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Entry deterrence via renegotiation-proof non-exclusive contracts[*]

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Abstract

We establish the entry-deterring role of vertical contracts in a setting that does not rely on asymmetric information, the exclusivity of the incumbent's contracts, limits on distribution channels, or restrictions on the ability to renegotiate contracts in case of entry. The optimal contract we describe is a three-part quantity discounting contract that involves the payment of an allowance to the downstream firm and a marginal wholesale price below the incumbent's marginal cost for sufficiently large quantities.

Key words: *entry, vertical contracts, exclusivity, renegotiation.*

JEL Classification: D21, L42.

Résumé

Nous établissons le rôle de dissuasion à l'entrée des contrats verticaux dans un cadre qui n'est pas basé sur l'information asymétrique, sur l'exclusivité des contrats de la firme en exercice, sur les limites des canaux de distribution, ou sur des restrictions sur la capacité de renégocier les contrats en cas de entrée. Le contrat optimal décrit est un contrat avec remise sur quantité en trois parties qui implique le versement d'une indemnité à la firme en aval et un prix de gros marginal inférieur au coût marginal de la firme en exercice pour les quantités suffisamment importantes.

Mots clés: *entrée, contrats verticaux, exclusivité, renégociation.*

Classification JEL: D21, L42.

1 Introduction

There is by now a large literature showing how an incumbent can deter efficient entry by acting strategically, such as through sunk costs or reputation effects.[1] One strand of this literature looks at entry deterrence through contracts. Many theories of entry deterrence in this branch can be criticized since they rely on the incumbent offering contracts that are not renegotiation proof in case the rival does enter, or where they are renegotiation proof, rely on exclusive contracts which completely tie up the distribution options for the entrant and are assumed costly to breach. Other theories that avoid such assumptions rely on the use of asymmetric information between the different parties. In this paper we provide a new theory of credible entry deterrence that does not rely on asymmetric information, exclusive contracts, limits in distribution channels, contracts that condition on entry, or there being no contract negotiation following entry.

We consider a Bertrand environment in which the incumbent signs a contract with a downstream firm to keep out a more efficient entrant. A key feature of the optimal vertical contract we describe is quantity discounting or declining *marginal* prices. For low levels of purchases, the downstream firm purchases at a wholesale price set above the incumbent's marginal cost, thereby providing a way for the incumbent to extract the profit of the downstream firm. For purchases beyond some higher level, the downstream firm purchases at a wholesale price set below the incumbent's marginal cost, thereby ensuring that in the face of competition the downstream firm will want to compete aggressively, constraining the rival's price without actually needing to sell anything itself. To prevent the entrant contracting with the downstream firm, the incumbent's optimal contact has to leave the downstream firm with a rent equal to the entrant's efficiency profit. This rent has to be paid to the downstream firm irrespective of the quantity purchased, i.e., it represents an allowance, known as a slotting allowance in the context of retailing (see Foros and Kind, 2008).

We show a three-part contract (two linear parts and an allowance) is the simplest optimal contract for credible entry-deterrence. A powerful feature of the optimal contract we discuss

[1] See Wilson (1992) for a survey.

is that it allows the incumbent to indirectly condition its contract on entry. The non-linear nature of the incumbent's optimal contract exploits the fact the quantity purchased by the downstream firm will differ depending on whether it faces competition or not. This avoids the incumbent monopolist having to explicitly write a contingent contract in which its wholesale price is lowered in case of entry.

Our theory is related to a substantial body of work that studies the commitment benefits of vertical contracts. A standard result in this literature is that manufacturers can soften price competition if they can commit to contracts with retailers in which wholesale prices are inflated above cost. Examples of papers in this line include Bonanno and Vickers (1988), Rey and Stiglitz (1995). We explore a previously overlooked entry deterring implication of the commitment effects of vertical contracts if interbrand competition takes the homogenous Bertrand form in which no such softening of competition is possible.[2]

Another mechanism to deter entry that has been studied in the literature is the use of divisionalization, following the work of Schwartz and Thompson (1986). They establish that an incumbent may deter an equally efficient rival by creating independent competing divisions that emulate the behavior of the rival and therefore do not allow it to recover its fixed cost of entry. Their mechanism is akin to delegating production to competing downstream firms with a vertical contract in which the wholesale price is fixed at the incumbent's marginal cost of production (and profits recovered through a profit sharing agreement). In our setting, such an approach would not work given we assume the rival is more efficient and there is Bertrand competition. Nevertheless, the idea of committing downstream divisions or firms to be more aggressive to deter entry is related.

The issues of entry deterrence and renegotiation have also been considered in settings that involve the presence of asymmetric information. Aghion and Bolton (1987) show that including a provision for liquidated damages to be paid by the downstream firm to upstream firm if it switches to the entrant would effectively deter some efficient entry. Dewatripont

[2]Etro (2010) shows more generally how the conclusions in this literature change dramatically when entry is taken as endogenous rather that assumed away.

(1988) presents an example where a principal competing with a third party can benefit from the possibility of signing public contracts with her agent, even though secret renegotiation is possible. Caillaud et al. (1994) analyze precommitment effects in a more general contracting game between vertical structures when public contracts can always be secretly renegotiated.

Our theory also relates to the literature on exclusive contracting. In case the incumbent can make its initial contract exclusive, it no longer has to offer a positive rent to the downstream firm and the incumbent can attain the full monopoly profit while still preserving renegotiation-proofness. Thus our theory relates to a literature studying exclusive dealing between upstream and downstream firms in which the exclusive contract involves a price commitment (see Simpson and Wickelgren, 2001, Stefanadis, 1998, Erutku, 2006, and Appendix B of Fumagalli and Motta, 2006). For instance, Fumagalli and Motta show the incumbent manufacturer will commit to a low wholesale price (to deter entry), extracting the surplus enjoyed by downstream firms paying this low wholesale price through an upfront fee which it receives when the exclusive deal is signed. This enables the incumbent to deter entry although at a low price, meaning renegotiation would always be profitable. Our results imply the incumbent can do better, obtaining the full monopoly profit with a contract involving quantity discounting but which does not require an upfront fee or a restriction ruling out renegotiation of the initial contract. Our results also suggest that the exclusivity in such deals, while lowering the cost of entry deterrence, may not be strictly necessary to deter entry.

The rest of the paper proceeds as follows. The basic model setup is given in Section 2. Our main findings are derived in Section 3. Section 4 then considers several extensions, highlighting the role played by the various key assumptions. Section 5 briefly concludes.

2 Benchmark model

We focus on a model in which firms sell an identical good and set prices (i.e. homogenous Bertrand competition). There is an incumbent firm, which we will denote as I, which faces constant marginal costs of c_I. A potential entrant, denoted E, faces lower marginal costs of $c_E < c_I$ but some fixed cost of entry F. We assume that E enters only if it makes positive profit. Each firm I or E can sell by itself or through one or more downstream firm (denoted D if there is just one, or $\{D_1, D_2, ...\}$ more generally) which are assumed to be all identical (all with zero costs other than those arising from contracts, and all adding no additional value).[3] Whichever firm sets the lower price obtains the entire market demand at that price. If firms set the same price, we assume that there is some exogenous profit-sharing rule to ensure equilibria are well defined (for example, the firm facing the lower marginal cost obtains the entire market).

Market demand $Q(P)$, where P is the market price, is assumed to be continuous, non-negative and decreasing in price. We assume that the revenue function $R(Q) = P(Q)Q$ is strictly concave in Q. The inverse demand function is denoted $P(Q)$. The monopoly price given any constant marginal cost w is denoted

$$P_M(w) = \arg\max_P (P - w) Q(P).$$

For notational convenience, define $Q_M(w) = Q(P_M(w))$. The incumbent's monopoly price and quantity are defined as $P_M = P_M(c_I)$ and $Q_M = Q_M(c_I)$, with corresponding monopoly profit $\Pi_M = (P_M - c_I) Q_M$. Assume $P(0) > c_I$ which ensures that if the incumbent is a monopolist it will produce a positive output (and so can obtain a positive profit).

Our first key assumption is that the fixed cost of entry is not too large.

A1. F satisfies

$$0 \leq F < (c_I - c_E) Q(c_I). \tag{1}$$

If the cost of entry is too large, i.e. when $F \geq (c_I - c_E) Q(c_I)$, then I will be able to deter entry by competing directly with E. Thus, (1) allows us to consider the interesting case when it will always be profitable for E to enter if it competes directly with I.

[3] This assumption enables us to avoid the difficult equilibrium existence problems that otherwise arise when general multilateral contracting is allowed between upstream and downstream firms (see Miklós-Thal et al. 2010).

The next essential assumption states that the entrant is not too efficient.

A2. $P_M(c_E) > c_I$ and

$$\Pi_M = (P_M - c_I)\, Q_M > (c_I - c_E)Q(c_I) - F. \tag{2}$$

The first part of A2 states that the entrant's cost advantage is not drastic. The second part states that its efficiency profit $(c_I - c_E)Q(c_I) - F$, the profit E obtains when it competes directly with I (after taking into account its entry cost), is less than the monopoly profit. In Section 4 we show both assumptions are needed for entry deterrence.

The timing of the game is as follows:

- Stage 1 (Incumbent's contracting) I offers a contract (or contracts) to one or more downstream firms, which accept or not.

- Stage 2 (Entry) After observing I's contract(s) and the acceptance decisions, E can decide whether to enter the market (incurring the cost F).

- Stage 3 (Post-entry contracting / renegotiation) After observing whether E enters or not, I (and E if it enters) can simultaneously negotiate contracts with (any) downstream firms, or in the case of I, renegotiate its contract with downstream firms, if any.

- Stage 4 (Market competition) In the last stage all final contracts are observed and all firms (if they wish) set prices, and the terms of contracts are executed.

Our purpose is to investigate the possibility of entry deterrence using delegation under plausible and broad assumptions regarding exclusivity, commitment and renegotiation. The equilibrium concept is subgame perfection. We assume I and E can commit to their vertical contracts whereas downstream firms cannot. For example, we allow that downstream firm D can walk away from any contract which it finds unprofitable ex-post, i.e., after observing entry and even after observing the rival's contract, by not buying anything from I and not paying anything to I. Our set-up allows I and E to sell to the consumers directly even if they sign the contracts with some downstream firms. We assume upstream firms face some arbitrarily small cost of contracting and/or renegotiating contracts, so that contracts will only be offered or renegotiated if they strictly increase joint profits. In our set up I and E cannot negotiate directly with each other, which typically would violate standard antitrust laws on horizontal agreements. We start with the assumption that I cannot write an exclusive contract in stage 1, but E (and I) can write exclusive contracts in stage 3.[4] This represents the most challenging setting in which to consider entry deterrence. In section 4 we extend the analysis to settings in which either exclusive deals cannot be written at any stage or can be written by I in stage 1, showing how these make entry deterrence even more profitable for the incumbent.

Contract space. The feasible contracts depend only on the quantity downstream firms buy from respective upstream firms. Apart from E's possible entry, this is the only thing I can directly observe. If we allow contracts that depend explicitly on E's entry decision, i.e., to be entry contingent, then as Fershtman, Judd and Kalai (1991) proved, any individually rational outcome can be implemented. However, the contracts they consider will generally not be renegotiation proof after entry. Moreover, making wholesale prices an explicit function of whether the rival enters may violate antitrust law. One of the points of our paper is to show such explicit dependence on entry is not necessary to deter entry.

We consider the contract space $\mathcal{T}$ which consists of contracts $T(Q) = L + W(Q)$, where $W(Q)$ is a marginal price schedule, paid when $Q > 0$, and $L \in \mathbb{R}$ is a possible lump-sum payment. We require only that $W(Q)$ are lower-semicontinuous functions, which allows us to consider discontinuities in $W(Q)$. A lump-sum payment L is a fixed payment paid in stage 4, which can depend on whether the downstream firm buys a strictly positive quantity (an optional payment) or which can be a non-avoidable payment paid irrespective of the quantity the downstream firm actually buys. We allow for a negative payment or allowance $L < 0$, known as a slotting allowance in the literature (see Foros and Kind, 2008). We also allow for free-disposal, that the downstream firm may buy a small quantity from the upstream firm

[4] The results do not depend on whether I can write exclusive contracts in stage 3.

and freely dispose it. This makes the above two types of lump-sum payment equivalent in our context.[5]

Our set-up allows for I to offer a vector of contracts T_I to some subset of downstream firms. Given the efficiency of the entrant, an optimal contract must deter entry.

Definition: *An optimal contract T_I is a (vector) contract which leads to the highest payoff for the incumbent among the class of contracts $\mathcal{T}$.*

An optimal contract can be a very complicated function from $\mathcal{T}$. An important focus of our analysis will be to find the simplest optimal contract by using simple piece-wise linear marginal price schedules. The class $\mathcal{T}_A$ of all-units contracts consists of contracts in which marginal prices change at each increment, but the new marginal price applies to all units purchased rather than just marginal units. The widely used all-units quantity discounting contracts are just a special case of such contracts in which the marginal price declines at each increment.[6] Formally, the $n-$part contract $T(Q) = L + W(Q; w, S) \in \mathcal{T}_A^{(n)}$ is characterized by the lump-sum fee $L \neq 0$, the vector of marginal prices $w = (w_1, w_2, ..., w_{n-1})$ and the vector of price-breaks $S = (S_1, S_2, ..., S_{n-1})$, where $S_1 = 0$, such that $T(Q) = L + w_i Q$ if $Q \in [S_i, S_{i+1})$. Note that two-part contract $T(Q) = F + wQ$, where $F > 0$ is a fixed fee, is also a special case of the class of contracts we consider. For purposes of consistency with the literature we define all-units contracts with $L = 0$ and the vector of marginal prices $w = (w_1, w_2, ..., w_{n-1})$ as $n - 1-$ part contracts.

3 Optimal contract

We define two parameters $\underline{P}$ and r which are instrumental in constructing an optimal contract. The first parameter is the E's break-even price $\underline{P}$ defined by

$$\underline{P} = \min\{P \text{ such that } (P - c_E) Q(P) = F\}. \tag{3}$$

[5]The other possibility, that L is an up-front fee paid at stage 1 will be discussed in Section 4.

[6]In Section 4 we show a similar analysis can be done with incremental-unit contracts in which the marginal price applies only to the incremental units at each step. Incremental-units and all-units contracts are discussed in Munson and Rosenblatt (1998) and Kolay et al. (2004).

By assumption A1 this $\underline{P}$ exists and satisfies $c_E < \underline{P} < c_I$. Indeed (1) implies $(P - c_E)\, Q\,(P) > F$ when $P = c_I$ and $(P - c_E)\, Q\,(P) < F$ when $P = c_E$. Note also that since $P(c_E) < P(c_I) = P_M$ and $c_I < P(c_E)$ by A2, we have $\underline{P} < P_M$. The second parameter r, the entrant's efficiency profit, is defined by

$$r = (c_I - c_E)Q(c_I) - F. \tag{4}$$

By (1), $r > 0$.

Initially, we assume that the market revenue function is non-decreasing at E's break-even price. This is always true for constant elasticity and logit demand where the revenue function $R\,(Q)$ is always increasing in Q, but also for linear and exponential demand specifications provided the price elasticity of the market demand $Q\,(P)$ is greater than unity (in magnitude) at $Q\,(\underline{P})$). In Section 4 we will discuss how to modify $I's$ optimal contract when this condition does not hold.

Our goal is to find the simplest contract from the set $T_A^{(n)}$ (i.e. with minimal n) which is optimal among all contracts from T. It is useful to point out that by restricting to a simple linear contract, the incumbent cannot prevent entry. Indeed, to cover its costs for any level of sales, I must set its marginal price at or above c_I if it contracts with downstream firm(s) and its price at or above c_I if it sells directly. E can always propose to D a slightly lower marginal price (if necessary), or sell directly to the market for a price less than c_I, so that given (1), it will profitably take the whole market.

The next proposition characterizes the specific three-part contract that we claim is optimal.

Proposition 1 *There exists an optimal all-units three-part contract $T_I = L + W(Q; w, S) \in \mathcal{T}_A^{(3)}$ that exhibits quantity discounting and such that (a) $L < 0$; (b) the incumbent's profit is $\Pi_M - r$; (c) the lowest marginal wholesale price is below the incumbent's marginal cost.*

Proof. The proof is by construction. I offers a single downstream firm D the contract $T_I(Q) = L + W(Q; w, S)$, where $w = (P_M, \underline{P})$, $S = (0, Q(\underline{P}))$ and $L = -r$. The contract is depicted in Figure 1.

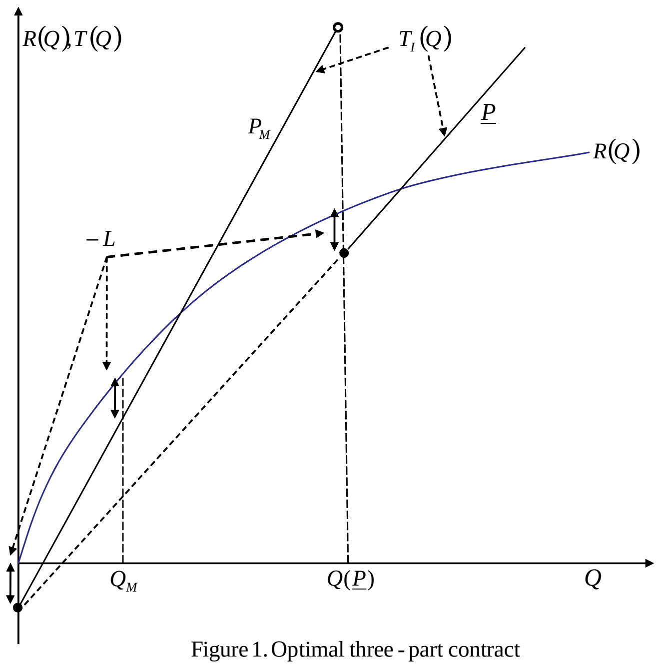

Figure 1. Optimal three - part contract

This contract has two marginal wholesale prices P_M and $\underline{P}$, which play the role of linear costs for D. A lump-sump payment r is paid to D in stage 4.

Assume first that D accepts $T_I(Q)$ and does not renegotiate with I. Also assume E enters in stage 2. In a market subgame in stage 4, D competes with I, E, and, possibly with other downstream firms that E contracts with. If in stage 3, the entrant does not contract with downstream firms then in stage 4 it competes directly with D. Consider an equilibrium (possibly involving mixed strategies) in this subgame.[7] Denote by P_l (P_l') the lower bound of retail prices chosen with positive probability by D (E). Assume first that $P_l' > \underline{P}$. Then

[7]Since we allow for lower-semicontinuous contracts we cannot guarantee the existence of pure equilibrium in pricing subgame. However, there exists a mixed strategy equilibrium (Reny, 1999). Indeed, a mixed strategy equilibrium exists for any final subgame (in normal form) if its mixed extension is payoff secure and reciprocally upper-semicontinuous. The Bertrand game is payoff secure (Reny, 1999). A sufficient condition for the mixed extension of a game to be reciprocally upper semi-continuous is that the sum of profits for the original game is upper semi-continuous. This is true for all subgames since $\Pi_i + \pi_i = R(q_i) - c_i q_i$, for $i = I, E$. Finally, the strategy spaces have to be compact sets. We do not require that the prices are bounded. However, since I competes in stage 4 in entry subgame we can restrict to prices in the interval $[0, c_I]$.

D can obtain a strictly positive profit by deviating to the pure strategy $P_D = P_l' - \varepsilon$ for $\varepsilon > 0$ such that $P_D > \underline{P}$ and E sells nothing. Thus, in the market subgame equilibrium, it must be that $P_l' \leq \underline{P}$. Then if the price set by E is equal to P_l', given (3) the expected profit of E cannot be greater than F. Since in a mixed strategy equilibrium the expected profit for E must be the same for all prices played with positive probability, the expected profit of E across all prices it randomizes over cannot be larger than F. It will therefore not want to enter.

Assume now E contracts with some downstream firms $D_1, D_2, ..., D_n$ in stage 3 (other than D) and in the following market equilibrium (possibly involving mixed strategies) the joint payoff of E and $D_1, D_2, ..., D_n$ is greater than F. Consider the following deviation of E (in stage 3). E does not contract with any downstream firm in stage 3. Instead, E replicates the outcome of the original strategy profile by playing the minimum price that would have arisen for each possible realization of the mixed strategies adopted by $E, D_1, D_2, ..., D_n$ with adjusted probabilities.[8] From I and D's perspective nothing has changed. Facing such a strategy of E in stage 4, the best D and I can do is to follow their original equilibrium strategies. It is clear that with this deviation the expected profit of E in stage 4 is the same as the joint payoff of E and $D_1, D_2, ..., D_n$ from the original strategy profile. However, E is strictly better off since it saves on the costs of contracting.

In the above entry analysis we did not consider the possibility E contracts with D. We now show this is not part of any equilibrium. Assume that in stage 3 E has entered and that it contracts with D. Then in stage 4, the equilibrium price cannot be greater or equal to c_I (given that I competes in stage 4). By A2 and concavity of the revenue function, we have

$$\max_{Q \geq Q(c_I)} (R(Q) - c_E Q - F) = r,$$

and $Q(c_I) = \arg\max_{Q \geq Q(c_I)} (R(Q) - c_E Q - F)$. Thus, the maximum that E can promise to D is r which leads by (4) to a profit less than or equal to F. Therefore, given the contract

[8] Any realization of the $n+1$ firms' mixed strategies will be a $n+1-tuple$ of prices. For each possible realization, E plays the minimum of these prices with a probability equal to the product of all probabilities for the prices in this $n+1-tuple$.

T_I, the entrant cannot cover its fixed costs.

We now show that I and D do not renegotiate the contract T_I in stage 3. In case entry occurs, the cost of entry F is sunk and E is ready to price down to its marginal cost c_E. Since $\underline{P} > c_E$, in equilibrium E must take the whole market. In this case, the joint profit of the pair (I, D) in this subgame is zero. Any re-contracting between I and D will lead to a loss either to I or to D or to both. I and D also do not renegotiate in stage 3 in the absence of entry. Any contract should leave D at least r. In this case the maximum that I can obtain is $\Pi_M - r$. Given the (arbitrarily small) cost of re-contracting, I is strictly worse off renegotiating its contract.

We established that given the acceptance of T_I in stage 1, it is not profitable for E to enter in stage 2. Consider the market subgame where there is no entry, I and D do not renegotiate their contract in stage 3, and I does not contract with other downstream firms in stage 3. It must be that the equilibrium retail price is P_M. Consider the two possibilities.

(a) If D sets the equilibrium price (or I and D share the market) then it must be that $P_D \leq P_I$. We show in this case that $P_D = P_M$. To see why note that if $P_D > P_M$ then I has a profitable deviation, to set the price P_M which is profitable given I otherwise obtains the same monopoly wholesale price but sells fewer units. If $P_D < P_M$, then D makes a loss from selling units below its wholesale cost P_M, and has a profitable deviation to set the price P_M.

(b) If I sets the equilibrium price P_I then it must be that $P_I < P_D$. We show in this case that $P_I = P_M$. To see why note that if $P_I > P_M$ then D has a profitable deviation, $P_D = P_I - \varepsilon > P_M$. If $P_I < P_M$ then I can increase P_I slightly and increase its profit since it will still take the whole market. Thus, in both cases the joint profit of the pair (I, D) is Π_M.

To show that T_I is optimal for I assume that there exists an equilibrium with I offering the vector $(T_1, ..., T_n)$, $T_I(Q) = L_i + W_i(Q)$, to downstream firms $(D_1, ..., D_n)$ such that I obtains strictly more than $\Pi_M - r$. This implies the downstream firms in total obtain (when there is no entry) $\sum_{i=1}^{n} \pi_i < r$, where $\pi_i \geq -L_i$ is D_i's profit when there is no entry. Suppose E enters and offers to each D_i the two-part contract $T_i'(Q) = L_i' + w_i Q$, where $L_i' = L_i - \varepsilon/n$

and the marginal price $w_i > P_M$, for $\varepsilon > 0$ such that $\sum_{i=1}^{n} \pi_i + \varepsilon < r$. Since D_i obtains $-L_i$ under the contract T_I in case of entry, it will accept T_i'. With this deviation, E and the downstream firms $(D_1, ..., D_n)$ are competing directly with I. By (4), entry will be profitable for E. Therefore, the minimum rent which downstream firms can obtain is r.

Finally, note that since $-L = r$ is an allowance paid irrespective of D's production, I cannot obtain more than $\Pi_M - r$ by contracting with other downstream firms in stage 3. ■

There are three instruments in the optimal contract T_I: two marginal prices $(P_M, \underline{P})$ and the rent paid to D. No instrument in the contract is redundant. The lower marginal price of $\underline{P} < c_I$, that applies if at least $Q(\underline{P})$ units are purchased, ensures that E does not find entry profitable when it competes by itself or through any other downstream firm(s) different from D. The first marginal price of P_M ensures the optimal choice of quantity and price in equilibrium when there is no entry. Finally, to avoid the possibility of contracting with the entrant, D has to obtain a positive rent r.

In Proposition 1 we constructed one particular optimal contract. The next proposition establishes that any optimal contract from the contract space $\mathcal{T}$ has similar properties. In particular, the optimal contract will involve only one downstream firm. This firm will be paid a strictly positive allowance.

Proposition 2 *The optimal contract T_I involves I only contracting with one downstream firm and has a form $T_I = L + W(Q)$, with a strictly positive allowance $L = -r, W(Q) \geq R(Q)$, for $Q \geq Q(c_I)$ and $W(Q(\underline{P})) = R(Q(\underline{P}))$.*

Proof. Suppose that I proposes contracts $\{T_1, ..., T_n\}$, $T_i(Q) = L_i + W_i(Q) \in T$ to n downstream firms $\{D_1, ..., D_n\}$ in stage 1, where L_i is not restricted to be negative. Assume that these contracts are all accepted by respective downstream firms. Consider the subgame in stage 4 with no entry. By Proposition 1, for these contracts to be optimal the joint profit of I and active downstream firms in stage 4 should be equal to Π_M. This implies the market price P_M and quantity Q_M. The main question is therefore, can I decrease the total rent offered to downstream firms by contracting with several downstream firms?

Consider an equilibrium $(P_I, P_{D_1}, ..., P_{D_n})$ of the game in stage 4, $P_M \le P \in \{P_I, P_{D_1}, ..., P_{D_n}\}$. Then $T_i(Q_M) = L_i + W_i(Q_M) = L_i + w_i^* Q_M$, where $w_i^* = \frac{T_i(Q_M) - L_i}{Q_M}$, is the average price paid at Q_M by D_i. There are three possibilities: (i) I sets the final price $P_M = P_I < P_{D_i}, i = 1, ..., n$, (ii) D_i (possibly a subset of $\{D_1, ..., D_n\}$) sets the final price $P_M = P_{D_i} < P_I$, (iii) I and D_i (possibly a subset of $\{D_1, ..., D_n\}$) share the market with $P_M = P_I = P_{D_i}$. Suppose that for some i we have $L_i > 0$. If D_i does not set the equilibrium price, $P_M < P_{D_i}$, then $\pi_{D_i} = -L_i < 0$ and D_i does not accept the contract in stage 1. If D_i sets the equilibrium price (or D_i shares the market with I or other downstream firms), $P_M = P_{D_i} \le P_I$. In this case if $P_M \le w_i^*$, then $T_i(Q_M) = L_i + w_i^* Q_M > R(Q_M) = P_M Q_M$ and thus $\pi_{D_i} = R(Q_M) - T_i(Q_M) < 0$. If $P_M > w_i^*$, then I has a profitable deviation, $P_I = P_M - \varepsilon$. With this deviation, I obtains the whole market and its profit (net of $\sum_{i=1}^n L_i$) is $(P_M - \varepsilon - c_I)\, Q(P_M - \varepsilon)$ which is larger than $W_I(Q_M) - c_I Q_M = (w^* - c_I)\, Q(P_M)$ for ε small enough. Thus, we have $L_i \le 0$ for all i.

Note that (a) if D_i sets the equilibrium price or when D_i and I share the market (possibly with other downstream firms), then $w_i^* = P_M$, and $L_i = T_i(Q^*) - P^* Q^* = -\pi_{D_i}$; (b) if I sets the equilibrium price, then $w_i^* \ge P_M$ for all $i = 1, ..., n$, and D_i obtains $-L_i$ for all $i = 1, ..., n$. Indeed assume that $P_M = P_{D_i} \le P_I$. If $P_M > w_i^*$ then I has a profitable deviation, $P_I = P_{D_i} - \varepsilon$. If $P_M < w_i^*$, then D_i has a profitable deviation, $P_{D_i} \ge P_I$. In this case D_i sells nothing (or shares the market) and obtains $-L_i$ (or $-L_i + \alpha\,(R(Q_M) - c_I Q_M)$ for some $0 < \alpha < 1$) which is larger than $R(Q_M) - T_i(Q_M) = (P_M - w_i^*)\, Q_M - L_i$. Therefore, in this case, $w_i^* = P_M$. Since $P_M = w_i^*$, we have $L_i = T_i(Q_M) - w_i^* Q_M = T_i(Q_M) - P_M Q_M = -\pi_{D_i}$. Assume that $P_M = P_I < P_{D_i}$. If $P_M > w_i^*$ then D_i has a profitable deviation, $P_{D_i} = P_I - \varepsilon$. Therefore, it must be that $P_M \le w_i^*$.

In both cases (a) and (b) the downstream firms contracting with I receive their profit only through allowances: $-L_i = \pi_{D_i}$. Therefore if $-\sum_{i=1}^n L_i < r$, then E proposes to each D_i the contracts $T_i' = L_i - \varepsilon/n + W_i$, where $\varepsilon > 0$ is such that $-\sum_{i=1}^n L_i + \varepsilon < r$. The downstream firms accept these contracts. Thus, the total rent paid to the downstream firms must be r to ensure that E cannot profitably contract with downstream firms in this way. E cannot offer contracts to only some of the n downstream firms. As soon as there exists one downstream firm who is ready to price down to $\underline{P}$, the entry will not be profitable.

Given the arbitrarily small cost of contracting, dealing with several downstream firms lead to higher cost of contracting than dealing with only one downstream firm given that Proposition 1 guarantees the same final allocation for I. Note finally that since the downstream firm obtains it profit only through the allowance it must be that $W(Q) \geq R(Q)$, for $Q \geq Q(c_I)$. The condition $W(Q(\underline{P})) = R(Q(\underline{P}))$ is therefore necessary for the optimality of T_I. ■

Note that the case when I rather than D sets the equilibrium price, as described in the proof of Proposition 2, can indeed be implemented. To do this I proposes a contract such that D is inactive in the absence of entry. The sole purpose of such contract is to deter entry and D only plays an active role in constraining E's price when entry occurs. For example, the first part of the piece-wise linear contract can be steep enough so that D does not find it profitable to buy some positive quantity from I in the absence of entry. In this case I acts as a monopolist and sets the final monopoly price. D however, still faces low wholesale prices for sufficiently large quantities and enjoys the rent $r > 0$ necessary to keep out the entrant. Thus, such contracts still work in essentially the same way as the contract in Proposition 1.

Proposition 1 proposes an optimal three-part contract with an allowance. It is easy to see that an optimal contract to one downstream firm cannot have lower dimensionality than that of a three-part contract.

Proposition 3 *For any optimal contract $T_I \in \mathcal{T}_A^{(n)}$ it must be that $n \geq 3$.*

Proof. By Proposition 2 we have $L < 0$ and $w^* \geq P^* = P_M$. Since in case of entry the marginal wholesale price has to be below or equal to $\underline{P}$, the optimal all-units contract must have at least two marginal prices. ■

4 Extensions

In this section, we discuss what happens when some of our assumptions are relaxed or modified from the above benchmark model.

The efficiency of the entrant: If the efficiency profit of E is larger than the monopoly profit of I, then the rent r in Proposition 1 will be greater than Π_M. I will not be able to prevent D from contracting with E and entry will occur. Thus, it is critical for our result that the cost advantage of the entrant cannot be too large. Similarly, the assumption that the cost advantage of the entrant be non-drastic is also critical. If the entrant has a drastic cost advantage, this means the rent that I must offer D to prevent it contracting with E will be equal to $(p_M(c_E) - c_E)\, Q(p_M(c_E))$ since this is the amount E can offer D in stage 3. Since this is necessarily more than Π_M, such entry cannot be deterred.

The entrant cannot write exclusive contracts: In order to consider the most difficult environment in which to deter entry, in our benchmark setting we assumed that E could write exclusive contracts upon entry. Given E is more efficient, this gave it considerable power in attracting D in stage 3 and meant that I had to offer D a non-trivial rent r to prevent entry. If instead E cannot write exclusive deals in stage 3, then E will no longer obtain the same advantage from attracting D. The three-part contract T_I described in Proposition 1 will continue to deter entry. Moreover, I can do better, offering D an arbitrarily small allowance $-L = \varepsilon > 0$. The downstream firm D will always accept such a contract since if it does not, then E will enter and D will be left with no surplus. Due to the structure of the contract T_I, D will continue to constrain the pricing decision of E, in this case even if E also contracts with D. In particular, E cannot sell anything at a price above $\underline{P}$ if it competes with D in the retail market (as before). If instead it sells through D it will still not be able to obtain a price above $\underline{P}$ given that D can buy at this price through I and since E is willing to undercut any retail price of D that exceeds the wholesale price it charges D. Thus, entry is again deterred, with I now obtaining almost full monopoly profits.

The incumbent can write an exclusive contract: In the main section, E is allowed to contract with D in stage 3 if E decides to enter. This possibility leads to a strictly positive allowance for D and less than monopoly profit for I. Suppose now I can offer an exclusive contract in stage 1 to prevent such contracting between E and D in stage 3. The timing of the game is unchanged except that in stage 3 the entrant cannot contract with D, i.e., there

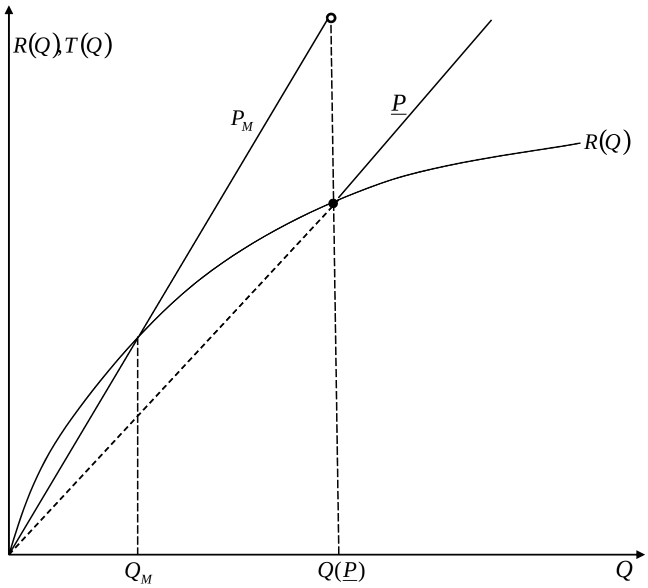

Figure 2. Optimal exclusive contract

is exclusive dealing between I and D.

Proposition 4 *Under exclusive contracting the incumbent will obtain full monopoly profits, deterring entry in the process. This can be achieved by using a two-part all-units contract.*

Proof. The proof follows from Proposition 1. I offers D the contract $T_I(Q) = L + W(Q; w, S)$, where $w = (P_M, \underline{P})$, $S = (0, Q(\underline{P}))$ and $L = 0$. This contract is depicted on Figure 2. ■

Note also that even when D is the only downstream firm available to upstream firms, it is still optimal for D to accept the exclusive contract proposed by the incumbent. Suppose D decides to reject this contract and contract with E in order to try to extract some rent from it. This will not work since in stage 3 when entry occurs, D does not bring any value to the upstream firms given that they can both sell directly to consumers (or through other identical retailers).

The "disposal-rent": When the revenue function is strictly decreasing at $Q(\underline{P})$, I must leave some additional rent to D. If there is no entry (as will be the case in equilibrium), D can

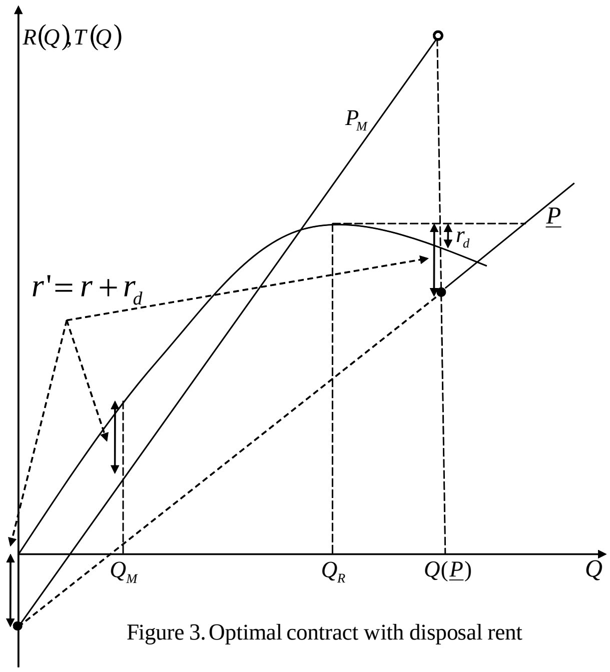

Figure 3. Optimal contract with disposal rent

buy $Q(\underline{P})$ units for $T_I(Q(\underline{P}))$ but then sell fewer units so as to obtain a higher revenue by setting a higher retail price. Indeed since $W(Q(\underline{P})) = R(Q(\underline{P}))$ and $R(Q(\underline{P})) < R(Q_R)$, where $Q_R = \arg\max_Q R(Q)$, D freely disposes $Q(\underline{P}) - Q_R$ additional units and obtains the extra profit $R(Q_R) - R(Q(\underline{P}))$.

To avoid D ordering $Q(\underline{P})$ units in equilibrium, I will offer D an extra rent $r_d = R(Q_R) - R(Q(\underline{P}))$. We call this rent the "disposal-rent", the extra-rent D can obtain in equilibrium given it can freely dispose of the good. The same amount has to be added to the allowance and rent D obtains when there is no entry. Thus, the incumbent may still deter entry, but its profit will be reduced by the size of this rent.[9] The resulting total rent that must be left to D is $r' = r + r_d$. The optimal contract for the benchmark case is depicted on Figure 3.

Upfront fees: Upfront fees can make it easier for I to deter entry since they provide a further first-mover advantage to I. In particular, they provide a mechanism for I to capture any rent r (or $r + r_d$) that must be offered to D in stage 4. Thus, they allow I to capture the full monopoly profit Π_M. In case there is entry and D does face competition, this upfront

[9]As a result, the assumption in A2 needs to be tightened so that $\Pi_M > (c_I - c_E)\,Q(c_I) - F + r_d$.

fee is a sunk cost for D, and does not affect the incentives facing D to undercut competitors as is required to prevent entry. This also means, with upfront fees, D may regret signing its contract with I, in the off-equilibrium case that there is entry. Other than this difference, the existing optimal contract continues to work as in Proposition 1.

Incremental-units quantity discounting: Proposition 1 shows that all-units quantity discounting can be used by the incumbent to deter entry. We note that another commonly analyzed type of piece-wise linear contract achieves the same goal. This type of contract is associated with incremental-units quantity discounting, which is a continuous, block declining contract, in which the marginal prices decline at each increment. The $n-$part contract $T(Q) = L + W(Q; w, S) \in \mathcal{T}_I^{(n)}$ is characterized by the vector of marginal prices $w = (w_1, w_2, ..., w_{n-1})$, a lump-sum fee $L \neq 0$ and the vector of price-breaks $(S_1, S_2, ..., S_{n-1})$ such that $T_I(Q_I) = L + w_1 Q_I$ if $Q_I < S_1$, $T_I(Q_I) = L + w_1 S_1 + w_2(Q_I - S_1)$ if $Q_I \in [S_1, S_2)$ etc. Incremental-units quantity discounting involves the declining marginal prices: $w_1 > w_2 > ... > w_{n-1}$.

The next proposition is a counter-part of Proposition 1. It shows that the incumbent can optimally deter entry by using a three-part block declining contract which exhibits incremental-units quantity discounting.

Proposition 5 *There exists an optimal incremental-units three-part contract* $T_I = L + W(Q; w, S) \in \mathcal{T}_I^{(3)}$ *such that (a)* $L < 0$; *(b) the incumbent's profit is* $\Pi_M - r$; *(c) the lowest marginal wholesale price is below the incumbent's marginal cost.*

The contract is depicted in Figure 4.

The profit obtained is identical to that obtained with the three-part all-units contract characterized in Proposition 1. The contract has the form $T_I(Q) = L + W(Q; w, S)$, where $w = (P_M, R'(Q(\underline{P})))$, $S = (0, \frac{(\underline{P} - R'(Q(\underline{P})))}{P_M - R'(Q(\underline{P}))} Q(\underline{P}))$ and $L = -r$.

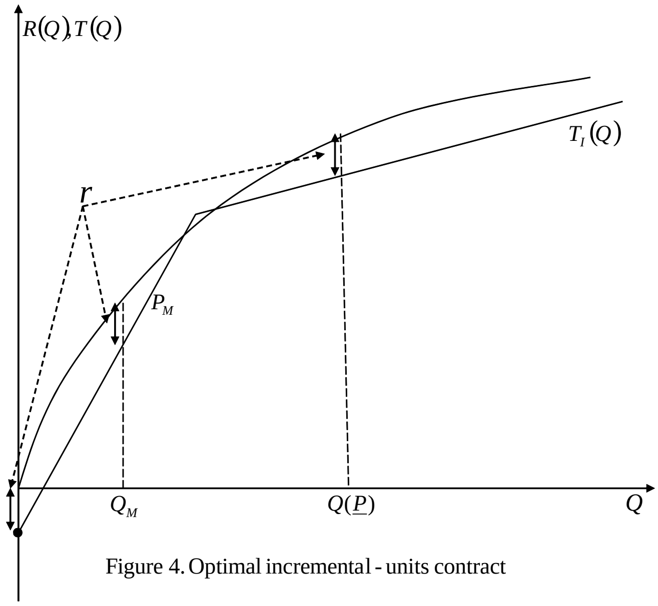

Figure 4. Optimal incremental - units contract

5 Conclusions

The key new idea developed in this paper is that commonly used forms of contracts involving quantity discounting can have entry deterring effects. An upstream incumbent can use such contracts to commit its downstream distributor to be more aggressive in the face of competition. For low levels of purchases, the downstream firm purchases at a wholesale price set above the incumbent's marginal cost, thereby providing a way for the incumbent to extract the downstream firm profit. For purchases beyond some higher level, the downstream firm purchases at a wholesale price set below the incumbent's marginal cost, thereby ensuring that in the face of competition, the downstream firm will want to compete aggressively, in such a way that the rival will not want to enter. A third instrument in the optimal contract includes an allowance paid to the downstream firm. This rent ensures that the downstream firm is not willing to contract with the rival instead, in case it enters. The amount of rent that needs to be paid is limited to the entrant's efficiency profit, given both firms can always sell to final consumers directly. The proposed optimal contract is also renegotiation-proof, thereby ensuring the incumbent can profitably deter entry even when its contract can be renegotiated for an arbitrarily small cost. Thus, we provide a new explanation of how efficient entry can be deterred based on vertical contracts, one that avoids making the usual assumptions such as asymmetric information, exclusivity or commitment without renegotiation.

The benchmark model we have provided can be extended in numerous directions. Several natural modifications have been analyzed in this paper, including to the cases in which the incumbent can use exclusive deals or upfront fees. In the former case, we showed exclusive deals eliminate the rent that has to be paid to the downstream firm so the incumbent can obtain full monopoly profit. In the latter case, the rent must still be paid ex-post but it can be fully extracted in the initial contract through an upfront fee.

One can think of the entry deterring vertical contracts we consider as a type of vertical limit pricing or predation given that the incumbent offers to sell below its own cost, for sufficiently large purchases. This suggests from a policy viewpoint, our theory supports the use of a predatory pricing standard for dealing with wholesale price discounts. In our theory, there are two testable features of entry-deterring contracts: marginal wholesale prices must fall below a firm's own marginal cost for sufficiently large quantities and it must either rely on allowances paid to the downstream firm or exclusive contracts.

An interesting direction for future research would be to explore a dynamic version of this vertical limit pricing story, in which downstream firms make a sequence of purchase decisions. The type of quantity discounting contracts we propose may be used to engage in traditional predation, but in a less obvious way. Thus, for instance, an incumbent manufacturer that wanted to build a reputation for toughness (along the lines of Kreps and Wilson, 1982), can use the seemingly standard quantity discounting contract we propose, which ensures its retailer only "fights" when necessary, while reducing the likelihood of antitrust action that might otherwise result from *shifting* to a more aggressive pricing schedule (involving a marginal price below cost) in the face of entry. The incumbent's incentive to keep a reputation for toughness in a multiperiod or multiple-entrant environment could also provide an additional reason why the incumbent may not want to renegotiate its contract in case of entry.

Finally, related to this last point, a very natural extension of the established literature would be to modify the standard signaling and reputation stories of limit pricing and predation based on asymmetric information so as to incorporate the fact that the incumbent sells to retailers rather than final consumers. In such a theory, a low wholesale price might signal that the incumbent has low cost, thereby deterring entry. However, an aggressive wholesale pricing schedule can also have a direct entry deterring effect, in addition to its signaling effect, along the lines considered in this paper. Moreover, in such a setting, the nature of limit pricing and predation could be quite different if rivals only observe retail prices rather than wholesale contracts. In other words, the analysis of signaling and reputation building in vertical settings is likely to make for interesting future research.

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