How buybacks eliminate opportunism in vertical contracting

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Abstract

A monopolist producer, offering private contracts to competing retailers, may be unable to exercise its monopoly power because of the scope for opportunistic behavior. In this paper we show that the producer eliminates this problem using bilateral contracts with buybacks, together with a price ceiling if needed (buybacks are a price paid by the producer to the retailer for each unit of unsold stock). Contracts with buybacks alone can be sufficient to solve the problem if either the elasticity of demand (at the monopoly price) is not too small or the number of retailers is large.

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1 Introduction

Over recent years there has been great interest from economists and lawyers about the appropriate treatment under competition law of price floors and Resale Price Maintenance. In the US this interest was created by the Supreme Court's ruling on the Leegin case, which concluded that RPM should no longer be per se illegal.[1] In the EU the interest was motivated by the Commission's review of its guidelines on vertical agreements. One argument against price floors is that they may be used to control producer opportunism and lead to higher market prices.[2]

In this paper we find the producer can always eliminate the opportunism problem using bilateral contracts with buybacks, together with a price ceiling if needed (buybacks are a price agreed to be paid by the producer to the retailer for each unit of its unsold stock). Both buybacks and price ceilings are typically legal and widely used in practice. Therefore the argument that a more lenient policy towards price floors and RPM would enable a monopolist producer to increase market prices by controlling opportunism should be less of a concern than previously thought—since instruments that allow for this are already available to the producer.

The current understanding of RPM has been largely influenced by what is now known as the Chicago Critique. It challenged a then long held view that an upstream monopolist would use vertical restraints to leverage its market power downstream. The argument was there is a single monopoly rent in a vertical chain and it can be extracted with nonlinear contracts (e.g. Spengler, 1950, Bork, 1954 and Mathewson and Winter, 1984). This favoured instead a view where vertical restraints serve efficiency motives. For example, price floors can encourage retailers to offer valuable advice which might not be offered otherwise because of free-riding among retailers (e.g. Telser, 1960 and Mathewson and Winter, 1984).

[1] Leegin Creative Leather Prods., Inc. v. PSKS, Inc., 551 U.S. 877 (2007), overruling Dr. Miles Med. Co. v. John D. Park & Sons, 220 U.S. (1911).

[2] See for example "Hardcore restrictions under the Block Exemption Regulation on vertical agreements: an economic view" by the European Commission's advisory group EAGCP (2009). The proceedings from OCDE's Roundtable on Resale Price Maintenance 2008 suggest that this concern is more prevalent in Europe than in the US, possibly due to the different mandates of the competition authorities.

Several authors have since argued that with private contracting, i.e. if the monopolist producer cannot commit to a set of public contracts, it may fail to extract the monopoly rent even with non-linear contracts (e.g. Hart and Tirole, 1990, O'Brien and Shaffer, 1992, McAfee and Schwartz, 1994, Rey and Verge, 2004 and, for a recent survey, Rey and Tirole, 2007). The reason is that the contracts that coordinate the vertical chain leave the producer an incentive to offer better terms to some retailers as it fails to internalize the effect this has on the profits of the other retailers. Such contracting externalities are thought to be more severe when the number of retailers is large, as the producer's equilibrium profit should then be negligible—known as "competitive convergence" (Segal and Whinston, 2003).

Price controls can help the producer restore its monopoly power and thereby raise market prices. Indeed, if retailers were to purchase from the producer only once a consumer places an order with them—i.e. make-to-order—the opportunism problem can be solved directly with a market-wide price floor, or indirectly (by eliminating the rent-shifting incentives) with contracts consisting of a price ceiling at the monopoly price level and wholesale prices that squeeze the retail margins (O'Brien and Shaffer, 1992).

In practice many consumer goods are however sold on a make-to-stock basis, i.e. stocks are first purchased by retailers who make products readily available on shelves to consumers—e.g. most foods, stationary, and apparel. In these situations vertical price controls are not sufficient to solve the opportunism problem. It has been suggested in a survey, but not yet formally studied, that in this case a "market-wide resale price maintenance, in the form of a price floor, together with a return option would obviously solve the commitment problem" (Rey and Tirole, 2007). We find that this combination does not generally achieve the proposed objective because it can leave retailers with a double marginalization incentive—i.e. induce retailers to set their prices above the monopoly level. Moreover, given that price floors and RPM have been illegal or seen with considerable suspicion by antitrust authorities, producers may need—and have probably found—alternative ways to control opportunism.

A main message of this paper is that, instead of using a market-wide price floor, in make-to-stock settings the producer can *always* eliminate producer opportunism by complementing bilateral buyback contracts with individual price ceilings—since this combination allows the producer to eliminate the retailers' quasi-rents.

In practice vertical price controls can be hard to monitor and enforce—either floors or ceilings. However we also find that private contracts with buybacks are on their own sufficient to restore monopoly power when either demand is sufficiently elastic (at the monopoly price) or when consumers can trade in secondary markets and the number of retailers is sufficiently high.[3] The latter challenges the notion of "competitive convergence" by suggesting that it is precisely in those situations where the retail sector is sufficiently competitive that the producer can capture the monopoly rent, even in the absence of vertical price controls—what can be called "monopoly convergence".

The intuition behind the paper's results is the following. Consider a market where an upstream monopolist, producing at a constant marginal cost c, offers individual contracts specifying a fee, a quantity and a buyback price r to each of n retailers—perceived as perfect substitutes by consumers and with no distribution costs. Each retailer can then accept or reject its contract and set its retail price. Let p^m, q^m and π^m denote respectively the monopoly price, quantity and revenue.

Suppose first that $r = 0$ and the producer offers each retailer the quantity q^m/n for a fee equal to π^m/n. If offers were final, i.e. if the producer could commit to those contracts, each retailer should accept its contract and set its retail price at the monopoly price level—the producer would then extract the full monopoly rent. However in that case the producer can benefit from secretly offering a slightly higher quantity to retailer i—which i can sell at a profit by setting its price just below p^m—at the expense of the sales and profits of the other retailers. Anticipating this scope for opportunistic behavior, if contracts are private the retailers should reject the initial contracts—and the producer would then fail to extract the monopoly rent.

Suppose now that the producer adds a buyback price $r = p^m$ to the initial contracts. In this case the producer and retailer i can no longer (jointly) benefit from overselling because it is now too costly to leave the remaining retailers with unsold stock. However, if retailer i holds q^m/n, and the remaining retailers are selling $(n-1)q^m/n$ at p^m, i becomes a monopolist on the residual demand curve with an effective marginal cost of $r = p^m$. This

[3] For example, if there is an efficient secondary market, when the monopoly percentage mark-up does not exceed the number of retailers—which means the monopoly margin should just be less than 200% with two retailers and less than 500% with five retailers, and margins of this magnitude are uncommon.

creates a double marginalization incentive since retailer i's optimal price will now exceed p^m—and the unsold portion of i's stock needs to be reimbursed by the producer. For i to set its retail price at p^m the buyback price needs to be below some level $\overline{r} < p^m$, which can open again the door to opportunism—since the producer may then want to sell an additional unit to a retailer j if $c + r < p^m$, i.e. its total marginal cost is less than what j can get by selling an additional unit.

The producer can control this problem in two ways. One, is to set $r = \overline{r}$ if that level is sufficiently high to remove the producer's incentive to oversell but still sufficiently low to avoid double marginalization. This is the case if the elasticity of demand is not too low or if the number of retailers is sufficiently large—as the elasticity of a retailer's residual demand tends to increase as the share of the monopoly output sold by the remaining retailers increases. A second alternative is to set $r = p^m$ and prevent the double marginalization directly with an individual price ceiling equal to p^m, eliminating in this way the retailers' quasi-rents.

This paper presents the first formal study of the role of buybacks in the context of producer opportunism. Our main contribution to that literature (discussed above) is to show that in make-to-stock settings buybacks can be an extremely powerful tool to eliminate producer opportunism, in particular when complemented with price ceilings. Our paper therefore also contributes to the literature on vertical restraints, and more specifically to the ongoing antitrust debate on the legal status of price floors and RPM.

There is in addition a large literature in economics and marketing on the use of buybacks by an upstream monopolist. That literature has two standard features: i) the producer commits to a set of public contracts and ii) buybacks can be useful in that case when there is demand uncertainty. Our paper differs from the previous literature on buybacks as it does not share either of these features. First, the problem of producer opportunism we study here is present precisely because the producer cannot commit to the contracts it offers to retailers. Second, buybacks play a central role in our model even if there is no demand uncertainty.

In that literature returns can transfer risk from a retailer to the producer (e.g. Kandel, 1996, Marvel and Peck, 1995). With a retail monopoly, a return policy and a linear wholesale price can also coordinate a supply chain with RPM (Pasternack, 1985) or improve profits over outright sales in the absence of price restraints (Marvel and Peck, 1995).

When retailing is perfectly competitive, buybacks can lead to optimal levels of inventory and price dispersion (Marvel and Wang, 2007). They may also be used as a substitute for a price floor and, by inhibiting the price cutting that would otherwise occur when demand is low, lead retailers to hold larger inventories (Deneckere, Marvel and Peck, 1996). This logic also extends to a retail oligopoly (Butz, 1997), and complementing two-part tariffs with buybacks can coordinate a supply chain under certain conditions—for example when there is substantial uncertainty over the level of demand (Narayanan et al., 2005) or if in addition there is uncertainty over consumers' preferences for differentiated retailers (Krishnan and Winter, 2007).

A general theme of the latter work is that with public contracting the producer commits to buy the unsold stock to create a de facto price floor, which corrects the retailers' incentives (horizontal pricing externality) and eventually encourages retailers to increase their stocks in equilibrium. In the present model with private contracts, the buyback price is instead used to correct the producer's incentives (to correct a contracting externality and substitute commitment) with the objective of reducing the equilibrium stocks levels.

There is also some work in the context of asymmetric information on demand. For example, returns may be used by the producer to signal to retailers private information on demand (Kandel, 1996), or they can be used to elicit private information on demand from retailers and provide them with incentives to acquire such information (Arya and Mittendorf, 2004 and Taylor and Xiao, 2009).

The rest of the paper is organized as follows. In section 2 we present the model and benchmarks. In section 3 we study the case of private contracting with buyback contracts alone and in section 4 we study their interaction with vertical price restraints. We conclude in section 5. All proofs can be found in the appendix.

2 Model

An upstream monopoly producer, u, can produce any quantity at a constant marginal cost $c > 0$. It sells to a set of undifferentiated retailers, $N = \{1, .., n\}$ with $n \geq 2$, who then sell in the downstream market at no additional cost. The set of all players is $M = N \cup \{u\}$.

The downstream market is characterized by demand $D(p)$, with $D'(.) < 0$ and elasticity $\varepsilon(p)$. Demand is well-behaved, in the sense that profits are strictly concave in the relevant ranges, and so the industry profit $\pi(p) = D(p)(p-c)$ is maximized with the monopoly price p^m satisfying the Lerner index, i.e. $p^m - c = p^m/\varepsilon(p^m)$, while selling $q^m = D(p^m)$.

A bilateral *buyback contract* k_i is a transfer t_i, a quantity x_i and a buyback price r_i paid by the producer to the retailer for each unit of unsold stock. Like in Hart and Tirole (1990), we do not need to impose particular restrictions on these contracts beyond the fact that each contract cannot condition on the contracts signed with the other retailers—in general k_i can be thought as the contract chosen by i from a general menu of contracts.[4]

Make-to-stock is efficient when shipping costs are high or consumers are sufficiently impatient relative to production and delivery time—e.g. most goods sold in supermarkets.[5] The following timing captures a *make-to-stock* interaction typical in retailing:

Stage 1. The producer offers a contract k_i to each retailer i.

Stage 2. If retailer i accepts contract k_i, it receives x_i, pays t_i and decides its price p_i.

Stage 3. Consumers observe prices and make purchases. The producer pays r_i to retailer i per unit of its unsold stock.

A pure strategy for the producer is a $n \times 3$ matrix K, where each row is a contract $k_i = (t_i, x_i, r_i)$, with $t_i \geq 0$, $x_i \geq 0$ and $r_i \geq 0$. T, X and R denote the respective columns of K. A pure strategy for retailer i is a set of acceptable contracts and a pricing rule for each contract matrix, i.e. $w_i(K) = (a_i, p_i)$ with $a_i \in \{0, 1\}$, where 0 denotes a rejection, 1 an acceptance, and $p_i \geq 0$ the retail price. W is the matrix with rows w_i and A and P are the respective columns of W.

Note that retailers are capacity constrained by their stocks when they choose prices. Therefore the quantity consumers purchase from retailer i, z_i, must be no more than the stock x_i and less or equal to the demand directed at retailer i, β_i^+. To specify β_i^+ we need

[4]The monopoly outcome can of course be achieved with contracts that condition directly on the total stock, with large penalties if the aggregate stock exceeds the monopoly quantity. Like previous authors, we view such contracts as hard to enforce and likely to violate competition laws.

[5]Make-to-order may be efficient if stocking costs are too high or consumers are patient enough. In that case vertical price controls play a key role in controlling opportunism (O'Brien and Shaffer, 1992).

a rationing rule. We consider a family of demand rationing rules, introduced by Davidson and Deneckere (1986), where the demand directed at retailer i is

$$\beta_i^+(X, W(K), \lambda) = \max\{0, \beta_i(X, W(K), \lambda)\}$$

with

$$\beta_i(X, W(K), \lambda) = \frac{x_i}{\sum_{j \in L_i} a_j x_j} \left(D(p_i) - \theta(W, \lambda) \sum_{j \in J_i} a_j x_j \right),$$

where L_i is the set of retailers with a price equal to p_i, J_i is the set of retailers that sell a positive amount by charging a price strictly below p_i, p_{J_i} is the highest price charged by a retailer in J_i, and

$$\theta(W, \lambda) = \lambda + (1 - \lambda) D(p_i)/D(p_{J_i}) \text{ with } \lambda \in [0, 1].$$

The extreme cases, $\lambda = 1$ and $\lambda = 0$, correspond respectively to the two most common modeling rules of efficient and random rationing.[6] The quantity purchased from retailer i is therefore

$$z_i(X, W(K), \lambda) = \min\left\{a_i x_i, \beta_i^+(X, W(K), \lambda)\right\}.$$

Suppose that the market demand results from the summation of individual heterogenous unit demands of a continuum of consumers. The parameter λ can then be interpreted as a measure of correlation between consumers' valuations and the time at which consumers learn about prices and make purchase decisions. *Random* or proportional rationing ($\lambda = 0$) captures a situation in which the order of purchases is random, and in this case a residual demand corresponds to a clockwise rotation of the original demand. *Efficient* or parallel rationing ($\lambda = 1$) captures a situation in which there is perfect correlation between consumers' valuations and the order in which they make purchase decisions, and in this case a residual demand corresponds to a parallel inward shift of the original demand. For $\lambda \in (0, 1)$ the high valuation consumers are more likely to purchase before low valuation consumer and there is both a shift and a rotation. We expect $\lambda > 0$ since consumers with

[6] Efficient rationing was first used by Levitan and Shubik (1972), and has since appeared, amongst others, in Kreps and Scheinkman (1983), Osborne and Pitchik (1986) and Deneckere and Kovenock (1992). Random rationing was used for example by Beckmann (1965), Allen and Hellwig (1986) and Davidson and Deneckere (1986). A similar specification can be found in Tasnadi (1999).

higher valuations have a higher incentive to learn about prices and purchase earlier than consumers with lower valuations.[7]

In addition λ can also capture the efficiency of a resale market where consumers can trade among themselves. In particular, if there is a perfectly efficient secondary market the equilibrium demand directed at a higher priced firm is captured by efficient rationing independently of the order of purchase decisions (Perry, 1984).

The producer and retailer i's profits are respectively $\pi_u(K, W(K), \lambda)$ and $\pi_i(K, W(K), \lambda)$. In the remainder of the paper we drop the notational dependence of π_u, π_i and z_i when this causes no ambiguity. The profits are then

$$\pi_u = \sum_{i \in N} a_i \left[t_i - c x_i - r_i (x_i - z_i) \right] \tag{1}$$

and

$$\pi_i = a_i \left[p_i z_i + r_i (x_i - z_i) - t_i \right].$$

Note that once a retailer accepts a contract, the buyback price r_i becomes retailer i's effective marginal cost, i.e. the opportunity cost of a unit of stock, since

$$\pi_i = (p_i - r_i) z_i + (r_i x_i - t_i)$$

and only the first term varies with p_i. As we will show later, for this reason a too high buyback price creates incentives for double marginalization.

S_i is the set of pure strategies of player i and, with $S = (S_i)_{i \in M}$, $G = (M, S, (\pi_i)_{i \in M})$ denotes the present game.

2.1 Solution concept and benchmarks

The outcome of the game depends crucially on whether retailers observe their rivals' contracts before deciding to accept or reject contracts and set prices. We say that *contracts are public* if K is made observed in stage 1 and that *contracts are private* if they remain unobservable throughout the game.

[7] Because a consumer with a higher valuation gains more when moving from a situation where no stock is available to a situation where some stock is still available, and it also gains more from a reduction in the price at which some stock remains available.

When contracts are public we can use the concept of subgame perfect equilibrium. It is well known that with non-linear contracts the producer can extract the full monopoly profit despite the externalities present here (see e.g. Segal, 1999). The producer chooses a set of contracts K that satisfies the retailers' participation and incentive constraints—since retailers' non-cooperative pricing decisions should form a Nash equilibrium in the capacity constrained pricing game. It is left without proof—but available from the author—that when contracts are observable the producer can extract the monopoly profit in a subgame perfect equilibrium with contracts that satisfy

$$\sum_{i \in N} x_i = q^m, t_i = x_i p^m \text{ and } r_i = 0.$$

So in the case of observable contracts the producer has no use for buybacks.

Characterizing the outcome of the private contracting game is more problematic. Such an incomplete information game naturally admits a multitude of perfect Bayesian equilibria because of the latitude given to players in revising their off-the-equilibrium path beliefs.[8] Several authors have studied this problem by requiring strategies to be renegotiation-proof—either directly or indirectly (e.g. Hart and Tirole , 1990, O'Brien and Shaffer, 1992, and McAfee and Schwartz, 1994). We adopt the concept of contract equilibrium from O'Brien and Shaffer (1992), first introduced by Cremer and Riordan (1987):

Definition 1. *A pure strategy contract equilibrium (with private contracts) is a matrix of contracts K^*, and Nash equilibrium responses induced by these contracts, W^*, such that for all $i \in N$, k_i^* induces retailer i to maximize the bilateral profits $\pi_u + \pi_i$ of the supplier and retailer i, taking (K_{-i}^*, W_{-i}^*) as given.*

A contract equilibrium requires contracts to be optimal for a pair formed by the producer and a retailer, holding the contracts of the other retailers and their responses fixed—because they cannot react to deviations they do not observe. A contract equilibrium is symmetric

[8] For example, the vertical integrated outcome can be implemented as a perfect Bayesian equilibrium if retailers conjecture that the equilibrium contracts are the ones from the game with public contracts and respond to any deviation with extreme pessimistic beliefs about the remaining contracts—and therefore reject any deviating contract. As previously argued in the literature, such conjectures seem implausible (see e.g. Hart and Tirole, 1990).

if there is an equilibrium with a contract $k = (t, x, r)$ that is offered to all retailers, who accept it and set the same retail price.

We now study contract equilibria in the absence of buybacks, i.e. when $r_i = 0$ for all $i \in N$. The results are similar to the finding of Hart and Tirole (1990), but here two retailers are already sufficient to drive industry profits to zero.

Proposition 1. *In the absence of buybacks, there exist contract equilibria (with private contracts). They involve mixed strategies and each player makes zero profit.*

The result follows from the next argument. In the absence of buybacks, for any set of proposed contracts the producer's payoff is

$$\sum_{i \in N} a_i \left[t_i - cx_i\right].$$

Like Hart and Tirole (1990) noted, from the producer's perspective each retailer then forms an independent market. So in any contract equilibrium the producer sells each retailer i a quantity x_i that retailer i would himself pick if it was one of n vertically integrated firms with cost c, and i sets p_i accordingly. For this reason, to a contract equilibrium of our game there is a Nash equilibrium of an associated game where n firms, each producing at cost c, choose their prices and quantities simultaneously. Gertner (1985) studied that game and found that in all equilibria competition eliminates the industry profits. So here too the producer and retailers make zero profits.

The equilibrium contracts are of the form $k_i = (cx_i, x_i, 0)$, but X is a random vector. In equilibrium retailer i chooses a price above c anticipating that with some probability it may not sell all its stock x_i but it has no incentive to change its price given its stock—and its expectation about rivals' stocks and prices, which is correct in equilibrium.

Opportunism has a severe effect on the producer's profits since in a contract equilibrium retailers do not respond to a change in their rivals' contracts, as is to be expected if retailers are unable to observe these contracts before choosing prices. Therefore the offered contracts do not create a capacity commitment that could be used to alleviate price competition—unlike in Hart and Tirole's (1990) model where retailers observe each other's quantities before choosing prices.

In some situations it is of course realistic to assume that capacity choices are observed before prices are chosen, like in Kreps and Scheinkmans' (1983) analysis of a situation where manufacturers make long-term capacity choices, such as the size of a plant—by their nature these investments can be either immediately observed or are likely to be learned by competitors over time.

However in retailing stocks are hard to observe, requires private warehouse information and—given the transient nature of stocks—historical data would not provide an exact estimate of current stocks levels. It therefore seems realistic to assume, as we do here, that each retailer cannot observe the stocks and buyback prices of all other retailers before choosing its price. While assuming that stocks are observable in a model of retailing can be justified technical tractability, in the present model this would make it complex and—we think—less realistic.[9]

3 Private contracting with buybacks

When the retailer complements the contracts with buybacks we find:

Proposition 2. *The producer can extract the monopoly profit in a contract equilibrium with private buyback contracts if the monopoly percentage markup is not too large, i.e.*

$$\frac{p^m - c}{c} \leq 1 + \lambda(n-1), \tag{2}$$

or equivalently the demand elasticity at the monopoly price is not too low, i.e.

$$\varepsilon(p^m) \geq 1 + \frac{1}{1 + \lambda(n-1)}.$$

The result follows essentially from two constraints. Consider a symmetric contract equilibrium where each retailer is offered a contract $k = (t^*, x^*, r)$. The first constraint deals with *opportunism*, i.e. the producer's temptation to sell a retailer i more than $x^* = q^m/n$ while expecting i to sell all its units by setting its price just below p^m. If the producer

[9]Such complexity is inherent to a model of capacity constrained price competition with heterogenous retailing costs (or here buyback prices), and which for that exact reason have been rarely used—for an exception with just two retailers and efficient rationing see Deneckere and Kovenock (1994).

sells an additional unit to i (which costs c to produce), retailer i will find it optimal to just undercut its rivals (so the total quantity remains unchanged and therefore the other retailers end up with an unsold unit in total, which costs r to compensate). To prevent such deviations the total cost of selling one additional unit to i, $c+r$, must then be higher than the marginal benefit i gets with that additional unit by setting its price arbitrarily close to p^m, i.e.

$$p^m \leq c + r.$$

A second one deals with *double-marginalization*. When the remaining retailers are selling $(n-1)q^m/n$ at a price p^m, retailer i is a monopolist on the residual demand curve with an effective marginal cost of r. If r is too close to p^m the retailer i finds it optimal to set its price above p^m and sell only a fraction of its stock. This incentive creates an upper bound on r which is

$$r \leq \overline{r}(n, \lambda) \equiv p^m(1 - \frac{1}{\varepsilon(p^m)(1 + \lambda(n-1))}).$$

These two constraints push r in opposite directions. By replacing $\overline{r}(n, \lambda)$ in the first constraint we obtain a single condition that determines the limit of buybacks in controlling opportunism in a symmetric contract equilibrium—which is simplified to (2) with the Lerner index.[10]

Because $\overline{r}(n, \lambda)$ increases with λ, condition (2) becomes less stringent as λ increases. The reason is that if some retailer i sets p_i above p^m its residual demand is a sample of the original demand, but this sample becomes more biased towards low valuation consumers as λ increases—as high valuation buyers are then more likely to purchase first at the lower price or to buy in a secondary market. Therefore the residual demand of a retailer with a higher price becomes more elastic as λ increases, which relaxes the constraint associated to double marginalization and allows r to be increased to correct the opportunism incentive.

In the limiting case of random rationing, where $\lambda = 0$, it requires that $p^m \leq 2c$, or equivalently $\varepsilon(p^m) \geq 2$. This seems to be the case of many branded consumer goods, such as breakfast cereals, beer and sodas (see e.g. Nevo, 2001, Pinkse and Slade, 2004, and Dhar et al., 2005). In the case of efficient rationing, $\lambda = 1$, the producer can extract the

[10] There is an additional constraint that is trivially satisfied: a retailer and the producer should not find it optimal to agree to sell less than q^m/n at a price above p^m.

monopoly rent with buyback contracts alone if the number of retailers is larger than the monopoly percentage markup, i.e.

$$\frac{p^m - c}{c} \leq n.$$

This is less than 200% with two retailers and less than 500% with five—in practice margins of this magnitude are uncommon.

This suggests that even with private contracts there are many situations where buyback contracts alone allow the producer to retain its monopoly power. For example, suppose that demand is linear and c is drawn from a uniform distribution between zero and the choke price, then the probability that (2) is satisfied is

$$\frac{2(1 + \lambda(n-1))}{3 + 2\lambda(n-1)},$$

which for $\lambda = 0$ is 66%—independently of n—and for $\lambda = 1$ is 80% with two retailers and becomes more than 90% with five.[11]

A similar logic also explains why (2) is relaxed as n increases. For $\lambda > 0$, when the remaining retailers are selling $(n-1)q^m/n$ at p^m, if i sets p_i above p^m its residual demand is biased towards low valuation buyers, and it is therefore more elastic than the original demand. Moreover that elasticity increases as the share of the monopoly output sold by the remaining retailers increases. So double marginalization is easier to control when n is large, meaning that the return price can then be increased to eliminate opportunism. We have what may be called "monopoly convergence":

Corollary 1. *For all $\lambda > 0$ and $c > 0$ there exists a finite $\underline{n}(c, \lambda)$ such that the producer extracts the monopoly profit with private buyback contracts in a contract equilibrium if $n \geq \underline{n}(c, \lambda)$. Moreover the critical $\underline{n}(c, \lambda)$ decreases with λ and c.*

This challenges the notion of "competitive convergence", i.e. that when the producer cannot commit to its contracts then the total industry profit becomes arbitrarily small when the number of retailers is large (e.g. Segal and Whinston, 2003). To the contrary, this result suggests that it is precisely in those situations that the producer should be able to obtain the monopoly rent with bilateral contracts alone.

[11] As with a linear demand the monopoly price is halfway between c and the choke price.

To summarize, the analysis of this section suggests that buyback contracts alone are more likely to be sufficient to control producer opportunism in markets with the following characteristics: market demand is relatively elastic, the marginal cost of production is not too low, consumers can trade in secondary markets and the number of retailers is high.

We show in the next section that when buyback contracts alone fail to solve the problem, we may have buybacks complemented with vertical price restraints, and in particular with individual price ceilings since that combination always eliminates the opportunism problem.

4 Buybacks and vertical price restraints

RPM is an agreement between the producer and the retailers that limits the prices the retailers can charge. With *strict RPM* the market price is fixed. Otherwise we can have a *price floor* (an agreement in which the retailer promises not to sell the product for less than a set minimum price), or a *price ceiling* (an agreement in which a retailer promises not to sell the product for more than a set maximum price). These agreements are also classified according to the range of applicability and may be *individual*, i.e. each agreement only limits the price charged by an individual retailer, or *market-wide*, i.e. applying simultaneously to all retailers.

On the issue of price ceilings there is considerable agreement that they should be legal because they help with double marginalization. For that reason price ceilings fall in the EU Commission block exemption for vertical agreements and are considered under a rule of reason in the United States since 1997.[12]

If we extend the producer's strategy space to allow for private contracts of the form $\widehat{k}_i = (t_i, x_i, r_i, \overline{p}_i)$, where $\overline{p}_i$ is a individual price ceiling, we find that buybacks can be a very powerful instrument in controlling opportunism:

Lemma 1. *Private buyback contracts with individual price ceilings are sufficient for the producer to extract the monopoly profit in a contract equilibrium.*

The reason is that the producer can raise the buyback price up to $r = p^m$ while con-

[12] See "Restrictions that remove the benefit of the block exemption", 4 (a) on EU Commission's regulation No 330/2010 and "State Oil Co. v. Kahn", 522 U.S. 3, 15 (1997).

trolling directly the double marginalization problem with a price ceiling. This eliminates the retailers' quasi-rents and the temptation to oversell.

We now turn our attention to price floors and strict RPM. Both have been seen unfavorably under competition law in most developed countries. The EU Commission has generally seen them as contrary to Article 81(1) and certain prohibitions exist for example in Australia, Canada, France, and the UK. Both were also per se illegal in the United States until 2007, when the U.S. Supreme Court's decision in the Leegin case made RPM come under a rule of reason.

We start with the case where the producer can commit ex-ante to a public market-wide price floor—since individual price floors have no effect. The producer's strategy space is then a matrix K of private contracts and a public and enforced price floor $\underline{p}$ applying to all retailers.

As Rey and Tirole (2007) argued, a industry-wide price floor alone cannot solve the commitment problem.[13] They suggested that complementing the price floor with buybacks would always solve the problem. With similar assumptions on demand, we find that this combination is not always sufficient because of the potential for double marginalization.

Lemma 2. *Private contracts with buybacks together with a public market-wide price floor are not always sufficient for the producer to extract the monopoly profit in a contract equilibrium.*

In some situations complementing buyback contracts with a market-wide price floor does solve the opportunism problem when buyback contracts alone would not. This may seem to confirm the idea that price floors will be used to control the opportunism problem. However, in the context of the present model, this does not seem to be the right conclusion. An industry-wide price floor would need to be public and apply to all retailers and such agreements are more complex to enforce than individual price ceilings (e.g. Alexander and Reiffen, 2005).

[13] As they explain, "suppose that $c = 0$, and that when both sellers charge the same price ... sellers sell an amount proportional to what they bring to the market. Let the upstream firm supply $q^m/2$ to each downstream firm and impose price floor p^m. Then the upstream firm can supply some more units at a low incremental price to one of the sellers, thus expropriating the other seller."

Strict RPM includes a price floor and a price ceiling, so strict RPM achieves at least the same as a price ceilings alone. The next proposition summarizes the last findings:

Proposition 3. *Private buyback contracts with individual price-ceilings, and by extension with strict RPM, are sufficient for the producer to extract the monopoly rent in a contract equilibrium, while private buyback contracts together with a public market-wide price floor are not always sufficient.*

To conclude this section we briefly consider what might happen in the absence of vertical price restraints when condition the condition of Proposition 2 is not satisfied. We may have thought, because producer opportunism cannot be completely eliminated, that the equilibrium price would then be below the monopoly level. The next result suggests that this may not be the case since the producer may use the buybacks to protect its profit.[14]

Proposition 4. *If the market demand is log-concave but the monopoly outcome cannot be sustained in a contract equilibrium, then the market price in any symmetric pure strategy contract equilibria exceeds the monopoly level.*

The reason is that when demand is log-concave the elasticity of the retailers' residual demand is high when the market price is also high, and vice versa. So the incentive for double marginalization is low when the market price is high, and vice versa. So, if the market equilibrium price is high, the producer can offer a high buyback price to control opportunism without inducing double marginalization, thereby sustaining that high price as an equilibrium. This may not work for prices below the monopoly level since in those cases the incentive to price above the equilibrium level can be too high—and hence such a price will not be sustained in equilibrium.

5 Conclusion

Producer opportunism may have important effects in vertical contracting. While there is both experimental and anecdotal evidence of the problem, we are not aware of direct

[14] Log-concavity of demand, i.e. $-p/\varepsilon(p)$ decreasing, is a standard assumption ensuring the monopoly problem can be solved with first order conditions—it is for example verified when demand is concave.

empirical tests.[15] We hope that the present work contributes to determine the set of conditions where we may expect to find producer opportunism and to explain why it may be less prevalent than the previous theory would suggest—beyond a generic folk theorem "anything can go" argument.

A key message of this paper is that buyback contracts should be particularly effective to solve the opportunism problem when complemented with individual price-ceilings, since this combination can always eliminate the problem—this result applies also in situations where retailers are differentiated.

In this paper we modelled the producer's lack of contractual commitment by assuming that contracts remained private throughout the game. The main results are however robust to alternative ways of capturing the lack of commitment—for example, in a model with initial public contracting but where it is known that, once retailers have accepted or rejected the offered contracts, the producer may have a last chance to secretly alter the agreed contract with some random retailer.

We hope the paper will contribute to the antitrust debate on price floors and RPM. There are three main arguments that make antitrust authorities wary of price floors (and by extension RPM): the opportunism problem with an upstream monopoly, and collusion and softening competition with oligopolies.[16] The joint message of this paper and O'Brien and Shaffers' (1992) work is that individual price ceilings and buybacks, both of which are typically legal, are sufficient to eliminate the opportunism problem in many situations—either with make-to-stock or make-to-order. This suggests that alternative explanations for the use price floors may be more relevant—such as reducing free-riding in services among retailers.

From a managerial perspective buybacks can offer an interesting alternative to other solutions that have been proposed in the literature. For example, it has been shown that the producer can achieve vertical control by integrating downstream (e.g. Hart and Tirole, 1990, McAfee and Schwartz, 1994, and Gans 2007). Buyback contracts offer an alternative

[15] See for example Martin et al. (2001) and "The supply of groceries in the UK market investigation" by UK's Competition Commission (2008).

[16] See e.g. "Hardcore restrictions under the Block Exemption Regulation on vertical agreements: an economic view" by the Commission's advisory group EAGCP (2009).

to avoid costs associated with integration or potential retail disruptions, and also in those cases where integration seems unpractical—for example, vertical integration does not seem a realistic solution in the case of supermarkets.

Another proposed solution are (term-by-term) most-favoured-nation clauses, which presupposes that retailers can observe the contracts of each other before deciding on their final contract (McAfee and Schwartz, 1994, De Graba, 1996 and Marx and Shaffer, 2004). This solution may be hard to implement given that often private contracting can be the initial source of the problem. On the other hand, the solutions proposed in this paper require only bilateral contracts, i.e. they do not depend on the agreements reached with the remaining retailers.

A tight capacity constraint, and more generally producing under decreasing returns to scale, can also help to control opportunism (Segal and Whinston, 2003). This effect can be reenforced with buyback contracts since in that case vertical control is even easier to sustain.

There are however circumstances that can limit the use of buybacks. As mentioned in the introduction, buybacks can allow for risk-sharing between the producer and the retailers. We found that to overcome opportunism the producer may need to offer buybacks within particular bounds. Such bounds may create active constraints that can lead to inefficient risk sharing.

Return systems can also be costly to administer and retailer moral hazard can be an issue.[17] A buyback policy can also raise additional and complex issues when the good sold by the upstream firm is an intermediate good used in production by the downstream firms, as they may distort the incentives of downstream firms to improve their production efficiency.

[17] As mentioned in Deneckere et al. (1997), an illustration of both aspects is provided by books and magazines, where the shipping costs are so high that often retailers only return the covers to guarantee their buyback reimbursement.

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Appendix

Proof of Proposition 1. In step we 1 show that when $R = 0$ there is no contract equilibrium in pure strategies. In step 2 we extend the game and the concept of contract equilibrium to mixed strategies. In step 3 we show that any contract equilibrium in mixed strategies must have a corresponding Nash equilibrium of an auxiliary game—which was studied by Gertner (1985). In step 4 we derive the implications to the players' strategies and profits.

Step 1. In a pure strategy contract equilibrium retailers make zero profits (since the producer can otherwise increase the fixed fee) and $z_i^* = x_i^*$ for all i (otherwise the producer could deviate to a lower x_i and save on the production cost). When $R = 0$ the producer's net benefit of contracting with any retailer i, $(p_i^* - c)x_i^*$, must be non-negative and the same for all $i \in N$ (suppose not, that $(p_i^* - c)x_i^* > (p_j^* - c)x_j^*$ for some i and j, then there exists $\varepsilon > 0$ such that the producer benefits from offering j a deviating contract $k_j' = ((p_i^* - 2\varepsilon)x_i^*, x_i^*, 0)$, which retailer j would accept as it can always undercut retailer i by ε and make a net profit εx_i^* instead of zero). Moreover $(p_i^* - c)x_i^* > 0$ for at least one i (since in an equilibrium one retailer i must sell $z_i^* > 0$ and therefore is a monopolist on its residual demand curve, and therefore the bilateral benefit can be increased by raising the price and decreasing x_i^*). It follows, since the net benefit of contracting with each retailer must be the same, that both $(p_j^* - c)$ and x_j^* must be strictly positive for all $j \in N$. But if $(p_i - c) > 0$ for all i then there exists $\varepsilon > 0$ such that the producer benefits from offering some retailer j, which in equilibrium charges the lowest price, a deviating contract $k_j' = ((p_j^* - 2\varepsilon)D(p_j^*), D(p_j^*), 0)$ with $(p_j^* - 2\varepsilon) > c$, which retailer j would accept as it can always undercut p_j^* by ε and make a net profit $\varepsilon D(p_j^*)$ instead of zero. But then $z_i^* \neq x_i^*$ for all $i \neq j$, which is a contradiction. This implies that there is no equilibrium in pure strategies.

Step 2. We therefore introduce the mixed strategy extension of G. Let $\Delta(S_i)$ be the set of probability measures over the subsets of S_i and $\sigma_i \in \Delta(S_i)$ denote a mixed strategy of player i. Extend the profits to this space by defining $\sigma = (\sigma_i)_{i \in M}$ and having $\pi_i(\sigma) = \int_S \pi_i(x)d\sigma$, and we obtain the mixed extension $\overline{G} = (M, \Delta(S_i)_{i \in M}, (\pi_i)_{i \in M})$. A mixed strategy contract equilibrium (with unobservable contracts) is a probability distribution over all possible contracts and Nash equilibrium responses induced by that distribution such that, for all $i \in N$, each contract realization k_i induces retailer i to maximize $\pi_u + \pi_i$ while taking the remainder of σ as given.

Step 3. From (1), when $R = 0$ for any realization K of σ_u the producer profit is

$$\pi_u(K, W) = \sum_{i \in N} a_i \left[t_i - cx_i\right],$$

and therefore the producer's benefit of contracting with each retailer is independent of the contracts it offers to the other retailers. Since the acceptance and pricing decisions of each retailer are unaffected by unobserved changes in the contracts offered to the other retailers, the stock offered to any retailer i should maximize the expected profit of that retailer i—conditional on that contract—as if i could himself produce at a constant marginal cost c and then choose its price. Therefore the distribution of X and P in any contract equilibrium of $\overline{G}$ should be similar to the distribution of the stocks and prices chosen by the retailers in a Nash equilibrium of a game $\overline{H}$ where retailers choose both quantities and prices simultaneously while producing at a marginal cost c, and for any realization X the fee t_i equals cx_i plus i's expected profit in $\overline{H}$ conditional on choosing x_i.

Step 4. Gertner (1985) showed that mixed strategy Nash equilibria of $\overline{H}$ exist and in all equilibria retailers make zero profits. It follows that in $\overline{G}$ the producer's payoff is also zero. Moreover for any σ_u^* the set of contracts K are such that $k_i = (cx_i, x_i, 0)$ but X is random, and retailers accept the realized contracts and each chooses a price $p_i(x_i)$ as if they had chosen x_i themselves in the game $\overline{H}$. Existence can be shown by construction using the equilibria identified by Gertner (1985).

Proof of Proposition 2. The proof proceeds in 3 steps. Step 1 ensures that contracts do not lead to double-marginalization, i.e. they induce each retailer i to set $p_i = p^m$ while taking the remaining contracts as given. Step 2 ensures that the producer does not have an incentive to behave opportunistically, i.e. it is not profitable to replace a contract k_i^* with a contract in which $x_i > x^*$. Step 3 ensures that there is no profitable deviating contract with $x_i < x^*$.

Step 1. If the monopoly outcome is to be sustained in equilibrium we must have that a set of contracts with

$$k_i^* = (t_i^*, x_i^*, r_i^*) = (\alpha_i^* p^m D(p^m), \alpha_i^* D(p^m), r_i^*)$$

is proposed by the producer, accepted by the retailers and induces the retailers to set the monopoly price—where $\alpha_i^* \geq 0$ represents the share of the monopoly quantity sold to retailer i and $\sum_n \alpha_i^* = 1$. In that case pricing below p^m is dominated for all retailers. Once retailer i accepts its contract it can either get $p^m \alpha_i^* D(p^m)$ with $p_i = p^m$ or set $p_i > p^m$ and get the profit made on its residual demand curve when its effective marginal cost of selling a unit is r_i^*, i.e.

$$(p_i - r_i^*) z_i(X, W, \lambda) + r_i^* \alpha_i^* D(p^m) \Leftrightarrow$$

$$(p_i - r_i^*) \max\left\{0, (D(p_i) - (1 - \alpha_i^*)(\lambda D(p^m) + (1 - \lambda) D(p_i)))\right\} + r_i^* \alpha_i^* D(p^m) \qquad (3)$$

When demand is well behaved, to insure that the retailer's optimal price does not exceed p^m it is sufficient that

$$\left.\frac{\partial(3)}{\partial p_i}\right|_{p_i = p^m} \leq 0 \Leftrightarrow \alpha_i^* \left[D(p^m) + (p^m - r_i^*) D'(p^m)\right] + \lambda(1 - \alpha_i^*) \left[(p^m - r_i^*) D'(p^m)\right] \leq 0 \quad (4)$$

The second left-hand term of (4) is strictly negative—except for $\lambda = 0$ where it is zero. For the first left-hand term, notice that

$$D(p^m) + (p^m - r_i^*) D'(p^m)$$

corresponds to the first-order condition of the vertical monopoly evaluated at $p_i = p^m$ when the cost of production is r instead of c. So this term is larger, equal or smaller than zero if r_i is respectively larger, equal or smaller than c. So, for all $\lambda \in [0, 1]$, (4) is satisfied if $r_i^* \leq c$, while (4) increases with α_i^* for $c < r_i^* \leq p^m$—obviously r_i^* should not exceed p^m. Since these constraints must be satisfied for all i, this set of constraints is then more easily satisfied if each retailer receives in equilibrium an equal share of the surplus, i.e $\alpha_i^* = 1/n$ for all $i \in N$. So the contracts do not induce retailers to set prices above p^m, i.e. there is no double-marginalization, if

$$r_i^* \leq p^m \left(1 - \frac{1}{\epsilon(p^m)(1 + \lambda(n-1))}\right) = \overline{r}(n, \lambda) \text{ and } \alpha_i^* = \frac{1}{n} \text{ for all } i \in N.$$

Step 2. We now check that the producer has no incentives to deviate to an alternative contract k_i' such that $x_i^{'} > x_i^*$ with some retailer i. Given that deviation, if retailer i prices above p^m it still does not sell more than x_i^*, so that deviation is unprofitable (otherwise the producer could deviate to x_i^* and save on the production cost). It may however price at p^m to sell

$$\frac{x_i'}{D(p^m) + (x_i' - x^*)} D(p^m),$$

which is less than x_i', or reduce its price to $p_i' < p^m$ and sell $\min\left\{x_i', D(p^{'})\right\}$. But for any $x_i^{'} > x_i^*$ undercutting the other retailers dominates pricing at p^m, and so $p_i < p^m$ if $x_i' > x_i^*$. Note that if a deviation with $p_i' < p^m$ and $x_i' > x_i^*$ takes place then the remaining retailers would not sell all their stock and therefore make a loss, i.e. they will be victims of producer opportunism. For such deviations to be unprofitable it must be the case that the most the producer can get from selling any additional unit to retailer i is less than the (average) value of buybacks that need to be paid to the remaining retailers, i.e.

$$p^m - c \leq \sum_{j \in N \setminus i} \frac{r_j \alpha_j^*}{1 - \alpha_i^*}. \tag{5}$$

Replacing each r_j in the expression above with the bound $\overline{r}(n, \lambda)$ and setting $\alpha_j^* = 1/n$, we get that all constraints associated with both double marginalization and opportunism can be simultaneously satisfied if for all $i \in N$

$$\alpha_i^* = \frac{1}{n} \text{ and } p^m - c \leq \overline{r}(n, \lambda) \Leftrightarrow \epsilon(p^m) \geq 1 + \frac{1}{1 + \lambda(n-1)}.$$

Using the Lerner index we find that this expression is also equivalent to (2).

Step 3. To complete the proof we should also consider deviations to some quantity $x_i < x^*$ and a price $p_i' > p^m$ (selling less at a lower price is then not optimal). Since profits are concave in p, when $\alpha_i^* = 1/n$ for all $i \in N$ such deviation is unprofitable if

$$\frac{\partial}{\partial p_i} \left[(D(p_i) - \frac{n-1}{n} D(p^m)(\lambda + (1-\lambda)\frac{D(p_i)}{D(p^m)}))(p-c) \right] \Bigg|_{p_i = p^m} \leq 0.$$

or equivalently

$$[D(p^m) + (p^m - c)D'(p^m)] + (p^m - c)(\lambda(n-1))D'(p^m) \leq 0.$$

Note that the first left-hand element is zero (from the first order conditions of monopoly), and the latter is negative since $D'(p^m) < 0$. So this condition is trivially satisfied for all $\lambda \in [0, 1]$.

Proof of Corollary 1. Follows directly from (2) that for all $\lambda \in (0,1]$ the producer can always extract the monopoly rent with buyback contracts alone if either $p^m \leq 2c$ or otherwise when $p^m > 2c$ if

$$n \geq 1 + \frac{p^m - 2c}{c\lambda}.$$

So for all $\lambda > 0$ and $c > 0$ there exists a finite $\underline{n}(c,\lambda) \equiv 1 + \max\left\{0, \frac{p^m - 2c}{c\lambda}\right\}$ such that for all $n \geq \underline{n}(c,\lambda)$ the producer extracts the monopoly profit in a contract equilibrium of G. Moreover $\underline{n}(c,\lambda)$ is decreasing in λ and c.

Proof of Lemma 1. A symmetric strategy profile with $\widehat{k}_i = (p^m \frac{D(p^m)}{n}, \frac{D(p^m)}{n}, p^m, p^m)$ and $w_i = (1, p^m)$ forms a contract equilibrium of $\widehat{G}$ because, taking the other contracts and prices as given, the bilateral benefit $\pi_u + \pi_i$ is maximized by selling q^m/n at p^m. There is no other set of contracts that improves upon it, since the producer already obtains the monopoly profit.

Proof of Lemma 2. If the monopoly outcome is to be sustained in equilibrium we must have that an industry-wide price floor p^m and a set of contracts with

$$k_i^* = (t_i^*, x_i^*, r_i^*) = (\alpha_i^* p^m D(p^m), \alpha_i^* D(p^m), r_i^*)$$

is proposed by the producer, accepted by the retailers and induces them to set the monopoly price—where $\alpha_i^* \geq 0$ represents the share of the monopoly quantity sold by retailer i and $\sum_N \alpha_i^* = 1$. It must then be the case that the producer has no incentive to offer a contract k_i' where retailer i is given $x_i^{'} > x_i^*$. If there is an industry-wide price floor at p^m retailer i cannot undercut its rivals, but it can set $p_i = p^m$ and sell

$$\frac{x_i'}{D(p^m) + (x_i' - x^*)} D(p^m),$$

which is less than x_i'. To avoid this deviation it must be the case that the net benefit made with i after paying the buybacks is less than the benefit made with the equilibrium contract, i.e.

$$p^m \frac{x_i' D(p^m)}{(1-\alpha_i^*) D(p^m) + x_i'} - \sum_{j \in N \setminus i} r_j^* \left(\alpha_j^* - \frac{\alpha_j^* D(p^m)}{(1-\alpha_i^*) D(p^m) + x_i'} \right) D(p^m) - c x_i' \leq (p^m - c) \alpha_i^* D(p^m). \tag{6}$$

In addition, the equilibrium contracts should not induce double marginalization which, like in Step 1 of Proposition 2, implies that for all $i \in N$

$$\alpha_i^* \left[D(p^m) + (p^m - r_i^*)D'(p^m)\right] + \lambda(1 - \alpha_i^*) \left[(p^m - r_i^*)D'(p^m)\right] \leq 0$$

or equivalently

$$r_i^* \leq p^m(1 - \frac{\alpha_i^*}{\epsilon(p^m)(\alpha_i^* + \lambda(1 - \alpha_i^*))}),$$

which is strictly less than p^m for all $\alpha_i^* > 0$. There must also exist at least one $i \in N$ such that there is some $j \neq i$ with $\alpha_j^* > 0$. For any such i note that the left-hand side of (6) is differentiable, equal to the right-hand side for $x_i' = \alpha_i^* D(p^m)$, and if we take the derivative of the left-hand side evaluated at that point is strictly positive for c sufficiently close to zero. This implies that for c sufficiently close to zero there exists no vector $\alpha = (\alpha_1, .., \alpha_n)$ with $\alpha_i \geq 0$ and $\sum_N \alpha_i^* = 1$ that satisfies both constraints for all $i \in N$. This means that for c sufficiently close to zero there always exists a profitable deviation, and hence in those cases there cannot be a contract equilibrium where the producer extracts the monopoly profit.

Proof of Proposition 4. Let $P(n, \lambda)$ be the set of prices that can be sustained in a symmetric contract equilibrium in pure strategies of G with n retailers, so that if $p^* \in P(n, \lambda)$ the producer offers each retailer the contract $k^* = (p^* D(p^*)/n, D(p^*)/n, r^*)$, which is accepted and each retailer sets $p_i = p^*$. The proof proceeds in 4 steps. Step 1 is ensuring that these contract induces each retailer i to set $p_i = p^*$ when it takes the remainder of S^* as given. The second step is to ensure that retailer i does not find it profitable to make an offer to the producer to replace its contract k^* with a contract in which $x_i > x^*$. The third step is ensuring that the same holds for a contract with $x_i < x^*$. Step 4 brings the constraints found in steps 1 to 3 together to characterize the set $P(n, \lambda)$.

Step 1. When the remaining retailers are selling an aggregate quantity of $\frac{n-1}{n} D(p^*)$ at a price of p^*, retailer i does not want to set $p_i < p^*$ since it can sell all its stock $\frac{1}{n} D(p^*)$ for p^* and make a higher profit—provided of course that $r^* \leq p^*$. On the other hand if $p_i > p^*$ it will sell less than x^* but it gets r^* on those units it does not sell and therefore its opportunity cost of selling each unit is r^*. With profits concave in p_i, to avoid double marginalization we must have

$$\left.\frac{\partial(p_i - r^*)\left(D(p_i) - (\frac{n-1}{n})(\lambda D(p^*) + (1-\lambda)D(p_i))\right) + r^*\frac{D(p^*)}{n}}{\partial p_i}\right|_{p_i=p^*} \leq 0$$

or equivalently

$$\frac{1}{n}\left[D(p^*) + (p^* - r^*)D'(p^*)\right] + \lambda(\frac{n-1}{n})\left[(p^* - r^*)D'(p^*)\right] \leq 0,$$

which implies that

$$r^* \leq p^*(1 - \frac{1}{\epsilon(p^*)(1+\lambda(n-1))}) \equiv r(p^*, n, \lambda).$$

Step 2. Consider now an alternative contract k_i' where retailer i is given $x_i^{'} > x_i^*$. Such deviation induces i to set $p_i \leq p^*$ as otherwise i does not sell more than x_i^*. Retailer i may then price at p^* to sell

$$\frac{x_i'}{D(p^*) + (x_i' - x^*)}D(p^*),$$

which is less than x_i', or reduce its price to some p_i' just below p^* and sell $\min\{x_i', D(p_i')\}$, and therefore undercutting p^* dominates pricing at p^*. So deviations to $x_i' \in (x_i^*, D(p^*)]$ are not optimal since if retailer i is offered a stock $x_i' \in (x_i^*, D(p^*)]$ he will sell all its stock by undercutting p^* and the net benefit the producer can obtain from this deviation instead of offering k_i^* is

$$(p_i' - c)x_i' - r^*(x_i' - x^*) - (p_i^* - c)x_i^*,$$

which if positive implies that

$$(p_i' - c - r^*)x_i' > (p_i^* - c - r^*)x_i^*$$

and therefore can be improved by selling i a stock $D(p_i') > D(p^*)$, which exceeds the proposed x_i' since $p_i' < p^*$. So we consider deviations to $x_i' > D(p^*)$, a situation in which the remaining retailers sell nothing and therefore the total paid in buybacks is

$$r^*\frac{n-1}{n}D(p^*).$$

To avoid such deviations it must be that

$$\max_{p_i \in [c, p^*)}\left[(p_i' - c)D(p_i') - r^*\frac{n-1}{n}D(p^*)\right] < (p^* - c)\frac{D(p^*)}{n},$$

which is satisfied if and only if

$$\frac{D(p^*)}{n}(p^* - c + r^*(n-1)) \geq \begin{cases} \pi(p^*) \text{ if } p^* \leq p^m \\ \pi(p^m) \text{ if } p^* > p^m \end{cases} \tag{7}$$

Step 3. Finally we look at deviations to some quantity $x_i < x^*$ with a price $p_i > p^*$ (selling less at a lower price is obviously not optimal). Since profits are concave in p, for any such deviation to be unprofitable we must have

$$\frac{\partial}{\partial p_i}\left[(D(p_i) - \frac{n-1}{n}D(p^*)(\lambda + (1-\lambda)\frac{D(p_i)}{D(p^*)}))(p-c)\right]\Bigg|_{p_i=p^*} \leq 0.$$

or equivalently

$$\frac{D(p^*)}{n} + (p^* - c)(\frac{1+\lambda(n-1)}{n})D'(p^*) \leq 0 \Leftrightarrow \frac{p^*}{\epsilon(p^*)} \leq (1+\lambda(n-1))(p^* - c) \tag{8}$$

Step 4. Replacing $r(p^*, n, \lambda)$ in (7) and rearranging the elements, we have that $p^* \in P(n, \lambda)$ if and only if (8) and

$$\frac{p^*}{\epsilon(p^*)} \leq \begin{cases} c(1+\lambda(n-1)) \text{ if } p^* \leq p^m \\ c(1+\lambda(n-1))(1 - \frac{n}{n-1}\frac{\pi(p^m)-\pi(p^*)}{cD(p^*)}) \text{ if } p^* > p^m \end{cases} \tag{9}$$

are simultaneously satisfied. D is log-concave if $p/\epsilon(p)$ is decreasing in p. It follows from (8) and (9) that for any $p < p^m$ we have $p \notin P(n, \lambda)$ if $p^m \notin P(n, \lambda)$, since the right-hand side of the inequalities are weakly incresing in p^* and the left-hand side decreasing, and so both inequalities become harder to satisfy as p^* decreases. For $p > p^m$ the left-hand side is again decreasing in p^*, the right hand side of (8) is increasing and the right-hand side of (9) is also increasing for prices sufficiently close to p^m (to see the latter take the derivative of the right-hand side of (9) with respect to p^*, evaluate it at $p^* = p^m$ and use the Lerner index to find that it is strictly positive). So for prices slightly above p^m both inequalities are relaxed as the price increases. It that when D is log-concave the set $P(n, \lambda)$ can be non-empty and not include p^m, but then $p^m < p^*$ for any $p^* \in P(n, \lambda)$.