Size-based input price discrimination under endogenous inside options

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DISCUSSION PAPER

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Abstract

Individual retailers may choose to invest in a substitute to a dominant supplier's products (inside option) as a way of improving its position towards the supplier. Given that a large retailer has stronger investment incentives than a smaller rival, the large retailer may obtain a selective rebate (size-based price discrimination). Yet, we often observe that suppliers do not price discriminate between retailers that differ in size. Why is this so? We argue that the explanation may be related to the competitive pressure among the retailers. The more fiercely the retailers compete, the more each retailer cares about its relative input prices. Other things equal, this implies that the retailers will invest more in the substitute the greater the competitive pressure. We show that if the competitive pressure is sufficiently strong, the supplier can profitably incentivize the retailer to reduce its investments in substitutes by committing to charge a uniform input price. Furthermore, we show that under uniform input pricing, the large retailer may induce smaller rivals to exit the market by strategically under-investing in inside options.

Keywords: Input price discrimination, size asymmetries, retail competition, inside options, entry, exit.

JEL classifications: D21, L11, L13.

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1 Introduction

Size-based input price discrimination in favor of large retailers is an age-old issue. Walmart's success, for instance, has partly been explained by size advantages in input prices (see e.g. Basker, 2007; Ellickson, 2016; Dukes, Gal-Or and Srinivasan, 2006); a ten percent increase in volume reduces Walmart's marginal upstream costs by two percent (Basker, 2007). Likewise, Amazon exploits its power as a large retailer to obtain low input prices in the book publishing market (Gilbert, 2015). In the US multi-channel TV market, the per customer input prices for a large firm like Comcast could be 25 percent lower than those faced by smaller firms (Crawford and Yurukoglu, 2012; Doudchenko and Yurukoglu, 2016). The UK competition authorities found a significant negative relationship between size in grocery retailing and unit input prices (Competition Commission, 2008). In 2019, the Norwegian Competition Authority (2019) made a comprehensive study of input prices in the grocery market; from some dominant suppliers, the largest retail chain obtains a selective rebate of more than 15 percent compared to the smaller rivals.[1] These examples indicate that input price discrimination takes place in a large array of industries. The aim of this paper is to shed some new light on why suppliers price discriminate, and to analyze whether it is actually in their interest to do so.

Suppliers cannot price discriminate unless they have some market power, but it is far from obvious why a supplier with market power should want to let input prices depend on the size of the respective buyer (hereafter labeled retailer). In the public debate, the typical story used to explain size-based input price discrimination is that it is more costly for the supplier to lose a contract with a large retailer than with a small retailer.[2] This strengthens the bargaining position of large retailers. The problem with this story, is that it neglects the fact that it is also more costly for a large than for a small retailer to lose the contract with the supplier. This strengthens the bargaining position of the supplier towards large

[1]The Norwegian Competition Authority (2019) confirms that the revealed price discrimination favored the largest chain on the margin, and the competition authority has started an investigation towards the largest chain and two dominant suppliers. Analogously, the investigation of the UK grocery market by the Competition Commission (2008, Appendix 5.3) found that "an increase in the volumes purchased by a retailer or wholesaler is associated with a reduction in both the unit and net price paid."

[2]This claim was given support by Galbraith's concept of countervailing buyer power (Galbraith, 1952). However, Galbraith offers no formal model, and Stigler (1954) was criticizing Galbraith for formulating a dogma rather than a theory. See also von Ungern-Sternberg (1996).

retailers. Katz (1987) shows that these effects exactly offset each other whenever size is the only difference between the retailers; there will be no price discrimination.[3]

Having established this, Katz (1987) then assumes that large retailers have better access to an alternative source of supply than do small retailers; if this is the case, price discrimination might evolve in favor of large retailers.[4] Put differently, size-based input price discrimination arises if there are transactional economies of scale, such that a large retailer's threat to leave (completely or partly) is stronger than that of smaller retailers. To prove this formally, Katz (1987) considers a game where the supplier at stage one sets input prices. At stage two, each retailer either accepts the input price he is offered or invests in an alternative source of supply. This constitutes an outside option since the retailers have not made any investments at the time when input prices are determined. The greater the retailer's output, the better it will be able to cover the investment costs. To prevent the retailers from making such investments, the supplier charges lower input prices from large than from small retailers. If the retailers compete in the output market, the large retailers will gain a competitive advantage due to their lower input prices.

In this setting, the supplier will lose profit if it does not price discriminate. To see why, assume that the supplier is obliged by law to charge a common uniform price from all retailers. The fact that the supplier then cannot provide selective rebates to large retailers does not remove the large retailers' threats of investing in the outside option. On the contrary, the threats become stronger; the supplier cannot favor large retailers with lower input prices than those offered to their competitors. To keep all retailers aboard, the supplier must therefore reduce all input prices – even those paid by the largest buyers. This in turn translates into lower consumer prices, but the supplier is clearly harmed.

Katz (1987) obviously captures important aspects of the relationship between retailers and suppliers. However, there is reason to question the robustness of the prediction that a supplier necessarily prefers to price discriminate. As an example, we observe that digital

[3]Katz (1987) assumes that the supplier can make take-it-or-leave-it offers. Inderst and Montez (2019) and Foros, Kind and Shaffer (2018) verify that the result holds also if input prices are determined through bargaining processes between the supplier and each retailer.

[4]Large retailers may also achieve a rebate compared to smaller ones if the supplier faces increasing marginal costs in the relevant area (Chipty and Snyder, 1999 and subsequent papers). More precisely, in the set-up of Chipty and Snyder (1999), the larger retailer realizes a size advantage given that the gross surplus function created by the transaction between the supplier and the retailer is concave.

platforms like Apple and Google commit to a non-discriminatory 30/70 split of revenues with content providers.[5] Moreover, in both digital and more traditional markets, most-favored customer clauses are regularly used between suppliers and retailers. This has the effect of ensuring that small and large buyers pay identical input prices. Could commitment to uniform pricing be an optimal strategy for a supplier if transactional economies of scale would otherwise generate price discrimination?

The answer is yes. To show this, we set up a truly simple model where a retailer prior to the determination of the dominant supplier's input prices, may choose to invest in an alternative source of supply, which for concreteness we may call a private label. The more the retailer invests, the lower the marginal cost of producing the private label. In the words of O'Brien (2014), the retailer has an inside option (as opposed to an outside option as in Katz) which it may use to press down the input price charged by the supplier. Now, suppose that there are several retailers and that the consumers perceive them as close substitutes. The retailers then compete fiercely, and it is important for each to gain a competitive advantage over its rivals. This business-stealing motivation results in high investments in the inside option, which is bad for the supplier, who is forced to set low input prices. So, what would happen if the supplier could commit to charging the same input price from all retailers (i.e. uniform pricing)? No retailer can then obtain a competitive advantage by putting pressure on the supplier's input price. The retailers' investment incentives are consequently reduced, and the supplier can increase input prices. Thus, it is profitable for the supplier to commit to uniform pricing, but since higher input prices translate into higher retail prices, the consumers will be harmed.

It is not always profitable for the supplier to commit to uniform pricing. This is most clearly seen if we assume that the retailers do not compete at all; there is then no business-stealing motivation of investing in the inside option, and the investment level of the largest retailer will then be independent of whether the supplier price discriminates. If the supplier uses uniform pricing in such a case, the only effect will be that it must charge lower input prices from smaller retailers, which clearly would harm the supplier, but be advantageous for the consumers. This result holds also if the competitive pressure between the retailers

[5] Apple uses this split independent of whether the decision on retail pricing is delegated (the agency model used for e-books and apps) or whether Apple decides the retail price (the wholesale model used for music in iTunes). See e.g. Gilbert (2015) and Foros, Kind and Shaffer (2017).

is relatively weak. Consequently, the supplier and the consumers have conflicting interests both with weak and strong retail competition. Interestingly, though, we find that if the competitive pressure is neither particularly weak nor particularly strong, both the supplier and the consumers prefer uniform pricing.

In the spirit of d'Aspremont and Jacquemin (1988), and subsequent papers on strategic R&D investments, we allow for investment spillovers between the retailers. We show that if the supplier price discriminates, and the investment spillover is not too strong, each retailer will strategically over-invest in the inside option to gain a competitive advantage. Under uniform pricing, on the other hand, retailers will under-invest in inside options in order to constrain output and increase prices.

We apply our findings to consider how a large retailer may induce exit (or prevent entry) of smaller rivals. The concern that input price discrimination causes exit and prevents entry goes back to the Robinson-Patman Act of 1936. We find that if the supplier commits to uniform pricing, the large retailer may induce exit by under-investing in the inside option.[6] The opposite is true under price discrimination unless investment spillovers are sufficiently strong.

2 Literature review

As explained above, in contrast to our model, the source of size-based price discrimination in the seminal paper by Katz (1987) is that outside options are available after the input prices are determined. Under uniform pricing, the supplier cannot provide a selective rebate to the large retailer, but the large retailer's bargaining power from the threat of using the outside option does not disappear. Consequently, the supplier offers a lower input price to all retailers to ensure that the large retailer stays on board.[7] Consumer prices are reduced.

[6] Doudchenko and Yurukoglu (2016) empirically quantify how bargaining power related to size affects the analysis of mergers and the profitability of entrants in the US multi-channel TV market. As mentioned above, they estimate that Comcast manages to negotiate about 25 percent lower unit input prices for content than smaller rivals.

[7] In the basic model, Katz assumes that only the large retailer can invest in the outside option, but in the appendix, he shows that the results hold also when the small retailers can invest in outside options. Katz considers the case where the retailers need to undertake a fixed cost investment to get access to the outside option. The qualitative results are not affected if the retailers instead make investments that

Since no investments take place, total welfare unambiguously increases if the supplier uses uniform pricing. However, since the supplier is worse off under uniform pricing, the supplier does not want to commit to uniform pricing under binding outside options.

O'Brien (2014) and Akgün and Chioveanu (2019) assume that price discrimination arises due to asymmetries in inside options among the retailers. O'Brien shows that average input prices are typically higher if the supplier cannot use price discrimination. In this case, consumer surplus tends to be higher under price discrimination (in contrast to Katz, 1987). Akgün and Chioveanu (2019) have a model with the same basic mechanisms as ours, but they do not consider differences in size between retailers. Their focus is on how a ban on price discrimination affects retailers' innovation incentives, and whether such a ban tends to favor more efficient or more inefficient retailers. They do not consider investment spillovers or whether retailers have incentives to over-invest or under-invest in inside options (e.g. private labels).

We deliberately assume that retailers are equally efficient at the retail level. Consequently, differences in retail marginal costs are not a source of price discrimination in our model. All other things equal, a retailer with lower marginal costs at the retail level has a larger market share than a less efficient rival. However, such asymmetries in retail efficiency cannot explain size-based price discrimination in favor of the large retailer. Quite the opposite; DeGraba (1990) and Katz (1987) show that an unconstrained supplier will price discriminate in favor of the less efficient retailer.[8] If the retailers can invest prior to the decision on input prices to reduce retail marginal costs, DeGraba (1990) shows that retailers invest less under price discrimination than under uniform pricing. The reason is that the more a retailer invests in retail marginal cost reductions, the greater the level of price discrimination in disfavor of the more efficient, and consequently larger, retailer.

Inderst and Valletti (2009) combine elements from DeGraba (1990) and Katz (1987). Like DeGraba, they allow retailers to invest in retail marginal cost reductions prior to the supplier's choice of input prices. Like in Katz, retailers may invest in an outside option after

reduce the marginal costs. The latter reflects our model, but where we switch the timing; investments are made after the decision on input prices. See Appendix A.4.

[8]Dukes, Gal-Or and Srinivasan (2006) show the opposite in a bargaining framework. If a large retailer has lower retail marginal costs, there is a potential gain from transferring sales to the more efficient retailer, thus increasing channel profit. Under bargaining, the supplier captures some of the gain from enhanced efficiency.

input prices are determined, and the threat of using the outside option is more credible for a large than for a small retailer. In contrast to DeGraba (1990), Inderst and Valletti (2009) show that retailers may invest more in retail marginal cost reductions under price discrimination than under uniform pricing.

Like all the above-mentioned papers, we consider linear input pricing. While real-world contracts typically involve more than a simple unit input price, linear input pricing seems to be a more reasonable assumption than non-linear contracts in many markets. One example is grocery retailing. Even though the contracts between suppliers and retailers are complex, comprehensive investigations by competition authorities in the UK and Norway (Competition Commission, 2008; Norwegian Competition Authority, 2019) reveal that rebates are given at the margin and that (average) variable input price components are decreasing in size (see also discussion by Inderst and Valletti, 2009). Linear input price contracts are also widely used in cable-TV markets (Crawford and Yurukoglu, 2012; Crawford et al., 2018; Doudchenko and Yurukoglu, 2016) and in the book publishing industry (see e.g. Gilbert, 2015). Further examples are provided by Gaudin (2019). Iyer and Villas-Boas (2003) provide a theoretical rationale for using linear input pricing.[9]

3 The model

We consider a context with $n \geq 2$ intrinsically identical and independent local markets. In each market there is a 'small' retailer, S, which only operates locally ($n_S = 1$). In $n_L \leq n$ of the markets there also exists a 'large' retailer, L. The large retailer has one outlet in each of the markets where it is present. We assume that $n_L \geq 2$.

A dominant upstream supplier U offers each retailer a good that it can resell to the

[9] Under non-linear pricing it is crucial whether wholesale contracts are secret or not. Under secret contracts, O'Brien and Shaffer (1992; 1994) show that there will be no price discrimination at the margin from an unconstrained supplier. Instead, input prices at the margin equal the supplier's marginal cost. In contrast to the outcome under non-linear pricing, Gaudin (2019) shows consumer prices may be higher under secret than observable (and credible) linear input prices. Most of the papers on input price discrimination under non-linear contracts assume an unconstrained supplier. One exception is Inderst and Shaffer (2019). They show that if retailers have access to outside options, the supplier may reduce the unit input price, and increase the fixed slotting fee, towards one of the retailers, and thereby reduce the value of the outside options for all other retailers.

consumers. If retailer i buys the good, it is charged a unit input price w_i $(i = L, S)$ by the supplier. Retailers are equally efficient with respect to retail costs. For simplicity, we normalize retailing costs to zero. Hence, asymmetries in retailing costs are not a source of input price discrimination in our model. Operating profit per retail outlet is then equal to $(p_i - w_i)q_i$, where p_i is the consumer price and q_i is output.

Rather than buy from the supplier, retailer i can produce a substitutable good in-house if it has previously made an adequate investment: in the words of O'Brien (2014), the retailer has an inside option. Let o_i denote the marginal cost of producing this inside option. The more the retailer has invested in the manufacturing process, the lower its marginal production cost o_i.[10] In the spirit of the seminal paper by d'Aspremont and Jacquemin (1988) on strategic R&D investments, we open up for the possibility that a retailer which invests in the production of an inside option, may generate positive side effects for the other retailer in the same market (e.g., due to knowledge spillovers concerning production technologies or – in a richer model – greater acceptance of e.g. private labels).

Hence, we assume that the marginal cost of producing the inside option is

$$o_i = 1 - (x_i + \theta x_j)\,, \text{ where } i, j = L, S; i \neq j. \tag{1}$$

The parameter $\theta \in [0, 1]$ in equation (1) reflects investment spillovers. There are no spillovers if $\theta = 0$, and perfect spillovers if $\theta = 1$.[11]

[10] As emphasized in the Literature Review, retailers' investment in reducing the cost of using an alternative to the supplier is also analyzed by Akgün and Chioveanu (2019). More specifically, Akgün and Chioveanu (2019) assume that the alternative is offered by competitive fringe supply, where retailers may invest in own assets specific to the alternative input. In grocery markets, among others, one interpretation may be investments in the ability to offer private labels. We could also envisage that each retailer makes investments that increase the consumers' willingness to pay for the private label (e.g., through marketing and quality improvements). The model becomes rather complex if we consider both cost-reducing and value-enhancing investments. To make our points as transparent as possible, we abstract from the latter and assume that the consumers perceive the inside option to be equally good as the original good offered by the dominant supplier.

[11] In (1) we have implicitly that the spillovers to the large retailer are independent of how many local markets it operates in. This seems technically reasonable, since the local retailers are identical and consequently make identical technological choices. An alternative specification of the spillover function would be to set $o_L = 1 - (x_L + \theta n_L x_S)$. This would presumably enhance the advantage of operating in several locations (greater economies of scale), but not change the qualitative results.

The cost of investing x_i is $C(x_i)$, where C is strictly increasing and strictly convex. Since the inside option and the original good are perfect substitutes, retailer i will sell the one which has the lower marginal cost. Defining $z_i = \min\{w_i, o_i\}$, we can write net profit of a representative small retailer and the large retailer, respectively, as

$$\pi_S = (p_S - z_S)q_S - C(x_S) \text{ and} \tag{2}$$

$$\Pi_L = \sum^{n_L}(p_L - z_L)q_L - C(x_L). \tag{3}$$

In each local market, consumer preferences are defined by a Shubik-Levitan (1980) utility function:[12]

$$\Psi(q_L, q_S) = 2(q_L + q_S) - (1-s)(q_L^2 + q_S^2) - \frac{s}{2}(q_L + q_S)^2, \tag{4}$$

where $s \in [0, 1]$ reflects the degree of differentiation between the outlets. Specifically, the consumers perceive the large and the small retailers in a given market as perfect substitutes if $s = 1$ and as unrelated if $s = 0$. By allowing imperfect substitutes, $s \in (0, 1)$, we analyze a greater variety of market competition than most existing literature.

Consumer surplus in a representative market is given by

$$CS = \Psi(q_L, q_S) - p_L q_L - p_S q_S. \tag{5}$$

Solving $\partial CS/\partial q_i = 0$, we find the inverse demand functions

$$p_i = 2 - (1-s)2q_i - s(q_L + q_S). \tag{6}$$

Below, we consider a game with the following timing in each of the n identical markets:

- Stage 1: The retailers decide how much to invest in the inside option (L and S choose x_L and x_S, respectively). This determines o_L and o_S.
- Stage 2: The supplier sets the input prices w_L and w_S that maximize own profit, taking into account the fact that retailer $i = L, S$ will buy the good only if $w_i \leq o_i$.

[12] The demand system by Shubik and Levitan (1980) has an attractive property, since we may vary the degree of substitution among retailers without affecting the size of the market (see e.g. discussion by Inderst and Shaffer, 2019).

- Stage 3: L and S decide q_L and q_S, where their marginal costs are given by $z_L = \min\{w_L, o_L\}$ and $z_S = \min\{w_S, o_S\}$, respectively.

The game is solved by backward induction.

3.1 Stage 3: Output.

At stage 3, the retailers choose their profit-maximizing output. Solving $\partial\pi_i/\partial q_i = 0$, the first-order condition for retailer i is given by

$$\frac{\partial \pi_i}{\partial q_i} = \frac{\partial p_i}{\partial q_i} q_i + (p_i - z_i) = 0. \tag{7}$$

This implies that

$$q_i = \frac{2(4-3s) - 2(2-s) z_i + s z_j}{(4-s)(4-3s)}. \tag{8}$$

3.2 Stage 2: The supplier chooses input prices.

At stage 2, the supplier offers retailer i the upstream good at price w_i. We normalize all costs for the upstream firm to zero, so that its profit level is given by:

$$u = w_L q_L + w_S q_S. \tag{9}$$

If none of the retailers has an adequate inside option, the supplier solves $\max_{w_L, w_S} u$. This yields

$$w_L = w_S = \widehat{w} = 1.$$

Our interest is in the case where retailer i has invested in an adequate inside option, such that $o_i < \widehat{w}$. This means that retailer i's cost of using the inside option is a binding constraint for the upstream firm; the retailer will not buy from the supplier unless $w_i \leq o_i < \widehat{w}$.

3.3 Stage 1: Investments by the retailers.

Let us now turn to stage 1, where the retailers decide how much to invest in the inside option. Solving $\partial\pi_i/\partial x_i = 0$ for a representative small retailer, and using the envelope theorem, we find

$$\frac{\partial\pi_S}{\partial x_S} = \underbrace{\left[-q_S\frac{dz_S}{dx_S} - C'(x_S)\right]}_{\text{Direct effect}} + \underbrace{\left[\left(\frac{\partial p_S}{\partial q_L}\frac{dq_L}{dx_S}\right)q_S\right]}_{\text{Strategic effect}} = 0. \tag{10}$$

The first square bracket of equation (10) measures the direct effect of investing in the inside option. The term $(-q_S dz_S/dx_S)$ captures the fact that by increasing x_S by one unit, the production cost for the inside good falls by dz_S/dx_S units for each of the q_S units the retailer sells. Other things equal, it is optimal to invest in the inside option until this marginal benefit is equal to marginal investment costs, $C'(x_S)$. The second square bracket measures the strategic effect of investing in the inside option: since an increase in x_S reduces marginal production costs for the small retailer, the large retailer will respond by changing its output (dq_L/dx_S). This, in turn, affects the price that the small retailer can charge ($\partial p_S/\partial q_L < 0$). Following Fudenberg and Tirole (1984) and Tirole (1988), we say that the small retailer will strategically over-invest if the second square bracket is positive (which is true if $dq_L/dx_S < 0$), while it will strategically under-invest if the bracket is negative (which is true if $dq_L/dx_S > 0$). We will analyze this in detail below.

For the large retailer, we likewise have

$$\frac{\partial\Pi_L}{\partial x_L} = \underbrace{\left[\sum^{n_L}\left(-q_L\frac{dz_L}{dx_L}\right) - C'(x_L)\right]}_{\text{Direct effect}} + \underbrace{\left[\sum^{n_L}\left(\frac{\partial p_L}{\partial q_S}\frac{dq_S}{dx_L}\right)q_L\right]}_{\text{Strategic effect}} = 0. \tag{11}$$

Investing in more efficient production technology is like obtaining a non-rival good for the large retailer; it benefits from lower marginal costs in all the locations in which it operates. Both the direct and the strategic effect of investing are therefore greater for the large retailer than for each of the small retailers, other things equal.

All markets are identical, and it is convenient to define the large retailer's profit in each market where it operates as $\pi_L = \Pi_L/n_L$. This allows us to write the first-order condition for both the small and the large retailer as

$$\frac{\partial \pi_i}{\partial x_i} = \underbrace{\left[-\frac{dz_i}{dx_i}q_i - \frac{C'(x_i)}{n_i}\right]}_{\text{Direct effect}} + \underbrace{\left(\frac{\partial p_i}{\partial q_j}\frac{dq_j}{dx_i}\right)}_{\text{Strategic effect}} q_i = 0, \qquad (i = L, S), \tag{12}$$

where $n_i = 1$ for $i = S$ and $n_i = n_L$ for $i = L$. Below, we will discuss when this first-order condition constitutes an optimum.

3.3.1 Input price discrimination (PD)

Let us start out by asking whether the supplier has incentives to price discriminate, i.e. to charge different prices from the large and the small retailers. To answer this question, we can use equation (12) to see how the investment incentives for the large and the small retailers depend on the number of outlets of the large retailer:

$$\frac{\partial}{\partial n_L}\left(\frac{\partial \pi_L}{\partial x_L}\right) = \frac{C'(x_L)}{n_L^2} > 0 \text{ and } \frac{\partial}{\partial n_L}\left(\frac{\partial \pi_S}{\partial x_S}\right) = 0. \tag{13}$$

Equation (13) shows that the larger is the large retailer, the more it invests in the inside good. The size of the large retailer does not directly affect the investment incentives of the small retailers, but it could, nonetheless, have an indirect effect. However, stability requires that $|dx_i/dx_j| < 1$. Since lower costs of producing the inside good force the upstream firm to charge a lower price for the original good, we can conclude:

Lemma 1 *Suppose that the supplier can price discriminate:*

(i) The supplier charges a higher input price from the small retailers than from the large retailer ($z_S > z_L$), and

(ii) more so the larger the size difference between the retailers ($d(z_S - dz_L)/dn_L > 0$).

The mechanism behind the result in the first part of Lemma 1 corresponds to Akgün and Chioveanu (2019). They show that a retailer with lower marginal cost of using the inside option, faces a lower input price. O'Brien (2014) shows in a bargaining framework that a retailer with better inside options than its rival, obtains a lower input price, but O'Brien does not model how asymmetries in inside options may arise. We show that this effect follows from exogenous differences in size between the retailers. Therefore, the ability to invest in inside options may explain size-based input price discrimination in favor of the large retailer, and that the degree of price discrimination is increasing in the size difference between the retailers.

While market players and policy makers often claim that input price discrimination is size-based, the literature only provides economies of scale with respect to outside options (Katz, 1987) and increasing marginal costs at the supplier level (Chipty and Snyder, 1999) as potential explanations for size-based price discrimination. Long-run investment in inside options may be an alternative explanation, and seems to be consistent with the observations that retailers in many industries undertake significant cost-reducing and value-enhancing investments regarding the ability to provide private labels and backward integrate (for further discussion, see the Concluding Remarks).

Let us now investigate how the investment incentives depend on the investment spillovers. We first note that higher investment by firm i affects output of good j as follows:

$$\frac{dq_j}{dx_i} = \underbrace{\frac{\partial q_j}{\partial z_i}\frac{dz_i}{dx_i}}_{<0} + \underbrace{\frac{\partial q_j}{\partial z_j}\frac{dz_j}{dx_i}}_{>0 \text{ if } \theta>0}. \tag{14}$$

The more firm i invests in the inside option, the lower its marginal costs ($dz_i/dx_i = -1$). Other things equal, an increase in x_i thus makes the local rival less competitive and induces it to produce less. This is captured by the first term in equation (14), which is consequently negative. However, if there are positive investment spillovers, a higher investment by firm i reduces marginal costs also for firm j ($dz_j/dx_i = -\theta$). In isolation, this tends to increase output from firm j, making the second term in equation (14) positive if $\theta > 0$. Using equation (8), we find that the net effect is

$$\frac{dq_j}{dx_i} = \left[\frac{2(2-s)}{(4-s)(4-3s)}\right]\left(\theta - \theta^{PD}\right), \quad \text{where } \theta^{PD} \equiv \frac{s}{4-2s}. \tag{15}$$

If the spillovers are sufficiently strong, $\theta > \theta^{PD}$, we consequently see that firm j's output is increasing in the investment level of firm i. Using equation (6), which implies that $\partial p_i/\partial q_j = -s$ (the negative price effect of greater output from the rival is larger the better substitutes the retailers sell), it follows that the sign of the strategic effect depends on the size of the spillovers:

$$\frac{\partial p_i}{\partial q_j}\frac{dq_j}{dx_i}q_i = -s\left[\frac{2(2-s)}{(4-s)(4-3s)}\right]\left(\theta - \theta^{PD}\right)q_i < 0 \text{ if } \theta > \theta^{PD}. \tag{16}$$

Let us next investigate how one retailer's investment incentives depend on the investment level of the rival. Differentiating equation (12) with respect to x_j, we have

$$\frac{\partial^2 \pi_i}{\partial x_i \partial x_j} = \left[\frac{4\left(2-s\right)^2\left(4-2s-s\theta\right)}{\left(4-3s\right)^2\left(4-s\right)^2}\right]\left(\theta-\theta^{PD}\right) > 0 \text{ if } \theta > \theta^{PD}, \tag{17}$$

which shows that investments are strategic complements if $\theta > \theta^{PD}$ and strategic substitutes if $\theta < \theta^{PD}$.

We can now state:

Proposition 1 *Suppose that the supplier price discriminates, and that*

(i) $\theta < \theta^{PD}$. Each retailer will strategically over-invest in the inside option. Investments are strategic substitutes.

(ii) $\theta > \theta^{PD}$. Each retailer will strategically under-invest in the inside option. Investments are strategic complements.

Figure 1 shows how the sign of the strategic effect depends on spillovers and the substitutability between the large and the small retailer in each market. Each retailer wants the rival to produce less. In the figure, this implies that each retailer will over-invest below the upward-sloping line ($dq_j/dx_i|_{\theta<\theta^{PD}} < 0$) and under-invest above it ($dq_j/dx_i|_{\theta>\theta^{PD}} > 0$).

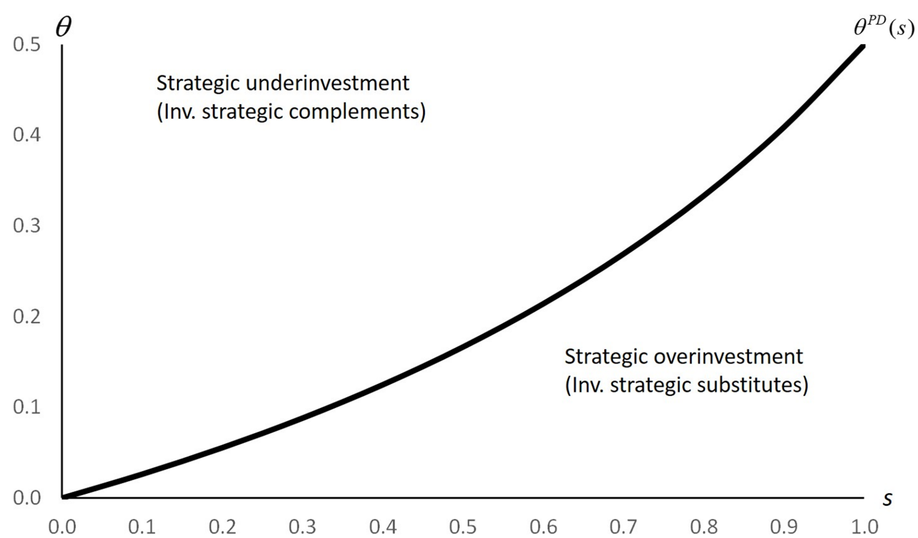

Figure 1: *Strategic investment behavior.*

Equation (13) tells us that an increase in n_L has a positive effect on x_L, but only an indirect effect on x_S. The sign of the indirect effect depends on the size of the spillovers, which determines whether investments are strategic substitutes or strategic complements. More precisely, from Proposition 2, we can deduce:

Corollary 1 *The small retailers' investment in inside options is*

a) decreasing in the size of the large retailer ($dx_S/dn_L < 0$) if $\theta < \theta^{PD}$.

b) increasing in the size of the large retailer ($dx_S/dn_L > 0$) if $\theta > \theta^{PD}$.

3.3.2 Uniform pricing (UP)

Now, assume that the upstream supplier does not price discriminate between the large and the small retailers, but rather sets a common $w_L = w_S = w$. At this stage, we will not discuss why it sets a uniform price; it could be due to competition policy. However, we shall also see that the supplier may be better off if it does not price discriminate.

It follows from the analysis above that the large retailer has stronger incentives than the small ones to invest in the inside option (this is true independent of whether the supplier price discriminates). The supplier will therefore be able to sell to both types of retailers only if it sets $w \leq o_L$. In an equilibrium where the supplier serves the whole market, we therefore have

$$w = 1 - (x_L + \theta x_S). \tag{18}$$

Inserting for this into (8), output at stage three can be written as

$$q_L = q_S = \frac{2 - w}{4 - s}. \tag{19}$$

The marginal direct benefit for the large firm of investing in the inside option is the same as when the supplier price discriminates; it reduces the per-unit input price from the supplier by one unit ($dw_i/dx_L = -1$). The disadvantage for the large retailer is that the lower input price now also applies for each of the local rivals, which respond by increasing output ($dq_S/dx_L = 1/(4 - s)$). The large retailer will therefore strategically under-invest. More precisely, inserting that $\partial p_L/\partial q_S = -s$ into equation (12), we have:

$$\frac{\partial \pi_L}{\partial x_L} = \underbrace{\left[q_L - \frac{C'(x_L)}{n_L} \right]}_{\text{Direct effect}} + \underbrace{\left(-\frac{s}{4 - s} \right) q_L}_{\text{Strategic effect (<0)}} = 0.$$

From equation (12), we can write the first-order condition for the small retailers' investment as

$$\frac{\partial \pi_S}{\partial x_S} = \underbrace{[\theta q_S - C'(x_S)]}_{\text{Direct effect}} + \underbrace{\left(-\frac{\theta s}{4-s}\right) q_S}_{\text{Strategic effect } (<0)} = 0.$$

Since $\partial \pi_S / \partial x_S|_{x_S=0} = \theta q_S \frac{2(2-s)}{4-s} - C' > 0$ if $C'(0)$ is not too steep, it is optimal for the small retailers to invest if $\theta > 0$ (for simplicity, we have assumed that there are no fixed costs involved in investing in the inside option). The small retailers have no incentives to invest in the inside option if $\theta = 0$. The marginal effect on the input price of investing is $dw/dx_S = -\theta$.

We further have

$$\frac{\partial^2 \pi_S}{\partial x_S \partial x_L} = \frac{2\,(2-s)}{(4-s)^2}\theta \text{ and } \frac{\partial^2 \pi_L}{\partial x_S \partial x_L} = \frac{4-2s}{(4-s)^2}\theta.$$

In contrast to what we found under price discrimination, investments are now always strategic complements.

We can conclude:

Proposition 2 *Assume uniform pricing and that $\theta > 0$. All retailers will strategically under-invest in inside options. Investments are strategic complements.*

4 Comparison of input price discrimination and uniform pricing

4.1 Inducing exit (or preventing entry)

So far, we have looked at the question of whether the retailers have incentives to over-invest or under-invest in the inside option, given that the rival(s) will remain in the market. In the public debate, much attention has been given to the question of whether price discrimination in favor of large retailers prevents entry or, analogously, induces exit of smaller rivals. In our framework, will the large retailer have incentives to strategically over-invest in the inside option in order to reduce the profitability of the small retailers (this could induce exit if the retailers e.g. have fixed operating costs that they need to cover)? To answer this question, we must examine how the large retailer's investment level affects profit for a small rival (i.e. not only the large retailer's own profit, which we looked at above). Using the envelope theorem, we have

$$\frac{d\pi_S}{dx_L} = q_S \left[\frac{\partial p_S}{\partial q_L}\frac{dq_L}{dx_L} + \left(-\frac{dw_S}{dx_L}\right)\right] = q_S \left[-s\frac{2\,(2-s)-\theta s}{(4-s)\,(4-3s)} + \theta\right]. \tag{20}$$

The more the large retailer invests in the inside option, the more it will sell (because the supplier will be forced to charge a lower input price). This will harm the small retailers if $s > 0$, and explains why the first term in the square bracket of equation (20) is negative. The second term, however, is positive if there are positive spillovers, such that the small retailers' marginal costs are decreasing in the large retailer's investment level. Whether the first or the second term dominates, depends on the size of the spillovers. More specifically, we find:

$$\frac{d\pi_S}{dx_L} = \frac{4\,(2-s)^2}{(4-s)\,(4-3s)}\left(\theta - \theta^{PD}\right) q_S.$$

If $\theta < \theta^{PD}$, we thus have $\frac{d\pi_S}{dx_L} < 0$. In this case, the large retailer can induce exit or prevent entry by over-investing in the inside option.

If the supplier does not price discriminate, higher investments by the large retailer will always benefit the small retailers:

$$\frac{d\pi_S^{UP}}{dx_L} > 0.$$

If the large retailer wants to induce exit under uniform pricing, it will therefore under-invest in inside options.

We can state:

Proposition 3 *Under uniform pricing, the large retailer may induce exit (prevent entry) by under-investing in the inside option. The opposite is true under price discrimination, unless spillovers are sufficiently strong ($\theta > \theta^{PD}$).*

4.2 Who benefits from uniform pricing (and who benefits from price discrimination)?

Henceforth, we abstract from entry and exit decisions, and we ask who is better off under price discrimination and who is better off under uniform pricing? We show that the degree of competition among retailers has critical impact on the answer to this question.

If there are perfect spillovers ($\theta = 1$), the costs of using the inside option will be the same for all the retailers. Then, their investment levels do not depend on whether the supplier in principle is able to price discriminate; the uniform pricing and price discrimination regimes are identical. In the rest of this paper, we will focus on the opposite extreme, and set $\theta = 0$. We will then analyze how the differences between the price discrimination and the uniform pricing regimes depend on the competitive pressure among the retailers, as measured by the substitutability parameter s. In order to obtain closed-form solutions, we further assume the simple quadratic investment cost function, $C(x_i) = (\gamma/2)x_i^2$. Our interest is in stable equilibria where both the large and the small retailers are operative and, in Appendix A.1, we show that all the necessary conditions for the existence of such equilibria are satisfied if $\gamma \geq 8$ and $n_L < 6$. We therefore set $C(x_i) = 4x_i^2$ and let $n_L \in [2, 6)$.

4.2.1 Consumers perceive the retailers as perfect substitutes ($s = 1$)

As a starting point, assume that the consumers perceive the large and the small retailers to be perfect substitutes ($s = 1$). The large retailer invests more in the inside option than any of its competitors, and will therefore be charged a lower input price by the supplier if the supplier can price discriminate. More precisely, we have

$$w_L^{PD} = \frac{16\,(6 - n_L)}{96 - 11n_L},\ w_S^{PD} = \frac{10\,(9 - n_L)}{96 - 11n_L};\ w_S^{PD} - w_L^{PD} > 0. \tag{21}$$

All calculations in this section are shown in Appendix A.2. The more outlets the large retailer has, the more it will invest in the inside option and the less will it be charged by the supplier ($dw_L^{PD}/dn_L < 0$). This means that the competitiveness of the small retailers is decreasing in n_L, so that their marginal profitability of investing in the inside option is also decreasing in n_L. This, in turn, allows the supplier to charge them an input price which is increasing in n_L ($dw_S^{PD}/dn_L > 0$).

The profit level at each outlet equals

$$\pi_L^{PD} = \frac{100\,(9 - n_L)}{(96 - 11n_L)^2},\ \pi_S^{PD} = \frac{32\,(6 - n_L)^2}{(96 - 11n_L)^2} => \pi_S^{PD} - \pi_L^{PD} < 0. \tag{22}$$

Since the input price for the large retailer is decreasing in its number of outlets, its profit level is increasing in n_L ($d\pi_L^{PD}/dn_L > 0$), while the opposite is true for the small retailers ($d\pi_S^{PD}/dn_L < 0$). Not surprisingly, profit per outlet is greater for the large than for the small retailers. We further find that consumer surplus and the profit level for the supplier are equal to, respectively,

$$CS^{PD} = \frac{18\,(11 - n_L)^2}{(96 - 11n_L)^2} \text{ and } u^{PD} = \frac{60\,(6 - n_L)\,(17 - n_L)}{(96 - 11n_L)^2}. \tag{23}$$

Equation (23) implies that $dCS^{PD}/dn_L > 0$ and $du^{PD}/dn_L < 0$. This simply reflects the fact that the direct effect of the large retailer increasing its size is that the supplier is forced to charge a lower input price to the large retailer, which partly spills over to lower consumer prices from the large retailer. This effect dominates over the indirect effect that the small retailers can be charged a somewhat higher input price if n_L increases (so that consumer prices from the small retailers increase).

If the supplier does not discriminate, we have

$$w^{UP} = 2\frac{18 - n_L}{36 - n_L}. \tag{24}$$

As expected, we find $dw^{UP}/dn_L < 0$; the large retailer invests more in the inside option the more locations it operates in, and thereby forcing the supplier to charge a lower price.

In Appendix A.2, we show that joint profit for the n_L outlets of the large retailer is greater than the profit level of a representative local competitor ($n_L\pi_L^{UP} - \pi_S^{UP} > 0$). However, an interesting difference from the price discrimination case is that since the small retailers can now free-ride on the investments undertaken by the large retailer, the large retailer makes a smaller profit at each location than its rival:

$$\pi_L^{UP} = \frac{144 - 4n_L}{(36 - n_L)^2},\ \pi_S^{UP} = \frac{144}{(36 - n_L)^2};\ \pi_S^{UP} - \pi_L^{UP} = \frac{4n_L}{(36 - n_L)^2} > 0. \tag{25}$$

It is straight forward to show that $w_L^{PD} < w^{UP} < w_S^{PD}$; the uniform input price lies between the low input price that the large retailer would otherwise pay and the high input price faced by the local retailers. This corresponds to the findings by Akgün and Chioveanu (2019).[13] The large retailer will consequently have to pay a higher input price under uniform pricing, and its competitive advantage over the small retailers erodes. For the same reason, a uniform price is unambiguously good for the small retailers; they will become more competitive, and also pay a lower input price.

[13] As emphasized above, they do not consider differences in size among the retailers, but assume that one of the retailers may be more efficient with respect to investments in inside alternatives.

Consumer surplus and profit for the supplier under uniform pricing equal

$$CS^{UP} = \frac{288}{(36 - n_L)^2} \text{ and } u^{UP} = \frac{48\,(18 - n_L)}{(36 - n_L)^2}. \tag{26}$$

In parallel to the results above, we have $dCS^{UP}/dn_L > 0$ and $du^{UP}/dn_L < 0$. More interestingly, from equations (23) and (26), we find that $u^{UP} > u^{PD}$. The supplier is thus better off if it charges the same price from each of the retailers than if it price discriminates. The difference is, moreover, increasing in n_L. The intuition for why it is advantageous for the supplier not to price discriminate, is that the large retailer will then have less incentives to invest in the inside option, since it cannot obtain any competitive advantage. The supplier can therefore charge a higher input price from the large retailer under uniform pricing than under price discrimination ($w^{UP} > w_L^{PD}$). The higher input price is partly passed on to the consumers, and from equations (23) and (26), it follows that $CS^{UP} < CS^{PD}$.

Other things equal, it is a dominant strategy for the supplier to price discriminate at stage two of the game if the retailers differ in their investments in inside options. Unless the supplier can credibly commit to uniform pricing before the retailers invest, we will therefore have a unique equilibrium where the supplier price discriminates.

Proposition 4 *Assume that the consumers perceive the large retailer and the small retailers as perfect substitutes. The supplier will then commit to uniform pricing if it is able to do so, and this will harm the consumers.*

As discussed in the Introduction, competition policy might require dominant suppliers to not price discriminate. This could solve the commitment problem for the supplier. Indeed, even if competition authorities do not actively pursue the non-discrimination policy, one might imagine that the supplier could appeal to the competition law to signal that it cannot price discriminate. An alternative device for committing to uniform pricing, is through a price-parity clause with at least one of the retailers in each market. When retailers' products are perfect substitutes, both the supplier and the small retailers in each market prefer uniform pricing. Consequently, they all benefit from such a clause.

It is interesting to compare the results above with those of Katz (1987), who assumes $s = 1$. A retailer can credibly threaten to *ex post* invest in an outside option (e.g. backward integration) unless the supplier charges a sufficiently low input price. As in our model, a large retailer has greater incentives than smaller retailers to invest in an alternative source of supply due to economies of scale. Katz derives conditions under which none of the firms will actually invest in the outside option. He finds that under reasonable assumptions, uniform pricing (e.g. due to a ban on price discrimination) can lower the input prices that the supplier charges from both the large and the small retailers. Consumer prices will then unambiguously fall, in contrast to what we find.

Before we leave the comparison with Katz (1987) for now, we note that welfare under price discrimination and welfare under uniform pricing in our case are given by, respectively,

$$W^{PD} = \frac{10\,(1035 - 226n_L + 11n_L^2)}{(96 - 11n_L)^2} \text{ and } W^{UP} = \frac{4\,(360 - 13n_L)}{(36 - n_L)^2}. \tag{27}$$

It can be shown that $W^{UP} > W^{PD}$ in the relevant area ($2 \leq n_L < 6$); total welfare is higher under uniform pricing than under price discrimination. The difference is, moreover, increasing in n_L, as shown in Figure 2. Consequently, a ban on price discrimination is arguably beneficial both in Katz's and our context, albeit for very different reasons. In Katz (1987) a ban is welfare improving because a *threat* of investing in an outside option forces the supplier to charge lower input prices. However, no investments actually take place in the equilibrium Katz analyzes. In contrast, in our model at least the large firm will make investments, but this will be in inside options that are not used *per se*; it invests to press down the price of the good it actually sells in equilibrium. In this sense, investments constitute a negative welfare effect.

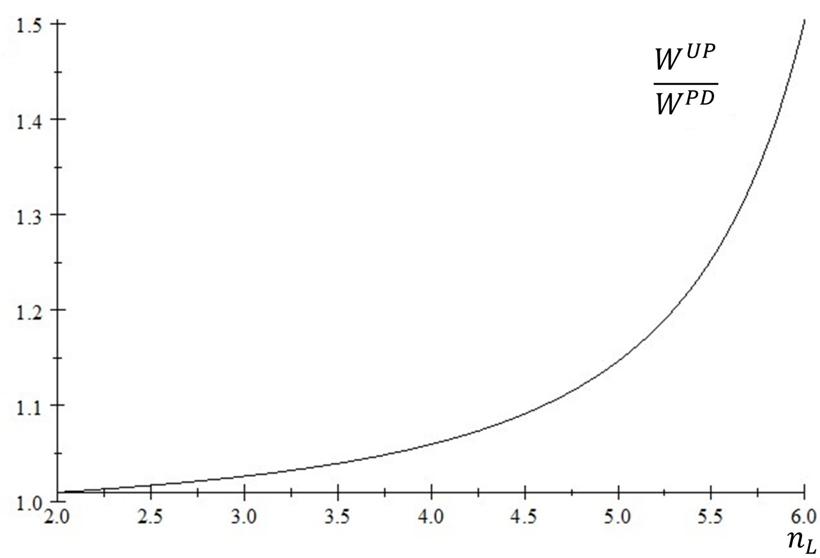

Figure 2: *Welfare higher under uniform pricing than under price discrimination ($s = 1$).*

4.2.2 Consumers perceive the retailers as unrelated ($s = 0$)

With $s = 0$, there is no competition between the retailers. Clearly, also in this case each of the local retailers invests less than the large retailer. They will therefore be charged a higher input price and be less profitable than the large retailer (all calculations in this section are shown in Appendix A.3):

$$w_L^{PD} = 2\frac{16 - n_L}{32 - n_L}, w_S^{PD} = \frac{30}{31}; w_S^{PD} - w_L^{PD} > 0 \text{ and } \pi_S^{PD} - \pi_L^{PD} < 0. \tag{28}$$

Turning to the regime with uniform pricing, note that since there is no retail competition, the large retailer's investment level is independent of which prices the small retailers charge. The supplier will consequently not be able to sell to the large retailer if it charges more than w_L^{PD}. Clearly, it does not want to charge a lower price either, so in equilibrium, we have

$$w^{UP} = w_L^{PD} = 2\frac{16 - n_L}{32 - n_L} < w_S^{PD}. \tag{29}$$

With $s = 0$, price discrimination thus harms the small retailers, but has no effect on the large retailer.

The fact that the small retailers can free-ride on investments by the large retailer, implies that we also now find that the profit level per outlet is highest for the former, $\pi_S^{UP} > \pi_L^{UP}$. It is nonetheless still true that $n_L \pi_L^{UP} - \pi_S^{UP} > 0$.

Since the small retailers pay lower input prices with uniform pricing than with price discrimination, while the input price for the large retailer is independent of the price regime, it immediately follows that uniform pricing harms the supplier and benefits consumers who buy from the small retailers. More precisely, we have

$$u^{UP} - u^{PD} = -\frac{16\left(16 + 15n_L\right)}{961\left(n_L - 32\right)^2}\left(n_L - 1\right) < 0, CS^{UP} - CS^{PD} = \frac{64\left(63 - n_L\right)}{961\left(32 - n_L\right)^2}\left(n_L - 1\right) > 0.$$

We can now state:

Proposition 5 *Assume that the consumers perceive the large retailer and the small retailers as unrelated (independent in demand). The supplier will price discriminate if it is able to do so, and this will harm the consumers.*

Finally, note that the loss in market power for the supplier implies that the dead-weight loss falls. Since the small retailers moreover save investments, welfare is necessarily highest under uniform pricing. As for $s = 1$, the welfare gain of uniform pricing is increasing in n_L.

4.2.3 Retailers are imperfect substitutes ($0 < s < 1$)

The analysis above indicates that the supplier prefers uniform pricing if the competitive pressure between the stores is sufficiently strong (i.e., for sufficiently high values of s), while the opposite is true for the consumers. This is illustrated graphically in Figure 3 (for $n_L = 2$). If it is observed that suppliers commit to uniform pricing (e.g., price-parity clauses) or appeal to the competition law to justify non-discrimination, policy makers should thus be skeptical. If suppliers appear to be negative to uniform pricing, on the other hand, we have an indication that uniform pricing would benefit the consumers. However, signals from suppliers should be interpreted with caution, since they can clearly have incentives to mislead policy makers.[14]

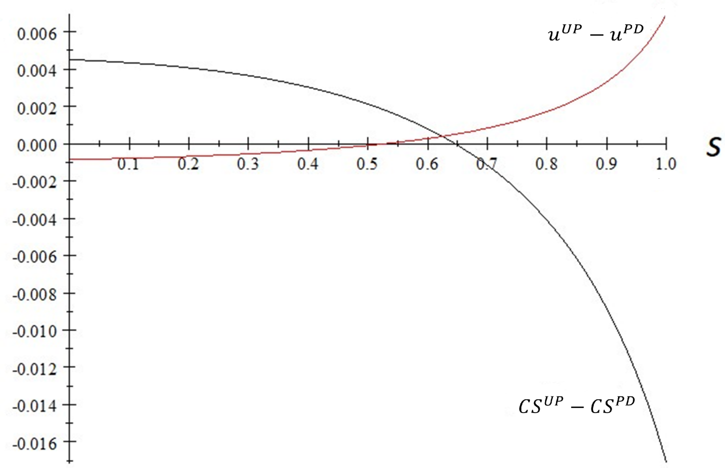

Figure 3: *Consequences of price parity for the supplier and for the consumers.*

5 Concluding remarks

We show how investments in inside options may give rise to size-based input price discrimination. The important distinction between outside and inside options is whether the

[14]According to our analyses, the arguments for allowing price discrimination is stronger if policy makers care about consumer surplus rather than about total welfare (i.e., if they abstract from the resource costs of higher investments in inside options). Katz (1987) focuses on the case where retailers credibly threaten to invest in an outside option, but where the outside options will not be used in equilibrium since the supplier responds by reducing input prices. In his framework (where it is assumed that the stores are perceived as perfect substitutes), a ban on price discrimination is therefore welfare improving if it increases consumer surplus.

investments take place before or after the supplier's decision on input prices. This distinction may have crucial impact on suppliers' incentives to price discriminate. In practice, retailers may improve their position towards suppliers through investments ex ante the negotiation with suppliers, as well as through a credible threat of switching to an outside option ex post of the negotiations.

Let us further discuss our applications from the Introduction; the grocery market, the book publishing market, and the multi-channel TV market. In grocery retailing, private labels may constitute an alternative source of supply. For many products, retailers probably need to make significant investments prior to negotiations over input prices with the brand suppliers to have a credible threat from private labels. If retailers decide to backward integrate and switch to a private label, they probably need to undertake further investments. With respect to investments in private labels, there may also be significant investment spillovers that retailers need to consider. If one retailer succeeds in introducing a private label in one product category, this will probably make it easier for a rival retailer to do the same.[15]

Amazon obtains low input prices from suppliers (publishers) due to its size.[16] Gilbert (2015, page 174) argues that an important part of Amazon's position is that they have a credible threat to backward integrate: "Publishers have the additional concern that they will become an antiquated and redundant component of the book industry as Amazon increasingly deals directly with authors to supply books. Publishers fear that Amazon will 'disintermediate' the supply chain, replacing the traditional role of publishers to source and distribute content." This example illustrates that Amazon's credible threat comes from a combination of inside and outside options. Amazon undertakes investments into backward integration (Amazon Publishing) which proves their ability to switch to an alternative source of supply.

In the multi-channel TV market, a large player like Comcast, with its 23 million subscribers, has a size advantage over smaller rivals, such as Google Fiber and Cablevision,

[15] Market shares of private labels differ between markets, but inside market differences among competing retailers are smaller.

[16] Gilbert (2015, page 173) writes "Amazon could seek to exploit its power as a large buyer to obtain low wholesale prices, rebates, or other concessions from its suppliers, and a credible concern is that Amazon will continue to press its suppliers for better terms. Publishers complain that at Amazon, today's wholesale price is the starting point for tomorrow's negotiations."

when it comes to using an alternative source of supply through backward integration into content programming. Doudchenko and Yurukoglu (2016) refer to the fact that Google Fiber emphasizes that they face a significant disadvantage due to size-based input price discrimination in favor of larger rivals such as Comcast. This certainly indicates that transactional economies of scale are needed to have a credible size advantage. In general, Google is one of the largest firms in the world. By the same token, the buyer group of smaller cable TV firms (the National Cable Television Cooperative) fails to achieve size-based rebates, since they cannot coordinate backward integration on behalf of their members (Doudchenko and Yurukoglu, 2016). Also in this example it seems reasonable that cable-TV providers need to make investments prior to the negotiations over content input prices in order to credibly threaten to – overnight – go to an alternative source of supply. Nonetheless, it will involve further costs if they put their threat into action.

It is obviously a question of to which extent a supplier can commit to uniform pricing. In our model, if the supplier cannot commit to uniform pricing, it will provide a selective rebate to the large retailer. In several markets, we observe that firms that control wholesale terms of trade may commit to non-discriminatory rules. In other markets, we observe that firms are lobbying for non-discriminatory obligations, such as net-neutrality. Indeed, even if competition authorities do not actively pursue the non-discrimination policy, one might imagine that the supplier could appeal to the competition law to signal that it cannot price discriminate.

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A Appendix

A.1 Existence of stable equilibria

In this appendix, we show the necessary conditions for the existence of stable equilibria where both the large and the small retailers are operative. It suffices to show this for $s = 1$, since the requirement will be stricter than with any lower value of s.

Insering (8) into (2) and (3), we have profit for retailer i, $\pi_i = \frac{(1-x_j-2x_i)^2}{9} - \frac{C(x_i)}{n_i}$, where $C(x_i) = (\gamma/2)x_i^2$. The stable equilibrium must satisfy the following two conditions:

1. The second-order condition: $d^2\pi_i/dx_i^2 < 0$, and
2. Stability: $|dx_i/dx_j| < 1$.

For $i = L$, we have that the second-order condition $d^2\pi_L/dx_L^2 = -(9\gamma - 8n_L)/9n_L < 0$ holds if $\gamma \geq \frac{8n_L}{9}$, and that the stability condition $|dx_L/dx_S| = -4n_L/(9\gamma - 8n_L) < 1$ is satisfied for $\gamma \geq 4n_L/3$. The latter is the stricter requirement that ensures the existence of stable equilibria.

Restricting our attention to the cases where $n_L < 6$, we must have that $\gamma \geq 8$ to ensure stable equilibria.

A.2 Consumers perceive the retailers as perfect substitutes ($s = 1$)

In this appendix, we demonstrate all calculations that are presented in section 4.2.1, where consumers perceive the firms as perfect substitutes, $s = 1$. The model,including the timing of the game, is presented in section 3. The game is solved by backwards induction.

Stage-three output is solved in equation (8). At the second stage, the supplier sets the input prices that maximize their own profits given that the retailer will only buy the good if $w_i \leq o_i$. In equilibrium, this will be binding, such that $z_i = o_i$. Therefore, we insert equation (1) into equation (8), to find the stage-two output

$$q_i = \frac{1 - x_j + 2x_i}{3}. \tag{A.1}$$

Stage 1: Optimal investments Moving to the first stage of the model, we distinguish between the two potential pricing regimes: input price discrimination and uniform pricing.

Input price discrimination At the first stage, retailer i solves $\partial\pi_i/\partial x_i = 0$, and we derive the best-response functions:

$$x_L(x_S) = \frac{n_L - n_L x_S}{18 - 2n_L};\ x_S(x_L) = \frac{1 - x_L}{16}.$$

Solving these simultaneously, yields the following optimal investments:

$$x_L^{PD} = \frac{5n_L}{96 - 11n_L} \tag{A.2}$$

and

$$x_S^{PD} = \frac{6 - n_L}{96 - 11n_L}. \tag{A.3}$$

From the optimal investment levels in (A.2) and (A.3), we then obtain the values of the input prices (as given in section 4.2.1):

$$w_L^{PD} = 1 - x_L^{PD} = 16\frac{6 - n_L}{96 - 11n_L};\ w_S^{PD} = 1 - x_S^{PD} = 10\frac{9 - n_L}{96 - 11n_L}. \tag{A.4}$$

This implies that $w_S^{PD} - w_L^{PD} = \frac{6}{96-11n_L}(n_L - 1) > 0$, which means that there is input price discrimination in favor of the large retailer, such that the small retailer pays a higher input price.

From equation (A.4), we find that $dw_L^{PD}/dn_L = -\frac{480}{(11n_L-96)^2} < 0$ and $dw_S^{PD}/dn_L = \frac{30}{(11n_L-96)^2} < 0$.

Once we have found the optimal investments in (A.2) and (A.3), and the input prices in (A.4), the subsequent expressions in section 4.2.1 follow directly.

Inserting (A.2) into (3), we obtain the profit of the large and the small retailer, respectively, given by the expressions in (22).

Combining (A.2) and (A.3) with (5) and (9), we find consumer surplus and the supplier's profit, respectively, as given in equation (23).

From equation (22), we find that the large retailer obtains a higher profit than the small retailer

$$\pi_S^{PD} - \pi_L^{PD} = -\frac{4(63 - 8n_L)}{(96 - 11n_L)^2}(n_L - 1) < 0. \tag{A.5}$$

Using equation (22), we find that $d\pi_L^{PD}/dn_L = 100\frac{11n_L-102}{(11n_L-96)^3} > 0$ and $d\pi_S^{PD}/dn_L = -1920\frac{n_L-6}{(11n_L-96)^3} < 0$.

From equation (23), we find that $dCS^{PD}/dn_L = 900\frac{n_L-11}{(11n_L-96)^3} > 0$ and $du^{PD}/dn_L = 60\frac{61n_L-36}{(11n_L-96)^3} < 0$.

Total welfare is the sum of retail profits, supplier profit and consumer surplus:

$$W^{PD} = CS^{PD} + u^{PD} + \pi_L^{PD} + \pi_S^{PD} = \frac{10\left(1035 - 226n_L + 11n_L^2\right)}{\left(96 - 11n_L\right)^2}. \tag{A.6}$$

Uniform pricing Suppose next that the supplier does not price discriminate, and offers both retailers the same, uniform, input price w.

When there is no price discrimination, the supplier must give all retailers the same take-it-or-leave-it offer. The supplier will be able to sell to both types of retailers only if it sets $w \leq o_L$ (i.e., the large retailer's integration constraint binds for both retailers). In equilibrium, we find that the input price is

$$w = 1 - x_L. \tag{A.7}$$

At the first stage, each retailer i solves $\partial\pi_i/\partial x_i = 0$, and we find the optimal investments:

$$x_L^{UP} = \frac{n_L}{36 - n_L} \text{ and } x_S^{UP} = 0. \tag{A.8}$$

It then follows directly from (A.7) that $w^{UP} = 1 - x_L^{UP} = 2\frac{18-n_L}{36-n_L}$ (equivalent to equation 21). Comparing this with (A.4), we see directly that $w_L^{PD} < w^{UP} < w_S^{PD}$.

We find that $dw^{UP}/dn_L = -\frac{36}{(n_L-36)^2} < 0$; the large retailer invests more in the inside option the more locations it operates in, and this forces the supplier to charge a lower price.

By inserting (A.8) into equations (2) and (3), we obtain the retailers' profits under uniform pricing as given by equation (25).

Equation (25) states that the small retailer receives a higher profit than the large retailer under uniform pricing. However, the joint profit for all $n_L < 6$ outlets is greater than the small retailer's profits: $n_L\pi_L^{UP} - \pi_S^{UP} = -\frac{4n_L}{(n_L-36)}(n_L^2 - 36n_L + 36) > 0$.

Combining (A.8) and equations (5) and (9), gives us the consumer surplus under uniform pricing and the supplier's profit, in equation (26).

From equation (26), we find that $dCS^{UP}/dn_L = -\frac{576}{(n_L-36)^3} > 0$ and $du^{UP}/dn_L = 48\frac{n_L}{(n_L-36)^3} < 0$.

Comparing (23) and (26), we find that

$$CS^{UP} - CS^{PD} = \frac{288}{\left(36 - n_L\right)^2} - \frac{18\left(11 - n_L\right)^2}{\left(96 - 11n_L\right)^2} < 0$$

and

$$u^{UP} - u^{PD} = -\frac{1}{(n_L - 36)^2}(48n_L - 864) - 60(n_L - 6)\frac{n_L - 17}{(11n_L - 96)^2} > 0.$$

Thus, the consumers prefer price discrimination, whereas the supplier prefers uniform pricing when consumers perceive the retailers as perfect substitutes.

Finally, total welfare is

$$W^{UP} = CS^{UP} + u^{UP} + \pi_L^{UP} + \pi_S^{UP} = \frac{4(360 - 13n_L)}{(36 - n_L)^2}. \tag{A.9}$$

Comparing (A.6) and (A.9), we find that

$$W^{UP} - W^{PD} = -\frac{1}{(n_L - 36)^2}\frac{(52n_L - 1440)}{(110n_L - 2260n_L + 10350)}(11n_L - 96) > 0.$$

Hence, in terms of total welfare, uniform pricing is preferred when consumers perceive the retailers as perfect substitutes.

A.3 Consumers perceive the retailers as unrelated ($s = 0$)

In this appendix, we demonstrate all calculations that are presented in section 4.2.2, where consumers perceive the firms as unrelated, $s = 0$. We proceed as we did in Appendix A.2, and demonstrate all the calculations in section 4.2.2. As above, output at the third stage is given by equation (8). We distinguish between the two potential pricing regimes, input price discrimination and uniform pricing.

Input price discrimination ($s = 0$) We regard the case where $z_i = o_i$ binds at the second stage. Inserting equation (1) into equation (8), assuming $\theta = 0$ and $s = 0$, we have stage-two output given by

$$q_i = \frac{1 + x_i}{4}. \tag{A.10}$$

At the first stage, retailer i solves $\partial \pi_i / \partial x_i = 0$, and we derive the optimal investments:

$$x_L^{PD} = \frac{n_L}{32 - n_L};\ x_S^{PD} = \frac{1}{31}. \tag{A.11}$$

By inserting (A.11) into equation (1), we find the optimal input prices given by equation (28). The local (small) retailer is charged more than the large retailer:

$$w_S^{PD} - w_L^{PD} = \frac{32}{31\left(32 - n_L\right)}\left(n_L - 1\right) > 0. \tag{A.12}$$

Combining (A.11) with (2) and (3), we obtain retail profits: $\pi_L^{PD} = \frac{4}{32 - n_L}$ and $\pi_S^{PD} = \frac{4}{31}$. This implies that $\pi_S^{PD} - \pi_L^{PD} = -\frac{4}{31(32-n_L)}\left(n_L - 1\right) > 0$.

Combining (A.11) with (5) and (9), we obtain the consumer surplus and the profit for the supplier, respectively:

$$CS^{PD} = \frac{64\left(1985 - 64n_L + n_L^2\right)}{961\left(32 - n_L\right)^2} \text{ and } u^{PD} = \frac{16\left(30\,736 - 1921n_L + 15n_L^2\right)}{961\left(32 - n_L\right)^2}. \tag{A.13}$$

Total welfare is the sum of retail profits, supplier profit and the consumer surplus:

$$W^{PD} = \frac{4}{961\left(n_L - 32\right)^2}\left(107n_L^2 - 11\,653n_L + 217\,200\right). \tag{A.14}$$

Uniform pricing ($s = 0$) Suppose next that the supplier does not price discriminate, and offers both retailers the same, uniform, input price w.

At stage three, the retailers choose quantities. Solving $\partial\pi_i/\partial q_i = 0$, we find optimal quantities at stage three (equation 8, with $s = 0$, $\theta = 0$, and $z_i = z_j = w$).

$$q_i = \frac{2 - w}{4}.$$

At the second stage, the input price will be determined by the large retailer's investments, such that

$$w = o_L = 1 - x_L. \tag{A.15}$$

At the first stage, retailer i solves $\partial\pi_i/\partial x_i = 0$, and we derive the optimal investments:

$$x_L^{UP} = \frac{n_L}{32 - n_L}; x_S^{UP} = 0. \tag{A.16}$$

By inserting (A.16) into (A.15), we find the uniform input price $w^{UP} = 2\frac{16 - n_L}{32 - n_L}$.

Retail profits become

$$\pi_L^{UP} = \frac{128 - 4n_L}{\left(n_L - 32\right)^2}; \pi_S^{UP} = \frac{128}{\left(n_L - 32\right)^2}.$$

This implies that the small retailer obtains a higher profit than the large retailer, $\pi_S^{UP} - \pi_L^{UP} = \frac{4n_L}{\left(n_L - 32\right)^2} > 0$. However, the joint operating profit of the large retailer exceeds the operating profit of the small competitor, $n_L\pi_L^{UP} - \pi_S^{UP} = -\frac{4}{(n_L - 32)^2)}(n_L^2 - 32n_L + 32) > 0$.

Combining (A.16) with (5) and (9), we find consumer surplus and profit for the supplier, respectively:

$$CS^{UP} = \frac{128}{(32 - n_L)^2} \text{ and } u^{UP} = \frac{32\,(16 - n_L)}{(32 - n_L)^2}. \tag{A.17}$$

Comparing (A.17) and (A.13), we find that

$$u^{UP} - u^{PD} = -\frac{16\,(16 + 15n_L)}{961\,(n_L - 32)^2}\,(n_L - 1) < 0$$

and

$$CS^{UP} - CS^{PD} = \frac{64\,(63 - n_L)}{961\,(32 - n_L)^2}\,(n_L - 1) > 0.$$

By comparing the results of price discrimination and uniform pricing, we now see that the consumers prefer uniform pricing, whereas the supplier prefers price discrimination. Both of these results are opposite from when consumers perceive the retailers as perfect substitutes ($s = 1$).

Total welfare under uniform pricing is the sum of retail profits, supplier profit and consumer surplus:

$$W^{UP} = CS^{UP} + u^{UP} + \pi_L^{UP} + \pi_S^{UP} = \frac{4}{(n_L - 32)^2}\,(224 - 9n_L)\,. \tag{A.18}$$

Comparing (A.14) and (A.18), we find that uniform pricing is always preferred, in terms of total welfare, $W^{UP} - W^{PD} = -\frac{4}{961(n_L-32)^2}\,(107n_L^2 - 3004n_L + 1936) > 0$.

A.4 Investment in marginal-cost reduction in outside options

In this appendix, we show (as promised in footnote 7) that the qualitative results of Katz (1987) are not affected if the retailers make investments that reduce the marginal costs rather than the fixed costs, to get access to the alternative source of supply. This reflects our model, but where we switch the timing; investments are made after the decision on input prices. The timing of the game is as follows (note that the order of stages one and two is switched from our model):

- Stage 1: The supplier sets input prices w_L and w_S that maximize own profit, taking into account that retailer $i = L, S$ will buy the good only if the retailer's profit from buying from the supplier (no integration) exceeds the profit from backwards integration ($\pi_i^{NI} \geq \pi_i^I$).

- Stage 2: The retailers decide how much to invest in the inside option (L and S choose x_L and x_S, respectively). This determines o_L and o_S. The retailers accept the supplier's offer, or reject it and invest in marginal-cost reductions in the outside option.

- Stage 3: The retailers compete à la Cournot; L and S decide q_L and q_S, where their marginal costs are given by $z_L = \min\{w_L, o_L\}$ and $z_S = \min\{w_S, o_S\}$, respectively.

The game is solved by backwards induction.

Stage 3: Cournot ($s = 1$) The basic set-up for the model, including the third stage of the game, is given in the main text. For the purpose of this appendix, we assume $\theta = 0$ and $s = 1$.

Stage-three outputs are solved in equation (8):

$$q_i = \frac{2 - z_j - 2z_i}{3} \tag{A.19}$$

where $z_i = \min\{w_i, o_i\}$.

A.4.1 Discriminatory pricing

Stage 2: Investments At the second stage, the retailers face two sourcing alternatives.

First, the retailers can buy the product directly from the supplier (and make no investments, i.e. no integration). Then, we set $z_i = w_i$ and $x_i = 0$ for all i. The non-integration profit (superscript 'NI') becomes

$$\pi_i^{NI} = \frac{(2 + w_j - 2w_i)^2}{9}. \tag{A.20}$$

The second alternative is to acquire the product from an alternative source (integrate backwards), such that $z_i = o_i = 1 - x_i$. Then, the integration profit (superscript 'I') becomes

$$\pi_i^I = \frac{(2 + (1 - x_j) - 2\,(1 - x_i))^2}{9} - \frac{C(x_i)}{n_i}. \tag{A.21}$$

The retailer i maximizes profits with respect to the investment level, $\partial\pi_i/\partial x_i = 0$. The best-response functions are

$$x_L(x_S) = \frac{n_L - n_L x_S}{18 - 2n_L};\ x_S(x_L) = \frac{1 - x_L}{16}.$$

Solving these simultaneously, yields the following optimal investments:

$$x_L^{PD} = \frac{5n_L}{96 - 11n_L};\ x_S^{PD} = \frac{6 - n_L}{96 - 11n_L}.$$

Inserting the optimal investments into equation (A.21) yields the integration profit for platform i, for $i = L, S$,

$$\pi_L^I = 100\frac{9 - n_L}{(11n_L - 96)^2};\ \pi_S^I = 32\frac{(n_L - 6)^2}{(11n_L - 96)^2}. \tag{A.22}$$

Stage 1: Supplier chooses input prices At the first stage, the supplier chooses input

prices. The supplier maximizes profits, such that the retailers are indifferent between buying from the supplier, and acquiring the product elsewhere. It follows that (A.20) must equal (A.22), and we solve for w_i and find the best-response functions (in Katz's words: the integration frontier):

$$w_i(w_j) = 1 + \frac{w_j}{2} - \frac{\sqrt{9}}{2}\sqrt{\pi_i^I}.$$

From the best-response functions, we find that the integration frontier is upward sloping ($\partial w_L(w_S)/\partial w_S = 1/2 > 0$), similar to Katz (1987).

We solve the two best-response functions simultaneously, and find optimal input prices

$$w_i^{PD} = 2 - 2\sqrt{\pi_i^I} - \sqrt{\pi_j^I}. \tag{A.23}$$

Observe that $w_L^{PD} < w_S^{PD}$ (since $\pi_L^I > \pi_S^I$), and we have input price discrimination in favor of the large retailer. In equilibrium, the retailers will not make any investments, such that $x_i = 0$ for all $i = L, S$. Inserting (A.23) into (A.20), retailer profits from buying from the supplier (no integration) are $\pi_L^{PD} = 100\frac{9-n_L}{(11n_L-96)^2}$ and $\pi_S^{PD} = 32\frac{(n_L-6)^2}{(11n_L-96)^2}$.

A.4.2 Uniform pricing ($z_i = w$)

Stage 2: Optimal investments Suppose now that the supplier only offers one uniform price to the retailers, such that $z_i = w$. Again, the retailer has two sourcing alternatives. It can buy from the supplier, for which $z_i = w$ and $x_i = 0$ for all i. Then, non-integration profit for retailer i is:

$$\pi_i^{NI} = \frac{(2-w)^2}{9}. \tag{A.24}$$

Alternatively, it can integrate backwards into supply and use an outside option, in which case $z_i = o_i = 1 - x_L$. This means that the input price is determined by the large retailer's investments. Then, integration profit for retailer i is given by

$$\pi_i^I = \frac{(2-(1-x_L))^2}{9} - \frac{C(x_i)}{n_i}. \tag{A.25}$$

Taking the derivative of equation (A.25) with respect to investments x_i, $\partial\pi_i/\partial x_i = 0$, yields the optimal investment levels $x_L^{UP} = \frac{n_L}{36-n_L}$ and $x_S^{UP} = 0$. We observe that $x_L^{UP} < x_L^{PD}$, so the incentives of the large retailer change with the pricing regime. The retailers' integration profits are

$$\pi_L^I = \frac{4}{36-n_L};\ \pi_S^I = \frac{144}{(n_L-36)^2}. \tag{A.26}$$

Stage 1: Supplier chooses input prices At the first stage, the supplier chooses input prices, such that the retailers are indifferent between buying from the supplier, and acquiring the product elsewhere. It follows that (A.24) must equal (A.26), and solve for a common w^{UP}:

$$w^{UP} = 2 - 6\sqrt{\frac{1}{(36-n_L)}}. \tag{A.27}$$

Comparing (A.27) with (A.23), we observe that $w^{UP} < \frac{w_L^{PD}+w_S^{PD}}{2}$. Thus, the supplier offers a uniform input price to all retailers that is lower than the average prices charged under price discrimination. This corresponds to Katz's Lemmas 1 and A.1. Hence, the qualitative results of Katz (1987) are the same whether we consider fixed-cost investments or marginal-cost reducing investments.

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