 1.3, $\Pi_c = H_c^*$, which implies that $\overline{p}_c = p_c^H$. Suppose $\overline{p}_c = \overline{p}_e = \overline{p}$. By Lemma 1.1, at most one firm has a mass point at \overline{p} . Thus, $\Pi_c = H_c^*$ again implies that $\overline{p} = p_c^H$.

Lemma 1.5 $\underline{p}_c = \underline{p}_e = p_c^I$.

Proof: From Lemma 1.3, $\Pi_c = H_c^*$. This implies

$$\underline{p}_c \ge p_c^I,\tag{A1.4}$$

since any price below p_c^I gives a profit strictly below H_c^* . Further,

$$\underline{p}_e \le p_c^I. \tag{A1.5}$$

Suppose not, then the conference can set a price $p \in (p_c^I, \underline{p}_e)$ such that it earns strictly more than H_c^* , which contradicts Lemma 1.3. Finally,

$$\underline{p}_e \ge \underline{p}_c. \tag{A1.6}$$

Suppose not, then the entrant's equilibrium profit is $\Pi_e(\underline{p}_e)$. But by charging a price $p \in (\underline{p}_e, \underline{p}_c)$, it earns strictly more than $\Pi_e(\underline{p}_e)$, a contradiction. Combining the inequalities in (A1.4), (A1.5) and (A1.6) yields $\underline{p}_c = \underline{p}_e = p_c^I$.

Lemma 1.6 $\Pi_e = L_e(p_c^I)$.

Proof: From Lemma 1.5, $\underline{p}_e = \underline{p}_c = p_c^I$. Thus, by charging p_c^I , the entrant gets either $L_e(p_c^I)$ or $T_e(p_c^I)$. Since $L_e(p_c^I) \ge T_e(p_c^I)$, this implies that $L_e(p_c^I) \ge \Pi_e$. Suppose a strict inequality holds. Then, noting that $L_e(p) = pK_e$, which is continuous on $[0, p_c^H]$, there exists an $\epsilon > 0$ such that $L_e(p_c^I - \epsilon) > \Pi_e$, but $(p_c^I) \notin [p_c^I, p_c^H]$, a contradiction. Thus, $L_e(p_c^I) = \Pi_e$.

Lemmata 1.1 to 1.6 establish that in a mixed strategy equilibrium, both the conference and the entrant's strategies share a common support $[p_c^I, p_c^H]$, and their respective equilibrium profits are H_c^* and $L_e(p_c^I)$. This completes the proof of Proposition 1.2.

Appendix 1B Cournot Competition

Suppose the conference and the entrant engage in Cournot (quantity) rather than Bertrand (price) competition in the event that the contract is rejected by the shipper. All other aspects of the game remain unchanged. Again, the game can be solved by the logic of backward induction. Consider the second-stage quantity game. Recall that the inverse demand function is

$$p = (a - Q)/b$$

where $Q = q_c + q_e$. The decision problem of firm *i*, *i*=*c*,*e*, is

$$\max_{q_i} (p - \alpha_i) q_i \quad \text{subject to} \quad q_i \le K_i \tag{A1.7}$$

where $\alpha_e = 0$.

Since (A1.7) is a well-defined maximization problem, there exists a pure-strategy equilibrium for the second-stage quantity game. Note that the capacity constraint of the entrant may or may not bind since the equilibrium quantities are typically smaller under Cournot competition.

Proposition A1.1 Under Assumptions 1.1 and 1.2, the pure-strategy equilibrium for the second-stage quantity subgame is given by

- (i) if $3K_e \ge a + b\alpha_c$, $q_c^* = \frac{1}{3}(a 2b\alpha_c)$ and $q_e^* = \frac{1}{3}(a + b\alpha_c)$,
- (ii) if $3K_e < a + b\alpha_c$, $q_c^{**} = \frac{1}{2}(a b\alpha_c K_e)$ and $q_e^{**} = K_e$.

Proof: Solving the firms' maximization problem in (A1.7), ignoring the constraints, gives rise to the following optimal-response functions:

$$q_c(q_e) = \frac{1}{2}(a - b\alpha_c - q_e),$$
 (A1.8)

$$q_e(q_c) = \frac{1}{2}(a-q_c).$$
 (A1.9)

Solving these optimal-response functions yields

$$q_c^* = \frac{1}{3}(a - 2b\alpha_c),$$
 (A1.10)

$$q_e^* = \frac{1}{3}(a+b\alpha_c).$$
 (A1.11)

Notice that the capacity constraint of the conference does not bind but the same does not hold for the entrant. Consider two cases. (i) Suppose the entrant is not capacity-constrained, i.e., $K_e \ge \frac{1}{3}(a + b\alpha_c)$. Then the expressions in (A1.10) and (A1.11) constitute the equilibrium quantities. (ii) Suppose the entrant is capacity-constrained, i.e., $K_e < \frac{1}{3}(a + b\alpha_c)$. Then, the capacity constraint of the entrant binds, and the optimal quantity for the entrant is $q_e^{**} = K_e$. The optimal response of the conference is, from (A1.8), given by

$$q_c^{**} = \frac{1}{2}(a - b\alpha_c - K_e).$$
 (A1.12)

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Given the solution for the second-stage quantity subgame, the equilibrium for the full game can be readily derived. Proposition A1.2 states that entry exclusion is still possible and profitable for the conference.

Proposition A1.2 Under Assumptions 1.1 and 1.2, and that the post-entry competition is Cournot in nature, the conference can always profitably exclude the potential entrant.

Proof: Consider two cases.

(i) Suppose $3K_e \ge a + b\alpha_c$. Then the entrant is not capacity constrained and the equilibrium quantities are given by (A1.10) and (A1.11). The total quantity demanded by the shipper is

$$Q^* = q_e^* + q_c^* = \frac{1}{3}(2a - b\alpha_c),$$

at the equilibrium price

$$p^* = (a - Q^*)/b = \frac{1}{3b}(a + b\alpha_c).$$

To show that $p^* > \alpha_c$, note that by supposition, $3K_e \ge a + b\alpha_c$, which is equivalent to $K_e \ge (a - 2K_e) + b\alpha_c$, but the expression in bracket is strictly positive due to Assumption 1.1. Thus,

$$K_e > b\alpha_c \tag{A1.13}$$

Next, Assumption 1.2 states that $a > K_e + b\alpha_c$. Combining this with the inequality in (A1.13) gives $a > 2b\alpha_c$. This inequality implies that $a + b\alpha_c > 3b\alpha_c$, which in turn implies that $p^* > \alpha_c$.

Since $p^* > \alpha_c$, there exists a price \tilde{p} such that

$$lpha_c < ilde{p} \le p^*$$

Suppose the conference offers a loyalty contract supplying the quantity Q^* at a price \tilde{p} . Since this is the same quantity demanded but at a lower price, the shipper will surely accept the contract. Note that the entrant is not able to offer such a contract since $K_e < Q^*$. To see this, note that by Assumption 1.1, $2a > 4K_e$, but $4K_e > 3K_e + b\alpha_c$ due to (A1.13). Combining the two inequalities yields $2a > 3K_e + b\alpha_c$, which after rearranging terms, gives $K_e < Q^*$.

It remains to show that the conference is strictly better off by offering the contract. By allowing entry, the conference earns

$$\Pi_c^* = (p^* - \alpha_c)q_c^*,$$

while by offering the loyalty contract, the conference earns

$$\tilde{\Pi}_c = (\tilde{p} - \alpha_c)Q^*.$$

Since Q^* is strictly greater than q_c^* while \tilde{p} can be set arbitrarily close to p^* , it follows then $\tilde{\Pi}_c > \Pi_c^*$.

(ii) Suppose $3K_e < a + b\alpha_c$. Then the entrant is capacity-constrained, and the equilibrium quantities are $q_e^{**} = K_e$ and q_c^{**} as given by (A1.12). The total quantity demanded by the

shipper is

$$Q^{**} = K_e + q_c^{**} = \frac{1}{2}(a - b\alpha_c + K_e),$$

and the equilibrium price is

$$p^{**} = (a - Q^{**})/b = \frac{1}{2b}(a + b\alpha_c - K_e).$$

It follows immediately from Assumption 1.2 that $p^{**} > \alpha_c$. Thus, the same reasoning in case (i) above applies, the conference is better off by offering a loyalty contract supplying the quantity Q^{**} at a price $\tilde{p} \leq p^{**}$, and it is to the advantage of the shipper to accept the contract. \P

Appendix 1C Derivation of the Entry Deterrence Condition

This appendix contains the algebraic derivation of the entry deterrence condition given in (1.10), which is reproduced as follow.

$$4aK_e(a - K_e + b\alpha_c) \le (a - K_e - b\alpha_c)(a + K_e - b\alpha_c)^2.$$
 (A1.14)

Recall that if the entrant can commit to charging a price equals to its marginal cost, then the average price the shipper pays is A_p^l , as given by (1.8). The conference, being the high-price firm, earns H_c^* if it allows entry. On the other hand, if the conference offers the shipper a loyalty contract, the highest price that is acceptable to the shipper is A_p^l , which gives the conference a profit of

$$\tilde{\Pi}_c(A_p^l) = (A_p^l - \alpha_c)(a - bA_p^l).$$
(A1.15)

After substituting in A_p^l , (A1.15) simplifies to

$$\tilde{\Pi}_{c}(A_{p}^{l}) = (H_{c}^{*} - \alpha_{c}K_{e})(1 + \frac{bp_{c}^{H}K_{e}}{(a - bp_{c}^{H})^{2}})$$
(A1.16)

A contract will be offered (and hence entry is deterred) if and only if $\tilde{\Pi}_c(A_p^l) \ge H_c^*$. Substitute (A1.16) into this expression yields

$$(a - bp_c^H)^2 \alpha_c > bp_c^H (H_c^* - \alpha_c K_e).$$
(A1.17)

Recall that $p_c^H = \frac{1}{2}(a - K_e + b\alpha_c)^2$ and $H_c^* = \frac{1}{4b}(a - K_e - b\alpha_c)^2$. Substituting these into (A1.17) gives

$$2b\alpha_c(a+K_e-b\alpha_c)^2 > (a-K_e+b\alpha_c)[(a-K_e-b\alpha_c)^2-4b\alpha_cK_e].$$

After adding and subtracting $2aK_e$ in the square-bracket term on the right-hand side, the desired expression in (A1.14) obtains.

Appendix 2

Appendix 2A Proofs of Results in Chapter 2

Proof of Proposition 2.2

(i) After substituting q_j^* and f_j into (2.11), the maximization problem of producer E becomes

$$S_e = \max_{w_j} \frac{1}{3} (w_j - c_u) (1 - 2w_j + w_i) + \frac{1}{9} (1 - 2w_j + w_i)^2 - S_j$$

subject to $w_j \le \frac{1}{2} (w_i + 1).$

Note that, given w_i , the objective function is strictly concave, hence a global maximum exists. We first ignore the constraint, and solve for the first-order condition, which gives the following 'reaction function' for producer E,

$$w_j = \frac{1}{4}(6c_e - w_i - 1).$$
 (A2.1)

Similar exercise gives the following 'reaction function' for producer U,

$$w_i = \frac{1}{4}(6c_u - w_j - 1). \tag{A2.2}$$

Solving (A2.1) and (A2.2) yields (w_i^*, w_j^*) in (2.12). It remains to verify that these prices satisfy the constraints in the respective maximization problems. First,

$$w_j^* - \frac{1}{2}(1 + w_i^*) = \frac{3}{5}(3c_e - 2c_u - 1) < 0,$$

where the inequality follows from Assumption 2.1. Hence, producer E's constraint is satisfied. Next, note that by supposition, $c_u \leq \frac{1}{3}(2c_e + 1)$, hence

$$w_i^* - \frac{1}{2}(1 + w_j^*) = \frac{3}{5}(3c_u - 2c_e - 1) \le 0.$$

Thus, producer U's constraint is also satisfied. The equilibrium profits in (2.13) are obtained by substituting (w_i^*, w_i^*) into the respective objective functions of producers U and E.

(ii) Given that $c_u > \frac{1}{3}(2c_e + 1)$, the derivation above suggests that producer U's constraint is binding. That is, producer U's 'reaction function' is now given by the constraint,

$$w_i = \frac{1}{2}(1+w_j). \tag{A2.3}$$

As before, producer E's 'reaction function' is obtained by first ignoring the constraint. This is given in (A2.1). Solving (A2.1) and (A2.3) results in (w_i^o, w_j^o) in (2.14). This case is illustrated in Figure A2.1. The shaded region represents the inequality constraint, $w_i \leq \frac{1}{2}(w_j + 1)$. However, the two reaction functions intersect at point A, which violates the constraint. Hence the equilibrium is at point B, which is the intersection of $w_i = \frac{1}{2}(w_j + 1)$ and retailer j's reaction function.

To show that producer E's constraint is satisfied, note that

$$w_j^o - \frac{1}{2}(w_i^o + 1) = c_e - 1 < 0,$$

where the inequality again follows from Assumption 1. Hence firm E's constraint is satisfied. The equilibrium profits in (2.15) are obtained by substituting (w_i^o, w_j^o) into the respective objective functions of producers U and E.

Proof of Proposition 2.3

To prove that (E, E) is a unique Nash equilibrium, it suffices to show that the conditions in (2.16) and (2.17) in Chapter 2 are satisfied. First, suppose $c_u \leq \frac{1}{3}(2c_e + 1)$. Then,

$$\Pi_{e-i} = \frac{2}{25}(1 - 3c_e + 2c_u)^2.$$



Figure A2.1: Reaction functions of firms U and E under case (ii)

Given $c_u > \frac{1}{13}(12c_e + 1)$, which is equivalent to $c_e < \frac{1}{12}(13c_u - 1)$, we have

$$\Pi_{e-i} = \frac{2}{25}(1 - 3c_e + 2c_u)^2 > \frac{2}{25}[1 - \frac{3}{12}(13c_u - 1) + 2c_u]^2 = \frac{1}{8}(1 - c_u)^2 = \frac{1}{2}\Pi_u^*.$$

Hence condition (2.16) is satisfied. Since in this case producer E sets

$$G = \frac{2}{25}(1 - 3c_u + 2c_e)^2 + \epsilon,$$

condition (2.17) is also satisfied. It remains to verify that producer E is willing to make such an offer, i.e., $\Pi_e^* \ge 2G$. Note that by Assumption 2.1,

$$\Pi_e^* = \frac{1}{4}(1 - c_e)^2 = \frac{1}{4}(1 - 3c_e + 2c_e)^2 > \frac{1}{4}(1 - 3c_u + 2c_e)^2$$

which is clearly greater than 2G. Hence (E, E) is a unique Nash equilibrium outcome.

Next, suppose $c_u > \frac{1}{3}(2c_e + 1)$. Then,

$$\Pi_{e-i} = \frac{2}{9}(1-c_e)^2.$$

Thus, condition (2.16) is clearly satisfied. Given that producer E in this case sets

$$G=\epsilon>0,$$

condition (2.17) is also satisfied. Hence (E, E) is a unique Nash equilibrium outcome.

Appendix 2B Bertrand Competition in a Differentiated Product Market: An Example

This Appendix considers an example of Bertrand competition in the downstream product market, where goods are substitutes. The purpose is to examine whether the central results in Chapter 2 remain valid in this case. Note that, as before, the two retailers, 1 and 2, use a homogeneous input, supplied either by the upstream incumbent, U, or the entrant, E.

We consider a particularly simple demand function facing firm i, i = 1, 2:

$$q_i(P) = 1 - p_i + \frac{1}{2}p_j,$$

where q_i and p_i denote, respectively, the quantity and price of firm *i*, and $P \equiv [p_i, p_j]$.

Consider first the decision problems of the two retailers. Let w_i and f_i be the wholesale price and fixed fee faced by firm *i*. Note that if both retailers acquire their inputs from the same producer, then $w_i = w$ and $f_i = f$, i = 1, 2. Retailer *i*'s decision problem is

$$R_i = \max_{p_i} \left(p_i - w_i \right) q_i(P) - f_i.$$

The first-order condition gives rise to retailer i's reaction function:

$$p_i = \frac{1}{2}(1 + w_i + \frac{1}{2}p_j), \quad i, j = 1, 2, \ j \neq i.$$
 (A2.4)

Solving the reaction functions of retailers 1 and 2 yields the following optimal retail prices, expressed as a function of the wholesale prices $W \equiv [w_i, w_j]$:

$$p_i(W) = \frac{2}{15}(5+4w_i+w_j), \quad i,j=1,2, \ j \neq i.$$
 (A2.5)

Substituting these prices into the demand function of firm i yields

$$q_i(W) = \frac{1}{15}(10 - 7w_i + 2w_j).$$
(A2.6)

Hence, retailer i's 'reduced-form' profit function is

$$R_i(W) = \frac{1}{225} (10 - 7w_i + 2w_j)^2 - f_i$$
(A2.7)

We next consider the two upstream producers' decision problems. Suppose each producer supplies to a different downstream firm. That is, we consider the case $\{U-i, E-j\}, i \neq j$. Producer U's decision problem is

$$\max_{w_i} (w_i - c_u) q_i(W) + f_i.$$
(A2.8)

Noting that $f_i = (p_i(W) - w_i)q_i(W) - R_i$, we can rewrite (A2.8) as

$$\max_{w_i} (p_i - c_u) q_i(W) - R_i.$$
 (A2.9)

The first-order condition gives producer U's reaction function:

$$w_i(w_j) = \frac{1}{112}(10 + 2w_j + 105c_u).$$
(A2.10)

A similar exercise gives the reaction function of producer E,

$$w_j(w_i) = \frac{1}{112}(10 + 2w_i + 105c_e).$$
 (A2.11)

Solving (A2.10) and (A2.11) gives the optimal wholesale prices,

$$w_i^* = \frac{1}{418}(38 + 7c_e + 392c_u),$$

$$w_j^* = \frac{1}{418}(38 + 7c_u + 392c_e).$$

Substituting these wholesale prices into producer U's profit function in (A2.9) yields the optimal joint profit of the alliance $\{U-i\}$:

$$\Pi_{u-i} = \frac{14}{(209)^2} (38 + 7c_e - 26c_u)^2, \quad i = 1, 2.$$
(A2.12)

The profit of the alliance $\{E-j\}$ is derived in a similar manner, and is given by

$$\Pi_{e^-j} = \frac{14}{(209)^2} (38 + 7c_u - 26c_e)^2, \quad j = 2, 1.$$
(A2.13)

Next, suppose both retailers acquire their inputs from the same upstream producer. That is, we consider the two cases $\{U-i-j\}$ and $\{E-i-j\}$. By the no-discrimination assumption, we

have $w_i = w$, and $f_i = f$, i = 1, 2. Hence, from (A2.5), (A2.6) and (A2.7), retailer *i*'s price, quantity and profit are, respectively,

$$p(w) = \frac{2}{3}(1+w),$$

$$q(w) = \frac{1}{3}(2-w), \text{ and}$$

$$R(w) = \frac{1}{9}(2-w)^2 - f.$$

Thus, the decision problem of producer k, (k = U, E) is

$$\max_{w}(w - c_k) q(w) + 2f = \max_{w} \frac{2}{9}(2 + 2w - 3c_k)(2 - w) - 2R.$$
 (A2.14)

Solving this maximization problem yields the optimal wholesale price

$$w^* = \frac{1}{4}(2+3c_k),$$

which, after substituting into (A2.14), gives the optimal profit for firm k as

$$\Pi_k^* = \frac{1}{4} (2 - c_k)^2, \quad k = U, E.$$
(A2.15)

Given the profits in (A2.12), (A2.13) and (A2.15), we can construct the normal form of the 'Choose a Supplier' game as in Figure 2.3. As before, for this game to be a standard Prisoner's Dilemma game, we require conditions (2.16) and (2.17) to hold. These conditions are reproduced as follows:

$$\Pi_{e-i} > \frac{1}{2} \Pi_u^*, \ i = 1, 2, \text{ and}$$
 (A2.16)

$$G > \prod_{u-i}, i = 1, 2.$$
 (A2.17)

In the present context, condition (A2.16) reduces to, approximately,

$$c_u > 0.056 + 0.972c_e. \tag{A2.18}$$

Compared to condition (2.19) in Chapter 2, which is illustrated in Figure 2.4, (A2.18) represents a weaker requirement, i.e., the shaded region associated with (A2.18) is larger than that of (2.19).

Next, condition (A2.17) is satisfied by setting

$$G = \Pi_{u-i} + \epsilon,$$

= $\frac{14}{(209)^2} (38 + 7c_e - 26c_u)^2 + \epsilon$

It is straightforward to verify that $2G < \Pi_e^*$, thus producer E is willing to pay the amount G to each retailer. The payoff under (E, E) is strictly lower than that under (U, U). To see this, note that by Assumption 2.1, $c_u > c_e$, hence

$$G = \frac{14}{(209)^2} (38 + 7c_e - 26c_u)^2 + \epsilon$$

$$< \frac{14}{(209)^2} (38 + 7c_u - 26c_u)^2$$

$$= \frac{14}{(209)^2} (2 - c_u)^2$$

$$< \frac{1}{8} (2 - c_u)^2.$$

This inequality implies that both retailers would like to coordinate their actions by choosing U, however, each is tempted to cheat by choosing E. As such, both retailers are willing to sign the long-term contract with the upstream incumbent in stage 1 to avoid this Prisoner's Dilemma. The proof of this is identical to that of Proposition 2.4.

Appendix 3

Appendix 3A Proofs of Results in Chapter 3

Proof of Proposition 3.1:

Suppose the monopolist produces $n \ge 2$ products of different qualities: $1 \le s_n < \cdots < s_2 < s_1 \le \overline{s}$. The monopolist incurs a sunk cost K for each quality it chooses. Define the (n+1)th 'product' to be the consumers' option of buying nothing, with $p_{n+1} = 0 = s_{n+1}$. Without loss of generality, suppose prices are set such that there exists a θ_k , $k = 1, \cdots, n$ where the consumer with characteristic θ_k is indifferent between buying product k and k+1. Then, it follows from (3.1) that

$$\theta_k = \frac{p_k - p_{k+1}}{s_k - s_{k+1}}$$

The demand for product s_1 is

$$Q_1 = 1 - F(\theta_1) = \theta_0 - \theta_1$$

and the demand for product s_k , $k = 2, 3, \dots, n$ is

$$Q_k = F(\theta_{k-1}) - F(\theta_k) = \theta_{k-1} - \theta_k$$

The monopolist's decision problem is

$$\max_{(p_1,\dots,p_n)} p_1 Q_1 + \dots + p_n Q_n - nK$$

The first-order conditions give rise to the following n equations:

$$p_{1} = \frac{1}{2}\theta_{0}(s_{1} - s_{2}) + p_{2},$$

$$p_{k} = \frac{p_{k-1}(s_{k} - s_{k+1}) + p_{k+1}(s_{k-1} - s_{k})}{s_{k-1} - s_{k+1}}, \quad k = 2, \dots, n,$$

$$p_{n} = \frac{s_{n}}{s_{n-1}}p_{n-1}$$

Note that these equations are recursive in nature. By substituting the nth equation into the (n-1)th equation, we obtain

$$p_{n-1} = \frac{s_{n-1}}{s_{n-2}} p_{n-2},\tag{A3.1}$$

and a similar expression is obtained if (A3.1) is substituted into the (n-2)th equation. The following solutions are obtained by successive substitutions:

$$p_k = \frac{1}{2}\theta_0 s_k, \quad k = 1, 2, \cdots, n.$$

Substituting these prices into the demand equations gives

$$Q_1 = \frac{1}{2}\theta_0$$
 and $Q_k = 0, \quad k = 2, 3, \dots, n.$

Thus the monopolist does not produce more than one product. The 'reduced-form' profit function of the monopolist is

$$\Pi^m = \frac{1}{4}s_1\theta_0^2 - K,$$

which is maximized by choosing $s_1 = \overline{s}$.

Proof of Proposition 3.4:

(a) Suppose firm A supplies two products with quality $s_{A1} = \overline{s}$ and $s_{A2} = 1$. If the entrant enters, it could only choose a quality level between s_{A1} and s_{A2} . Let θ_1 be the characteristic of the consumer who is indifferent between qualities s_{A1} and s_B . Let θ_2 be similarly defined. That is,

$$\theta_1 = \frac{p_{A1} - p_B}{s_{A1} - s_B}$$
 and $\theta_2 = \frac{p_B - p_{A2}}{s_B - s_{A2}}$
The demands for firm A's two products are

$$Q_{A1} = 1 - F(\theta_1) = \theta_0 - \theta_1,$$

 $Q_{A2} = F(\theta_2) = \theta_2 - (\theta_0 - 1).$

and firm B's demand is

$$Q_B = F(\theta_1) - F(\theta_2) = \theta_1 - \theta_2.$$

The entrant maximizes its profit $p_B Q_B - K_B$. The reaction function derived from the firstorder condition is

$$p_B(p_{A1}, p_{A2}) = \frac{1}{2(s_{A1} - s_{A2})} [p_{A1}(s_B - s_{A2}) + p_{A2}(s_{A1} - s_B)].$$
(A3.2)

Similarly, the incumbent maximizes its profit $p_{A1}Q_{A1} + p_{A2}Q_{A2} - 2K_A$. The resulting reaction functions are:

$$p_{A1}(p_B) = \frac{1}{2} [\theta_0(s_{A1} - s_B) + p_B],$$
 (A3.3)

$$p_{A2}(p_B) = \frac{1}{2}[p_B - (\theta_0 - 1)(s_B - s_{A2})].$$
 (A3.4)

Define the vector $s \equiv [s_{A1}, s_{A2}, s_B]$. Solving (A3.2), (A3.3) and (A3.4) yields

$$p_{A1}(s) = \frac{(s_{A1} - s_B)}{6(s_{A1} - s_{A2})} [3\theta_0(s_{A1} - s_{A2}) + (s_B - s_{A2})],$$
(A3.5)

$$p_{A2}(s) = \frac{(s_B - s_{A2})}{6(s_{A1} - s_{A2})} [(s_{A1} - s_B) - 3(\theta_0 - 1)(s_{A1} - s_{A2})],$$
(A3.6)

$$p_B(s) = \frac{1}{3(s_{A1} - s_{A2})} [(s_{A1} - s_B)(s_B - s_{A2})].$$
(A3.7)

Substituting (A3.5), (A3.6) and (A3.7) into Q_B yields the equilibrium demand for the entrant's product, which is $Q_B^* = 1/3$. The 'reduced-form' profit function of the entrant is therefore

$$\Pi_B(s) = \frac{1}{9(s_{A1} - s_{A2})}(s_{A1} - s_B)(s_B - s_{A2}) - K_B.$$
(A3.8)

Since (A3.8) is concave in s_B , the optimal quality choice is $s_B^* = \frac{1}{2}(s_{A1} + s_{A2})$, which gives a maximum profit of

$$\Pi_B^* = \frac{1}{36}(s_{A1} - s_{A2}) - K_B. \tag{A3.9}$$

It is straightforward to verify that, by virtue of Assumption 3.2, every consumer buys a unit of one of the products.

Since $s_{A1} = \overline{s}$ and $s_{A2} = 1$, it follows then $\prod_B^* = \frac{l}{36} - K_B$. Thus, it does not pay for the entrant to enter the market if $K_B \ge \frac{l}{36}$.

(b) Note that $s_{A2} > \overline{s} - 36K_B > 1$, since $K_B < \frac{l}{36}$. Thus the entrant can either choose a quality level that is between s_{A2} and \overline{s} , or one that is lower than s_{A2} . Consider the former, i.e.,

$$s_{A2} < s_B < s_{A1}.$$

Then, from the proof of (a) above, the entrant's optimal quality choice is

$$s_B^* = \frac{1}{2}(s_{A1} + s_{A2})$$

with a net profit of

$$\Pi_B^* = \frac{1}{36} (\overline{s} - s_{A2}) - K_B.$$

But $s_{A2} > \overline{s} - 36K_B$, which implies that $\Pi_B^* < K_B$. Thus, choosing a quality level between \overline{s} and s_{A2} is not profitable for the entrant.

Next, suppose the entrant chooses a quality level that is lower than s_{A2} , that is,

$$s_B < s_{A2} < s_{A1}$$
.

The entrant effectively competes only with the lower-quality product of the incumbent.¹ From Proposition 3.2, the entrant's optimal quality choice is $\tilde{s}_B = 1$ with a profit of

$$\tilde{\Pi}_B^* = \frac{1}{9}(2-\theta_0)^2(s_{A2}-1) - K_B.$$

But $s_{A2} < 1 + \frac{9K_B}{(2-\theta_0)^2}$ implies that $\tilde{\Pi}_B^* < K_B$. Thus, choosing a quality level that is lower than s_{A2} is not profitable for the entrant either.

¹Again, by virtue of Assumption 3.2, every consumer buys a unit of one of the products.

Therefore, whether the entrant chooses a quality lower than s_{A2} or one between \overline{s} and s_{A2} , it cannot make a positive profit net of its sunk cost K_B . It remains to show that there always exists such a quality choice s_{A2} . To show this, note that by Assumption 3.3,

$$K_B > \frac{l}{9} \cdot \frac{(2-\theta_0)^2}{1+4(2-\theta_0)^2}$$

which, after rearranging terms, and noting that by definition, $l = \overline{s} - 1$, gives

$$1 + \frac{9K_B}{(2-\theta_0)^2} > \overline{s} - 36K_B.$$
(A3.10)

The inequality in (A3.10) ensures that the incumbent can always find a quality level s_{A2} such that entry is never profitable if $K_B < \frac{l}{36}$.

Further, from Proposition 3.1, the monopolist's profit is maximized by setting $Q_{A2} = 0$.

Proof of Lemma 3.1:

Note that by definition of K^* , we have

$$K^* - \frac{l}{9}(2 - \theta_0)^2 = \frac{1}{4}\overline{s}\theta_0^2 - \frac{l}{9}[(1 + \theta_0)^2 + (2 - \theta_0)^2].$$
 (A3.11)

After some algebraic manipulations, and noting that $l = \overline{s} - 1$, (A3.11) reduces to

$$K^* - \frac{l}{9}(2 - \theta_0)^2 = \frac{1}{4}\theta_0^2 - \frac{l}{36}(10 + \theta_0)(2 - \theta_0).$$
(A3.12)

Since the last term on the right-hand side of (A3.12) is positive, and from Assumption 3.2, $0 < l < 3(\theta_0 - 1)/(2 - \theta_0)$, by substituting $l = 3(\theta_0 - 1)/(2 - \theta_0)$ into the right-hand side of (A3.12), we get

$$K^* - \frac{l}{9}(2 - \theta_0)^2 > \frac{1}{4}\theta_0^2 - \frac{1}{12}(10 + \theta_0)(\theta_0 - 1).$$
(A3.13)

After simplifying terms, (A3.13) reduces to

$$K^* - \frac{l}{9}(2 - \theta_0)^2 > \frac{1}{12}(\theta_0 - 2)(2\theta_0 - 5).$$
(A3.14)

It is straightforward to show that for $\frac{8}{7} < \theta_0 < 2$, the expression on the right-hand side of (A3.14) is strictly positive. \P

Proof of Proposition 3.7:

(i) There are two existing products in the market, Q_A and Q_B , with quality levels $s_A = \overline{s}$ and $s_B = 1$. Given that firm A holds the exclusive right to the new technology, it has to decide whether to make use of the new technology by introducing a new product. Suppose firm A introduces a new product, denoted by Q_A^N , with quality s_A^N . Define θ_1 as the characteristic of the consumer who is indifferent between buying Q_A^N and Q_A . Similarly, define θ_2 as the characteristic of the consumer who is indifferent between buying Q_A^N and Q_B . Let p_A^N , p_A , and p_B be the prices of products Q_A^N , Q_A , and Q_B , respectively. Then, the problem is equivalent to the one considered in Proposition 3.3. The profit function of firm A is, from (3.11), and noting that $s_A = \overline{s}$ and $s_B = 1$,

$$\Pi_A^N(s_A^N) = \frac{1}{4}\theta_0^2(s_A^N - \overline{s}) + \frac{l}{9}(\theta_0 + 1)^2 - K.$$

Hence, firm A maximizes its profit by setting $s_A^N = \overline{s} + \alpha$; and the resulting profit is

$$\Pi_A^N = \frac{\alpha}{4}\theta_0^2 + \frac{l}{9}(\theta_0 + 1)^2 - K.$$
 (A3.15)

On the other hand, if firm A decides not to introduce a new product, it continues to earn its duopoly profit Π_A^d , which is given in (3.8). Therefore, it is profitable for firm A to introduces a new product if and only if $\Pi_A^N \ge \Pi_A^d$, which, after rearranging terms, gives the required condition in (3.22).

(ii) Since firm B holds the exclusive right to the new technology, if it introduces a new product, denoted by Q_B^N , with quality s_B^N , there are then three products in the market. Firm B cannot do worse than producing only the new, high-end product Q_B^N by abandoning its low-end product Q_B , i.e., set $Q_B = 0$. By doing so, firm B's optimal quality choice is $s_B^N = \overline{s} + \alpha$, and it earns the duopoly profit

$$\Pi_B^N = \frac{l+\alpha}{9}(\theta_0 + 1)^2 - K,$$

which represents the lower bound of firm B's profit.

On the other hand, if firm *B* decides not to introduce a new product, it continues to earn the duopoly profit Π_B^d given in (3.9). Thus, it is profitable for firm *B* to introduce the new product if $\Pi_B^N \ge \Pi_B^d$, which simplifies to the desired inequality in (3.23).

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