Entry deterrence via renegotiation-proof non-exclusive contracts

Aggey Semenov[*] and Julian Wright[†]

Abstract

We study the entry-deterring role of contracts in a Bertrand environment. The incumbent may prevent efficient entry by using renegotiation-proof, non-exclusive contracts with downstream firms. The optimal contract we describe is two-part linear quantity discounting involving an allowance. A marginal price is below the incumbent's marginal cost for sufficiently large quantities.

1 Introduction

Existing theories of limit pricing and predation treat buyers as final consumers, focusing on the price charged by an incumbent firm to consumers, and whether this price is set low enough to keep out (or drive out) a rival. In contrast, in many important cases of limit pricing and predation, the incumbent is actually an upstream firm that offers a non-linear contract to downstream firms.

In this paper we provide a new theory of credible entry deterrence in Bertrand environment which works through the contract signed between an incumbent and a downstream firm to the detriment of a potential entrant. A key feature of the pice-wise linear optimal

[*]Department of Economics, University of Ottawa.

[†]Corresponding author. Department of Economics, National University of Singapore, AS2 Level 6, 1 Arts Link, Singapore 117570. Email jwright@nus.edu.sg.

vertical contract we describe is quantity discounting or declining *marginal* wholesale prices. For low levels of purchases, the downstream firm purchases at a marginal 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 marginal 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. To prevent contracting with the entrant the downstream firm should obtain some strictly positive rent. This rent has to be paid to the downstream firm irrespective of quantity purchased, i.e., it represents the allowance. The limit marginal price, even though it is below the incumbent marginal cost, is above the entrant marginal cost. This leads to renegotiation-proofness. Two-part contracts with allowance are therefore the simplest optimal tariffs.

A powerful feature of the optimal contract we discuss 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 marginal price is lowered below cost in case entry occurs, since doing so is likely to be deemed to be anticompetitive. Instead, 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.

From a policy viewpoint, our theory provides a particular setting which supports the use of a predatory pricing standard for dealing with wholesale price discounts in single-product cases. In our theory, there are two testable features of entry-deterring contracts: it must include allowance and marginal wholesale prices must fall below a firm's own marginal cost for sufficiently large quantities. Where there are no efficiency justifications for these features, such contracts are therefore anticompetitive.

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 (1988, 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.

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 the entry. In the presence of asymmetric information, Dewatripont (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.[1]

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 (costlessly) 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. Nevertheless, the idea of committing downstream divisions or firms to be more aggressive to deter entry is the same.

Our analysis allows considering the case of exclusive contracting. In this case the rent

[1] Caillaud et al. (1994) analyze precommitment effects in a more general contracting game between vertical structures under asymmetric information when public contracts can always be secretly renegotiated.

of the downstream firm is zero and the incumbent can attain the full monopoly profit still preserving renegotiation-proofness. Thus our theory relates to the large literature studying exclusive dealing.[2] This has been considered by Simpson and Wickelgren (2001), Stefanadis (1998), 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 retail buyers 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. Our results imply the incumbent can do better, often obtaining the full monopoly profit, with a contract involving quantity discounting but which does not require an upfront fee or exclusionary terms. Our results also suggest that such exclusive deals (i.e. involving commitments to low wholesale prices) may actually be better understood as a form of vertical limit pricing or vertical predation rather than as a form of exclusive dealing. Whether the entrant is denied access to retailers or not may not matter much if the incumbent's retailers enjoy low wholesale prices.

Finally, our theory relates to the literature on contingent contracts. Katz (2006) provides a nice analysis of the power of contingent vertical contracts in delegation games. In a framework where contracts are directly contingent on the rival's contract he obtains a "folk theorem" result.

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 positive 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 downstream firms $\{D, ...\}$ which

[2] In other theories in which the incumbent uses exclusive (or partially exclusive) contracts as a barrier to entry (e.g. Aghion and Bolton, 1987, Rasmusen *et al.*, 1991, and Segal and Whinston, 2000), contracts are signed directly with final consumers and the mechanisms at work are very different to ours.

are assumed to be all identical (all with zero costs other than those arising from contracts, and all adding no additional value). 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 strictly 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

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

If the cost of entry is sufficiently large, i.e. when $F \geq (c_I - c_E)\, Q(c_I)$, then I is able to deter entry without contracting with downstream firm(s) and 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.

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.

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. 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 there is some arbitrarily small cost of contracting and renegotiating, so that contracts will only be renegotiated if they strictly increase joint profits. We do not allow I and E negotiate directly with each other, which typically would violate standard antitrust laws on horizontal agreements.

Contract space. The feasible contracts depend only on the quantity downstream firms buy. This is something I can directly observe. If we allow contracts that depend explicitly on E's entry decision, i.e., to be entry contingent, then as Judd, Fershtman and Kalai (1991) proved, any individually rational outcome can be implemented. However, making wholesale prices an explicit function of whether the rival enters may well violate antitrust law.

We consider the contract space $\mathcal{T}$ which consists of contracts $T(Q) = L + W(Q)$, where $W(Q)$ is a marginal price schedule, $W(0) = 0$, 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 discontinuous contracts. A lump-sum payment L can be a fixed payment paid or received at the end of stage 4 irrespective of quantity the downstream firm buys (a non-avoidable payment), or when the downstream firm buys a strictly positive quantity (an optional payment). We allow for a negative payment or allowance $L < 0$, known as a slotting allowance in the literature. There is a third possibility when L is an up-front fee paid at Stage 1 - before the entry/no entry decision (at the moment of signing the contract between I and D). We will discuss the consequences of up-front fee on the optimal contract in the discussions section.

Out 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 deters entry, renegotiation-proof and non-exclusive.*

An optimal contract can be a very complicated function from $\mathcal{T}$. An important focus of our analysis will be to see whether the incumbent can optimally deter entry by using simple piece-wise linear contracts. 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. All-units quantity discounting contracts are just a special case of such contracts in which the marginal price declines at each increment. 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, the vector of marginal prices $w = (w_1, w_2, ..., w_n)$ and the vector of price-breaks $S = (S_0, S_1, ..., S_{n-1})$, where $S_0 = 0$, such that $T(Q) = w_i Q + L$ if $Q \in [S_{i-1}, S_i)$.

3 Optimal contract

We provide 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

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

By assumptions A1 and A2 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 $P = c_E$. The second parameter r, the entrant's ex-ante profit if E enters and compete directly with I, is defined by

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

By (1) $r > 0$.

Initially, we assume that $R'(Q(\underline{P})) \geq 0$ so 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 $Q(\underline{P})$). We will subsequently discuss how to modify $I's$ optimal contract when this condition does not hold.

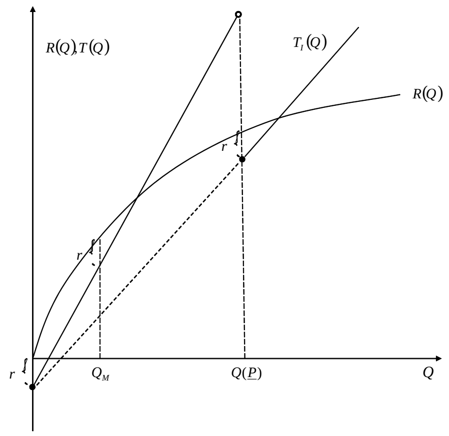
Our goal is to find a simplest contract, preferably from the set $\mathcal{T}_A^{(n)}$ with minimal n, which is optimal among all contracts from $\mathcal{T}$. It is useful to point out that by restricting to linear contracts, the incumbent cannot prevent entry. Indeed, to cover its costs for any level 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 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 describes the specific two-part contract with allowance that we claim is optimal.

Proposition 1 *The incumbent can optimally deter entry by using a contract to one of downstream firms D such that a) the optimal contract is all-units two-part* $T_I = L + W(Q; w, S) \in$

$\mathcal{T}_A$ with a strictly negative allowance, $L < 0$, b) I's profit is $\Pi_M - r$, c) the lowest marginal price is below the incumbent's marginal cost.

Proof. The proof is by construction. 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 $L = -r$. The contract is depicted in Figure 1.



Assume first that D accepts $T_I(Q)$ and does not renegotiate with I. In a market subgame at Stage 4 D competes with I, E, and, possibly with other downstream firms. Consider an equilibrium (possibly mixed) in this subgame.[3] Denote by P_l the lower bound of strategies played with positive probability by E or downstream firms contracted with E. Then either $D < P_l$, in which case the entrant has no market share, or $D \geq P_l$, in which case D's profit is zero. In the latter case, if $P_l > \underline{P}$ then D obtains a strictly positive profit by deviating to $P_D = P_l - \varepsilon$ for $\varepsilon > 0$ such that $P_l - \varepsilon > \underline{P}$. Thus, it has to be $P_l \leq \underline{P}$, and, by (3) the joint profit of E and contracted downstream firms cannot be greater than F. Therefore, the entry decision cannot be equilibrium.

[3]Since we allow for discontinuous profits we cannot guarantee the existence of pure equilibrium in pricing subgame. However, there exists a mixed equilibrium (Reny, 1999). Indeed, a mixed strategy equilibrium exists for any final subgame (in normal form) if its mixed extention is payoff secure and reciprocally upper-semicontinuous. The Bertrand game is payoff secure (Reny, 1999). A sufficient condition for the mixed extention 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, we will show that in the entry subgame we can consider prices from the interval $[0, c_I]$.

Assume now that at Stage 3 E contracts with D. At Stage 4, the equilibrium price cannot be greater or equal to c_I (given that I competes at Stage 4). By A1, we have

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

and the maximizer is $Q(c_I)$. Thus, the maximum what E can promise to D is r. Since, the allowance promised by I is r, E should give up the rent r which leads by (4) to a profit lower than F.

We show that I and D do not renegotiate the contract T_I at Stage 3 after the entry decision. When entry occurs, the cost of entry F is sunk and E is ready to price down to its marginal cost c_E. Since $\underline{P} > c_E$, D does not price below c_E and in equilibrium E takes 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 to I.

We established that given the acceptance of T_I at Stage 1 it is not profitable for E to enter at Stage 2. Consider market subgame where there is no entry and I, D do not renegotiate or re-contract (in case of I).

a) If D sets the equilibrium price (or I and D share the market), $P_D \leq P_I$, and if $P_D > P_M$ then I has a profitable deviation, $P_I = P_{D_i} - \varepsilon > P_M$. If $P_D < P_M$, then D has a profitable deviation, $P_D \geq P_I$. In this case D sells nothing (or shares the market) and obtains $-L$ (or $-L + \alpha \Pi_M$) which is larger than $R(Q_M) - T_I(Q_M) = (P_D - P_M) Q_M - L$. Therefore, in this case, $P_D = P_M$.

b) If I sets the equilibrium price P_I, $P_I < P_D$, and 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. Therefore in this case, $P_I = P_M$.

Thus, in both cases the joint profit of the pair (I, D) is Π_M and, therefore, the contract T_I is optimal for the pair (I, D). Since $-L = r$ is an allowance the maximum what I obtains is $\Pi_M - r$.

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 at 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. Note that 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 compete by itself or through any other downstream firm(s) different from D. The first marginal price ensures the optimal choice of quantity and price in the final stage of the game. Finally, to avoid the possibility of contracting with the entrant, D has to obtain a positive rent r. Normally, competition among downstream firms drives the rent, obtained by one of them, down. However, in our setting I cannot discipline D since it can buy below cost and still obtain the rent.

The allowance L plays an important role in the design of an optimal contract in Proposition 1. We will establish that any optimal contract from the general contract space $\mathcal{T}$ should involve allowance. Suppose that at Stage 1 I proposes contracts $T_i(Q) = L_i + W_i(Q) \in \mathcal{T}$ to the set of downstream firms $\{D_1, ..., D_n\}$, where $L_i \gtrless 0$. Consider the market subgame with no entry. Since the joint profit of I and active firms at Stage 4 should be equal to Π_M, the equilibrium price $P^* = P_M$ and quantity $Q^* = Q_M$. This rules out the possibility of mixed equilibria. Consider an equilibrium $(P_I, P_{D_1}, ..., P_{D_n})$ with the equilibrium price $P^* = P_M \in \{P_I, P_{D_1}, ..., P_{D_n}\}$ and $Q^* = Q_M$. Then $T_i(Q^*) = L_i + W_i(Q^*) = L_i + w_i^* Q^*$, where $w_i^* = \frac{T_i(Q^*) - L_i}{Q^*}$, is the average price paid at Q^*. There are three possibilities: a) I sets the price, $P^* = P_I < P_{D_i}, i = 1, ..., n$, b) D_i (possibly a subset of $\{D_1, ..., D_n\}$) sets the price, $P^* = P_{D_i} < P_I$, c) I and D_i (possibly a subset of $\{D_1, ..., D_n\}$) share the market, $P^* = P_I = P_{D_i}$.

The next proposition establishes properties of general optimal, non-exclusive, renegotiation-proof contracts.

Proposition 2 *1) The fixed fee L_i is an allowance, $L_i \leq 0$, 2a) If D_i sets the equilibrium price or when D_i and I share the market (possibly with other downstream firms), then $w_i^* = P^* = P_M$, and $L_i = T_i(Q^*) - P^* Q^* = -\pi_{D_i}$, 2b) If I sets the equilibrium price, then $w_i^* \geq P^*$ for all $i = 1, ..., n$, and $P^* = P_M$. D_i obtains $-L_i$ for all $i = 1, ..., n$.*

Proof. *1)* Suppose that $L_i > 0$. Two cases are possible:

i) D_i sets the equilibrium price (or D_i and I share the market), $P^* = P_{D_i} \leq P_I$. If in this case $P^* \leq w_i^*$, then $T_i(Q^*) = L_i + w_i^* Q^* > R(Q^*) = P^* Q^*$ and thus $\pi_{D_i} = R(Q^*) - T_i(Q^*) < 0$. If $P^* > w_i^*$, then I has a profitable deviation: $P_I = P^* - \varepsilon$. In this case I obtains the whole market and its profit (net of $\sum_{i=1}^n L_i$) is $(P^* - \varepsilon - c_I)\, Q(P^* - \varepsilon)$ which is larger than $W_I(Q^*) - c_I Q^* = (w^* - c_I)\, Q(P^*)$ for ε small enough.

ii) I sets the equilibrium price, $P^* = P_I < P_{D_i}$. In this case $\pi_{D_i} = -L_i < 0$ and D_i does not accept the contract at Stage 1. Therefore, it must be that $L_i \leq 0$ for all $i = 1, ..., n$.

2a) Assume that $P^* = P_{D_i} \leq P_I$. If $P^* > w_i^*$ then as in *i)* I has a profitable deviation, $P_I = P_{D_i} - \varepsilon$.

If $P^* < w_i^*$, then D_i has a profitable deviation, $P_{D_i} \geq P_I$. In this case D_i sells nothing (or shares the market) and obtains $-L_i$ (or $-L_i + \alpha\,(R(Q^*) - c_I Q^*)$) which is larger than $R(Q^*) - T_i(Q^*) = (P^* - w_i^*)\, Q^* - L_i$. Therefore, in this case, $w_i^* = P^*$. Since this is true for all downstream firms who possibly set the price P^* and share the market, I's profit is $\sum_{i=1}^n \mu_i T_i(Q^*) - c_I Q^* = (\sum_{i=1}^n \mu_i w_i^* - c_I)\, Q^* + \sum_{i=1}^n L_i = (P^* - c_I)\, Q^* + \sum_{i=1}^n L_i$, where $\mu_i = 0$ if $P_{D_i} > P^*$ and $\sum_{i=1}^n \mu_i = 1$. Therefore, $P^* = P_M$.

Since $P^* = w_i^*$ we have $L_i = T_i(Q^*) - w_i^* Q^* = T_i(Q^*) - P^* Q^* = -\pi_{D_i}$.

2b) Assume that $P^* = P_I < P_{D_i}$. If $P^* > w_i^*$ then as in D_i has a profitable deviation, $P_{D_i} = P_I - \varepsilon$. Therefore,it must be that $P^* \leq w_i^*$. It is clear that if $P^* \neq P_M$ then I can increase its profit. ■

Note that I may propose contracts such that downstream firms do not participate in the market game when there is no entry (Proposition 22b). The purpose of such contracts is to deter entry; the downstream firms are active only when entry occurs (out of equilibrium). For example, the first part of piece-wise linear contract can be steep enough so that D does not find it profitable to buy some positive quantity from I when there is no entry. In this case I sets the final monopoly price. D however, enjoys the rent r. We established in Proposition 2 that this rent is less or equal to zero: $L_i \leq 0$. Since E can contract with the any of downstream firms we show that $L_i < 0$.

Lemma 3 $-\sum_{i=1}^n L_i \geq r > 0$.

Proof. Suppose that $-\sum_{i=1}^{n} L_i < r$. If E proposes to each D_i the allowance (bribe) equal to $-L_i + \varepsilon/n$ such that $-\sum_{i=1}^{n} L_i + \varepsilon < r$ (or, equivalently, E may propose the feasible contracts $T_i(Q) = -(L_i + \varepsilon/n) + w_i Q$, where $w_i > c_I$). This contract will be accepted by each D_i since $-L_i + \varepsilon/n > \pi_{D_i}$, and leads to the profit $\Pi_E > F$. ■

Proposition 1 proposes an optimal two-part contract with an allowance. Next we establish that an optimal contract cannot have lower dimensionality.

Proposition 4 *For any optimal contract $T_I \in \mathcal{T}_A^{(n)}$ it must be that $n \geq 2$.*

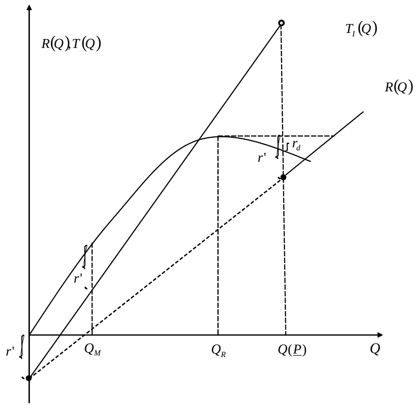
Proof. By Lemma 3 $L < 0$ and by Proposition 2 $w^* = P^*$. Since in case of no entry $Q^* < Q(c_I)$ and in case of entry $Q^* > Q(c_I)$ the minimal contract must have at least two linear parts. ■

4 Discussions

In this section, we discuss assumptions and different modifications of the above benchmark model.

The "disposal-rent": When the assumption $R'(Q(\underline{P})) \geq 0$ does not hold I must leave some additional rent for D. If there is no entry (as will be the case in equilibrium), D can always make a positive extra profit buying $Q(\underline{P})$ units for $T_I(Q(\underline{P}))$ but then selling fewer units so as to obtain a higher revenue given $T_I(Q(\underline{P})) + r = R(Q(\underline{P}))$ and $R'(Q(\underline{P})) < 0$, freely disposing of the additional units. In fact, D will optimally sell only the revenue maximizing number of units, $Q_R = \arg\max_Q R(Q)$.

Therefore, I will offer D an extra rent r_d for selling the monopoly output level Q_M, $r_d = R(Q_R) - R(Q(\underline{P}))$. We call this rent the "disposal-rent", the rent D can obtain in equilibrium given it can freely dispose of the good. Thus, the incumbent may still deter entry, but its profit will be reduced by the size of this rent. The total rent is $r' = r + r_d$. The optimal contract is depicted on Figure 2.



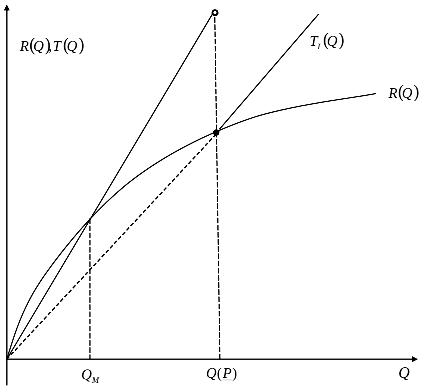
Upfront fees: Upfront fees can make it easier for I to deter entry since they provide a further first-mover advantage to I. In equilibrium, D sets the price and I extracts the expected profit in equilibrium through its upfront fee. If D does face competition, this upfront fee is a sunk cost for D, allowing I to collect more in total from D while still ensuring it will undercut the competitors as is required to prevent entry. This also means, with upfront fees, D may regret signing its contract with I, in the case when there is entry. Despite this difference, the existing optimal contract continues to work as in proposition 1.

Exclusive contracts: In the main section the entrant is allowed to contract with D after entry decision. This possibility leads to a strictly positive allowance for D and suboptimal (lower than monopoly) profit for I.

Let us consider the exclusive dealing. The timing of the game is unchanged except that in Stage 3 the entrant cannot contract with D, i.e., there is exclusive dealing between I and D.

Proposition 5 *Under exclusive contracting the incumbent will obtain full monopoly profits, deterring entry in the process. This can be achieved by using two-part contracts.*

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 3.



■

Note that an upfront fee becomes necessary to achieve optimally when the assumption $R'(Q(\underline{P})) \geq 0$ does not hold.

Other piece-wise linear contracts: Proposition 1 shows that all-units quantity discounting can be used by the incumbent to deter entry. We note that another type of piece-wise linear contracts also achieve the same goal. This type of the contract is associated with incremental-units quantity discounting, which is a continuous, block declining contract, in which the marginal prices declines at each increment. The contract is characterized by the vector of marginal prices $(w_1, w_2, ...)$, a lump-sum fee L and the vector of price-breaks $(S_1, S_2, ...)$ 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: $w_1 > w_2 > ...$

The next proposition is a counter-part of Proposition 1.

Proposition 6 *The incumbent can optimally deter entry by using a two-part block declining contract which exhibits incremental-units quantity discounting. The lowest marginal prices is below the incumbent's marginal cost.*

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 marginal 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 marginal 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. Finally, the third instrument in the contract includes an allowance paid to the downstream firm. This rent exclude the possibility of contracting with the entrant. The proposed optimal contract is renegotiation-proof, thereby ensuring it can profitably deter entry even when its contract can be freely renegotiated. Thus, we provide a new explanation of limit pricing (or predation), one which does not depend on asymmetric information.

The benchmark model we have provided can be extended in numerous directions. Several natural modifications have been analyzed in this paper, most significantly to the case which involves exclusive dealing. In this case, the rent paid to the downstream firm is zero and the incumbent obtains full monopoly profit.

An interesting direction for future research would be to explore a dynamic version of the vertical limit pricing story, in which downstream firms make a sequence of purchase decisions. This version of our vertical limit pricing story should be able to formally explain the use of rebates to deter entry or drive existing rivals out. In particular, it could be used to formalize the reputation story we gave, in which the incumbent's incentive to keep a reputation for toughness in a multiperiod or multiple-entrant environment provided an additional reason why it 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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