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MANAGING CHANNEL PROFITS WHEN RETAILERS HAVE PROFITABLE OUTSIDE OPTIONS

Abstract

The channel-coordination literature typically focuses on how a supplier canovercome channel inefficiencies stemming from misaligned pricing incentives. In contrast, we show that when an incumbent supplier faces competition from other suppliers to supply the downstream firms, it may want to create inefficiencies. Our analysis offers useful prescriptions for how incumbent suppliers should react to competitive threats by smaller competitors, how manufacturers should react to powerful retailers who can produce their own private-label brands, and how upstream firms should optimally treat downstream firms who may have different marginal costs of distribution. Our analysis also explains why wholesale prices and thus final-goods prices would be expected to decrease when there is an increase in upstream or downstream competition.

JEL Classification: N/A

Keywords: channel coordination, Game theory, Distribution channels

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Managing Competing Channels through Nonlinear Contracts*

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Abstract

An upstream supplier constrained by downstream competition and the threat of demand-side substitution faces a trade-off between maximizing overall joint-profit and extracting surplus. By inducing more intra-brand competition through lower wholesale prices, the supplier makes it less attractive for downstream firms to switch to alternative sources of supply. This insight yields various implications that are strikingly different from those of extant models of vertical contracting: (1) Though the supplier can control competing channels through non-linear supply contracts, marginal wholesale prices and final goods' prices both decrease when either downstream competition intensifies or the supplier becomes more constrained by the threat of demand-side substitution. (2) It may be optimal for the supplier to "balance" his sales across competing channels through disadvantaging more efficient downstream firms, thereby smoothing out differences in market shares.

JEL Classification: L13, L41, L42.

Keywords: vertical control, price discrimination, input market.

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1 Introduction

This paper explores a model of nonlinear vertical contracting that delivers the following key results: (1) The supplier uses wholesale prices strategically to reduce the value of downstream firms' outside options. As a consequence, even though the supplier could fully control competing channels, he will optimally allow for joint profit dissipation through downstream competition. (2) This effect becomes stronger as downstream competition intensifies or as alternative upstream options become closer substitutes. The model thereby yields the prediction that both wholesale and retail prices monotonically decrease in downstream competition and upstream substitutability. (3) Also through this effect, the supplier may optimally enhance the competitiveness of less efficient downstream firms, relative to those of more efficient and in equilibrium larger competitors, through offering the former a lower marginal wholesale price. Thereby, the supplier ends up achieving more "balanced" sales across competing channels.

In our model, a supplier could fully control its channels through the use of observable non-linear contract, albeit his ability to extract profits is restricted by downstream firms' ability to switch to alternative sources of supply. The use of non-linear supply contracts allows one to distinguish between a firm's average wholesale price (which divides the surplus) and its marginal wholesale price (which affects a firm's competitiveness *vis à vis* its rivals). The supplier can set the marginal wholesale price to dampen downstream competition as desired and the infra-marginal terms to divide the surplus. It is well known that an *unconstrained* upstream monopolist would optimally set each retailer's marginal wholesale price to induce the monopoly outcome in the downstream market while dividing the surplus through the use of fixed fees or other infra-marginal terms. (Below we review the literature that considers only linear contracts, thereby severely constraining the supplier's ability to efficiently manage even a single channel.) We find, however, that the supplier no longer wants to implement the monopoly outcome once we consider the often more realistic case where downstream firms have access to an alternative source of supply. The reason for this - our result (1) - is as follows:

Although (joint) *surplus maximization* calls for relatively high marginal wholesale prices for all downstream firms, *surplus extraction* will be higher when the supplier instead charges relatively low marginal wholesale prices. The reason is that by reducing the marginal wholesale price for one downstream firm, say downstream firm i, the value of the outside option of rival firms, say of downstream firm j, is reduced. This follows because even after switching to another source of supply, firm j will still find itself in competition with firm i, which prices more competitively when it benefits from a lower marginal wholesale price. With the attractiveness of switching suppliers thus reduced for firm j, the supplier can extract more of their joint surplus. Because the same logic applies also with respect to the value of firm i's outside option, the supplier thus has an incentive to stimulate competition by lowering the marginal wholesale prices of all downstream firms.[1] This effect generates two key implications - our results (2) and (3). These implications are, as we discuss next, different from those in the extant literature and seem to conform well with observations.

As the alternative supply options become closer substitutes, or as the downstream market becomes more competitive (e.g., the number of firms increases or they become less differentiated), we find that the supplier will respond by cutting its marginal wholesale prices even further - our result (2). This result is again strikingly different from that obtained in the frequently analyzed benchmark case of unconstrained channel management by an upstream monopolist. There, final goods' prices end up being *independent* of the degree of downstream competition as the unconstrained supplier would optimally counteract an increase in the competitiveness of the downstream market by *raising* its marginal wholesale prices in order to maintain the monopoly outcome in the face of smaller downstream mark-ups. Implications are also different in another benchmark case of the literature, namely that where channel management is limited by non-observability of contracts. Hart and Tirole (1990) and others have shown that when contracts are unobservable and nonlinear, an upstream supplier may have an incentive to engage in opportunistic behavior against its downstream firms, which can lead to extreme intra-brand competition. Then, the supplier becomes in essence its own worst competitor, so that wholesale prices may no longer depend *at all* on either downstream or upstream competition.[2] Against these

[1] In Segal (1999) a principal's optimal contracts in a common agency setting similarly trade-off joint-surplus maximization and surplus extraction. Similarly, Fauli-Oller and Sandonis (2011) analyze the trade-off between maximizing industry profits and reducing outside options in a model of endogenous downstream mergers, and in Caprice (2006) a supplier's profits can increase when downstream competition becomes more intense as this erodes the value of outside options.

[2] For example, under a "passive-beliefs" restriction (under downstream Cournot competition, the result is more general), or in a contract equilibrium (cf. O'Brien and Shaffer, 1992), the supplier sets its marginal wholesale prices equal to its marginal cost. See Rey and Vergé (2004) for a comprehensive treatment.

two benchmarks, each of which also considers non-linear contracts, our model yields the predictions that both wholesale prices and prices in the final goods' markets decrease when either the supplier or the downstream firms are more constrained by competition.

Our model also yields implications across heterogeneous downstream firms - our result (3). If all firms were offered the same marginal wholesale price, the more efficient downstream firms would set lower final goods' prices than the less efficient downstream firms. Given this heterogeneity, how should the supplier optimally adjust its wholesale prices? Again, the tension between joint surplus *maximization* and surplus *extraction* determines the answer to this question. Here, the novel effect that we isolate is the following. The previously discussed adverse impact on a firm's outside option when its rivals are made more competitive through lower marginal wholesale prices is larger when the former firm is more efficient. Intuitively, this follows as the firm's larger margin implies that it suffers a larger absolute loss in profits when it loses a given volume of sales to a competitor. A lower marginal wholesale price for the less efficient firms thereby allows the supplier to extract a higher share of total surplus. Instead, to maximize total profits it would be required to handicap, rather than support, less efficient firms, thereby counteracting the higher margins that more efficient firms apply (cf. Inderst and Shaffer 2009).[3] We show how with linear demand the first (novel) effect can dominate, so that the supplier will optimally want to smooth out the competitive disadvantage of the less efficient firms.

In our model, the supplier may thus offer the less efficient firms a discount on its marginal wholesale price because this enhances its bargaining position with respect to the more efficient firms. As a consequence, the supplier's sales become more "balanced" across the different downstream firms (e.g., across the supplier's different distribution channels,

There, an analysis with "wary beliefs" and downstream price competition is also undertaken. They show that this leads to marginal wholesale prices that are set above the supplier's marginal cost. Even with linear demand and symmetry, only an implicit characterization (for linear-quadratic beliefs) is obtained.

[3] We abstract in our model from well-known other explanations in the literature for why some buyers may obtain (size-related) discounts, such as the ability of larger buyers to distribute a fixed cost of switching supplier over a larger volume. See, for example, the articles by Katz (1987) and Inderst and Valletti (2009). Another view is that larger buyers are inherently more powerful and can thus demand a discount. However, with nonlinear supply contracts, it is not clear why such a discount would have to be given "on the margin," thereby affecting intra-brand competition. Through a different mechanism, Raskovich (2003) has also found that smaller buyers might receive greater discounts than larger buyers. He finds that although large buyers can be pivotal to a supplier's decision whether or not to produce, and although one might think that a buyer's bargaining position would be improved by being pivotal, the opposite can hold because "If other buyers' payments fall short of costs, a pivotal buyer must cover the shortfall or forfeit consumption."

or across different outlets in the case of retailing). This is consistent with the observation of the UK Competition Commission that seemingly less competitive retailers sometimes receive more advantageous terms of supply (see, for example, its recently concluded investigation into the grocery retail market).[4] It is also consistent with what one of the authors learned in the course of (unpublished) interviews that were conducted during this investigation. In these interviews, producers of branded products alleged that they often employ various strategies designed to strengthen particular distribution channels. In order to support smaller retailers that purchase through wholesalers, for instance, producers occasionally sell lots and package sizes at a discount that is (functionally) exclusive to these smaller retailers. Using a simple static framework, our model provides a formal underpinning for such a strategy.[5]

In sum, based on a simple model of channel management through non-linear contracting, our main contribution is to derive predictions both on how wholesale and retail prices change in upstream and downstream substitutability and on how wholesale terms differ across heterogeneous buyers. An implicit assumption in competition policy, for instance, is that a tightening of competitive constraints would be expected to depress prices regardless of whether the tightening occurs in the upstream or downstream markets. We thus provide a framework with nonlinear supply contracts in which competitive constraints in both the upstream and downstream markets have the expected monotonic and intuitive impact on equilibrium wholesale and final goods' prices, which is strikingly different from the "benchmark" settings of unobservable contracts or of channel management by an unconstrained monopolistic supplier. As we show, apart from allowing us to isolate novel effects that should influence a supplier's optimal choice of wholesale prices, our model is also tractable enough to obtain explicit results for wholesale and retail prices in standard (workhorse) examples.

Sudhir and Datta (2009) have recently surveyed the business literature on pricing, noting the often starkly differing implications depending on which form of contracts is considered. So far we have contrasted our results to the literature that also allows for channel management with non-linear contracts, as we do in this paper. We claimed that compared to this literature, our model often yields both richer and more plausible impli-

[4] See http://www.competition-commission.org.uk/rep-pub/reports/2008/fulltext/538.pdf.

[5] In Chen (2003) a manufacturer boost sales to (at a larger scale) less efficient fringe retailers by lowering their wholesale price, as his other channel consists of a (dominant) retailer with bargaining power.

cations, and we stressed, in particular, the novel prediction that the supplier may wish to support weaker channels. With linear contracts price discrimination between different, competing channels - our result (3) - has been analyzed by numerous contributions, under varying specifications. These models can also generate the implication that the supplier charges a higher wholesale price to the "stronger" channel. The reason is, however, different to that in our model: Constrained by linear contracts, the supplier charges a higher wholesale price in a channel where (inverse) demand is less elastic (DeGraba 1990, Yoshida 2000, Dukes et al. 2006).[6] Viewed from this perspective, our result (3), together with these findings, thus provides strong support for the hypothesis that a supplier may, under some circumstances, optimally disadvantage more efficient and ultimately larger retailers, provided that this is not counteracted by asymmetric bargaining power.

However, though the comparative analysis with respect to downstream competition is generally ambiguous in the case of linear wholesale contracts, with linear demand results are again strikingly different to the implications in our model. Then, with linear wholesale contracts, the optimal wholesale price is invariant to both a change in downstream differentiation and a change in the number of downstream firms, while in our model both the wholesale price and the retail price decrease.[7] This provides a testable difference in implications. That said, note that in this paper we are agnostic as to which contractual assumptions are in general more suitable, though we would like to posit that this should depend on the particular industry under consideration.[8] Likewise, in this paper we do also no claim that our assumption of observable contracts is always more suitable than that of non-observable contracts. Whether observability is likely to hold in practice is context specific.[9] The predictions of our model are more likely to hold when (1) the supplier can commit not to renegotiate list prices (given that such renegotiations would also undermine its own bargaining power - compared to the envisaged situation where it makes take-it-or-leave-it offers to all downstream firms), and (2) the supplier is wary of losing its reputation

[6] A different implication is obtained in Inderst and Valletti (2009).

[7] Precisely, this holds for the linear demand function from Shubik and Levitan (1990), which is chosen to ensure that a increase in competition does not, at the same time, change the size of the total market (that is, for given symmetric prices).

[8] The use of linear vs. non-linear contracts may depend on firms' sophistication, legal constraints, or other factors such as problems of opportunistic behavior (e.g., Iyer and Villas-Boas 2003).

[9] It also allows us to abstract from supplier opportunism as the reason why overall joint profits may not be maximized. As noted above, we identify a different reason why this is the case and show how the resulting effect gives rise to various implications.

for only granting discounts that are anticipated by other downstream firms (which is more likely to hold when firms repeatedly interact). The predictions are less likely to hold when downstream firms are in a position to make credible counteroffers in bilateral negotiations or when reputation provides a weak discipline for the supplier (because interaction with downstream firms occurs relatively infrequently).

The rest of the paper is organized as follows. Section 2 introduces the model. Section 3 shows how intra-brand competition persists under the supplier's optimal contracts. Sections 4 and 5 conduct a comparative statics analysis both with respect to the downstream firms' cost characteristics and with respect to the level of competitive constraints faced in the upstream and downstream markets. Section 6 discusses various extensions and alternative applications of our modeling approach to vertical contracting. Section 7 offers some concluding remarks. The Appendix contains omitted proofs and additional calculations.

2 The Model

Consider a market with N competing downstream firms. Each firm $n \in \{1, ..., N\}$ operates at constant marginal cost c_n. Each firm also requires the use of an upstream input. Although our results extend to any technology that uses the input in fixed proportions, we assume for simplicity that one unit of the upstream good can be transformed into one unit of the downstream good. This would apply, in particular, to the case of retailing. Hence, our subsequent analysis is applicable, in particular, to contracting between a manufacturer and retailers. Then, our focus is on the supply relationship between a single supplier and the downstream firms through which it sells to consumers.

Downstream firms can substitute for the considered supplier, though the alternative supply option is less attractive (at least in equilibrium).[10] Precisely, suppose the incumbent supplier operates at constant marginal cost m, which, to simplify expressions, we normalize to zero ($m = 0$), while units from the alternative source can be purchased at constant marginal cost $\widehat{m} > m = 0$. Turning to the alternative source may also incur fixed costs $F \geq 0$, e.g., in the case of integrating backwards as in Katz (1987), though then the integrating firm may lack the necessary expertise to produce equally efficiently. Or, it

[10] See also, for instance, Katz (1987), O'Brien (1989, 2011), or Inderst and Valetti (2009) for other models that explicitly consider the threat of demand-side substitution, albeit there only linear supply contracts are considered.

may be that the incumbent supplier is a local producer and the input can alternatively be procured from the wider market at a competitive, albeit higher price, given higher transportation costs. Note that our results with linear demand would be unchanged if instead of putting a firm at a cost disadvantage, the alternative supply source would reduce the quality of the final product.

As will become clear, any fixed costs of switching to the alternative source of supply affect only the distribution of surplus between the supplier and downstream firms and do not affect marginal wholesale prices or final goods' prices.[11] To simplify the expressions, we thus set $F = 0$. Then, the difference $\Delta_m \equiv \widehat{m} - m$ fully captures the advantage the incumbent supplier has due to its superior product or technology. Intuitively, the smaller is this difference, the less the supplier will be able to extract from each of the downstream firms. Variations in Δ_m thus intuitively capture the degree of upstream substitutability or competitive pressure on the supplier.

For our main analysis we make the following specifications regarding vertical contracting. (In Section 6 we discuss how these specifications can be modified.) We assume the incumbent supplier can make take-it-or-leave-it offers. Each offer specifies a pair (t_n, w_n), which consists of a fixed transfer t_n together with a constant marginal wholesale price w_n. Let $k_n = c_n + w_n$ denote downstream firm n's marginal cost of operating if it accepts the offer and $\widehat{k}_n = c_n + \widehat{m}$ denote downstream firm n's marginal cost of operating if it rejects the offer and instead chooses its alternative supply option. The offers, as well as the accept or reject decisions, are observed by all market participants.

After the offers are made, and after they are accepted or rejected, downstream firms compete by choosing their final goods' prices p_n according to the demand each faces for its respective good. Sales to consumers are then made and payoffs are realized for all market participants.[12]

To summarize, the timing of moves is as follows. First, the incumbent supplier makes its offers (t_n, w_n). Second, offers are accepted or rejected. If a downstream firm rejects its offer, it can turn to its alternative supply option and procure the input at constant marginal cost $\widehat{m} > 0$. If it accepts its offer, it can procure the input according to the terms

[11] In contrast, fixed costs of switching to the alternative supply do affect marginal wholesale prices in the models in Katz (1987) and Inderst and Valletti (2009a), which restrict attention to linear supply contracts.

[12] Our set-up does not allow for the possibility of renegotiation if an offer is rejected. We comment in Section 6 on the case in which renegotiation is allowed and the supplier can make a new offer not only to those buyers who had accepted their initial offers but also to those buyers who had rejected their offers.

of its accepted contract. Third, the downstream firms compete by setting final prices p_n.

3 Persistence of Downstream Competition

Let $\mathbf{k}$ denote the vector of downstream marginal costs when all offers are accepted, where the nth component of $\mathbf{k}$ is given by $k_n = c_n + w_n$. We assume for convenience that, for given $\mathbf{k}$, there is a unique price equilibrium in pure strategies in the downstream market.

Denote the respective equilibrium final prices by $p_n(\mathbf{k})$, the vector of final prices by $\mathbf{p}(\mathbf{k})$, and the respective demands that follow from these prices by $q_n(\mathbf{p})$. Then, the respective downstream profits *gross of the fixed transfers* $(t_1, ..., t_n)$ are given by

$$\pi_n(\mathbf{k}) = q_n(\mathbf{p}) \left[p_n(\mathbf{k}) - k_n \right],$$

and thus the sum of the upstream and downstream profits when all offers are accepted is

$$\begin{aligned} \Omega(\mathbf{k}) &= \sum_{n=1}^{N} \left[\pi_n(\mathbf{k}) + q_n(\mathbf{p}) w_n \right] \\ &= \sum_{n=1}^{N} q_n(\mathbf{p}) \left[p_n(\mathbf{k}) - c_n \right]. \end{aligned}$$

We will refer to $\Omega(\mathbf{k})$ as the total industry surplus, or equivalently, as the industry profit.

Unconstrained Monopolist. Suppose for a moment that the supplier is an *unconstrained* monopolist, so that downstream firms have no outside option (or, equivalently, have an outside option of value zero). Then, through the respective choice of the fixed parts t_n, the supplier's take-it-or-leave-it offers would extract *all* industry profits, $\Omega(\mathbf{k})$. As a consequence, the supplier's optimal choices of $w_1, ..., w_n$ would maximize $\Omega(\mathbf{k})$. That is, they would induce the downstream firms to fully internalize the effect of the final goods' prices on $\Omega(\mathbf{k})$. The outcome in this case would thus be the same as what a vertically-integrated firm would obtain if it were to control both the input production and the sale of the final goods at all N downstream firms (cf. Inderst and Shaffer (2009) for details).

Optimal Wholesale Prices of a Constrained Supplier. Now suppose that the downstream firms do in fact have a viable outside option. In this case, the incumbent supplier will be constrained by the threat of demand-side substitution, which in turn will constrain its optimal choice of contracts. In the event a single downstream firm n were to reject the supplier's offer and turn instead to its alternative supply option, downstream equilibrium prices and profits would no longer be determined using the marginal operating costs $k_n = c_n + w_n$ for firm n, but, instead, would be determined using $\widehat{k}_n = c_n + \widehat{m}$. In a slight abuse of notation, we let $\pi_n(\widehat{\mathbf{k}}_n)$ denote the (off-equilibrium) profits of firm n when firm n is the only firm that rejects the incumbent's offer. Here, $\widehat{\mathbf{k}}_n$ is the relevant *vector* of downstream marginal costs, where $k_{n'} = c_{n'} + w_{n'}$ for all firms $n' \neq n$ and $\widehat{k}_n$ for firm n.

To solve for the equilibrium contracts in this case, we proceed in two steps. We first derive the respective fixed parts t_n. We then turn to the derivation of the marginal wholesale prices w_n. The respective downstream firm accepts the supplier's offer only if

$$\pi_n(\mathbf{k}) - t_n \geq \pi_n(\widehat{\mathbf{k}}_n).$$

By optimality for the supplier, this participation constraint will be binding, which yields

$$t_n(\mathbf{k}) = \pi_n(\mathbf{k}) - \pi_n(\widehat{\mathbf{k}}_n). \tag{1}$$

Using the expression for $t_n(\mathbf{k})$ in (1), the supplier's total profits are thus

$$\begin{aligned} \Pi &= \sum_{n=1}^{N} [t_n(\mathbf{k}) + q_n(\mathbf{p}) w_n] \\ &= \Omega(\mathbf{k}) - \sum_{n=1}^{N} \pi_n(\widehat{\mathbf{k}}_n). \end{aligned}$$

Differentiating Π with respect to w_n, and using the fact that w_n affects not only $\Omega(\mathbf{k})$ but also the outside options of all firms other than firm n, we thus have the constrained incumbent supplier's respective first-order condition for the optimal wholesale price w_n:

$$\frac{d}{dw_n}\Omega(\mathbf{k}) = \frac{d}{dw_n} \sum_{n' \neq n} \pi_{n'}(\widehat{\mathbf{k}}_{n'}). \tag{2}$$

It is convenient to suppose that the supplier's maximization problem is strictly quasi concave and that, in equilibrium, all downstream firms are active. Then, the system of first-order conditions in (2) pins down a unique set of wholesale prices at which $q_n > 0$.

The choice of wholesale prices maximizes total industry surplus if and only if the right-hand side of (2) is zero. However, the right-hand side of (2) will not in general be zero when the downstream firms' demands interact because in that case the marginal operating cost of firm n, i.e., k_n, would affect the (off-equilibrium) profits of all other firms n'. This follows because w_n, and hence k_n, affects the price p_n set by firm n. In this paper, we focus on the case where the firms' products are substitutes, so that for all $q_n > 0$ and $\pi_{n'} > 0$,

$$\frac{d\pi_{n'}}{dk_n} > 0 \text{ for all } n' \neq n. \tag{3}$$

That is, all else equal, firms gain when their rivals have higher marginal operating costs.[13]

In the presence of binding outside options for downstream firms, the supplier's respective choice of each marginal wholesale price w_n thus trades off two conflicting objectives: to maximize total industry surplus, given that the supplier becomes the "residual claimant" through his choice of t_n, and to minimize the value of each downstream firm's outside option. These objectives correspond to the left and right-hand sides of (2), respectively.

If w_n were chosen by the supplier so as to maximize total industry surplus, for a given choice of $w_{n'}$ for all other firms, a marginal change of w_n would have a zero first-order effect on industry profits. On the other hand, from (3), a marginal decrease in w_n, and thus in $k_n = c_n + w_n$, would have a strictly negative first-order effect on the outside option of all other firms n'. Thus, it follows straightforwardly that, despite the presence of non-linear contracts, a constrained supplier will no longer set its marginal wholesale prices so as to fully monopolize the downstream market. We have thus arrived at the following result.

Proposition 1 *When the supplier's choice of nonlinear contracts is constrained by the outside options of the downstream firms, the optimal marginal wholesale prices w_n satisfy the first-order condition in (2). It follows that, for given $w_{n'}$, the choice of w_n is strictly lower compared to the case in which the downstream firms have no valuable outside option.*

Relative to the case of unconstrained monopoly, the supplier benefits from a reduction in w_n because this reduces the outside option value of all other downstream firms $n' \neq n$.

In what follows, we will use the characterization of wholesale prices in (2) to obtain additional implications. In Section 4 we obtain comparative-statics results across downstream firms with different cost efficiencies and thus different sizes. In Section 5 we analyze how competition in the upstream and downstream markets affect wholesale and final prices.

[13] Under standard regularity conditions, this follows when the cross-price effect is positive (substitutes).

4 Heterogeneous Downstream Firms

We now analyze how marginal wholesale prices are affected by cost differences among firms. Although our qualitative results extend readily to an arbitrary number of downstream firms, we facilitate exposition by setting $N = 2$ and stipulating that demand be symmetric (i.e., $q_n = q(p_n, p_{n'})$ for $n' \neq n$). Suppose then, without loss of generality, that $c_1 < c_2$.

To proceed, we begin by writing out the left-hand side of condition (2) more explicitly. Once again, it is convenient to consider first the case of an unconstrained monopolist.

Unconstrained Monopolist. Using the downstream firms' first-order conditions with respect to p_n, which imply $\frac{\partial \pi_1}{\partial p_1} = \frac{\partial \pi_2}{\partial p_2} = 0$, the condition $d\Omega/dw_1 = 0$ can be written as

$$\frac{\partial \pi_1}{\partial p_2}\frac{dp_2}{dw_1} + \frac{\partial \pi_2}{\partial p_1}\frac{dp_1}{dw_1} + w_1\left[\frac{\partial q_1}{\partial p_1}\frac{dp_1}{dw_1} + \frac{\partial q_1}{\partial p_2}\frac{dp_2}{dw_1}\right] + w_2\left[\frac{\partial q_2}{\partial p_1}\frac{dp_1}{dw_1} + \frac{\partial q_2}{\partial p_2}\frac{dp_2}{dw_1}\right] = 0. \quad (4)$$

The first two terms in (4) correspond to the indirect effect on the downstream firms' profits from an increase in w_1, and the last two terms in (4) correspond to the indirect effect on the supplier's profit from an increase in w_1.[14] The condition $d\Omega/dw_2 = 0$ is symmetric.

Simplifying (4) and combining the respective conditions for $n = 1, 2$ yields

$$\begin{aligned} &\left[\frac{dp_1}{dw_1} - \frac{dp_1}{dw_2}\right]\left[(p_2 - c_2)\frac{\partial q_2}{\partial p_1} + w_1\frac{\partial q_1}{\partial p_1}\right] \\ = &\left[\frac{dp_2}{dw_2} - \frac{dp_2}{dw_1}\right]\left[(p_1 - c_1)\frac{\partial q_1}{\partial p_2} + w_2\frac{\partial q_2}{\partial p_2}\right]. \end{aligned} \quad (5)$$

Condition (5) must hold if the supplier is choosing w_1 and w_2 to maximize total industry surplus. The first term in brackets on both sides of (5) captures the difference in the pass through to a firm's final price of a change in a firm's own marginal wholesale price compared to a change in its rival's marginal wholesale price. Although these terms would be the same under symmetry (i.e., when evaluated at the same quantities and final prices), with cost differences, they will generally not be the same. This follows because the quantities sold and the prices set may in general differ. As a result, without some restrictions on demand, it is not possible to determine *a priori* for which firm the difference will be larger.

To obtain further results, and to isolate the new effects we wish to examine, we now turn our attention to the case of linear demands. This allows us to use the fact that the respective marginal effects on both sides of (5) are independent of the realized demand.

[14] The direct effect of an increase in w_1 is a pure transfer from downstream firm 1 to the supplier.

This means that the pass-through effects will be the same for both firms, regardless of the different quantities sold, as will the own-price and cross-price effects, which we denote by

$$\frac{\partial q_n}{\partial p_n} = \beta < 0 \text{ and } \frac{\partial q_n}{\partial p_{n'}} = \gamma > 0.$$

With this simplification, condition (5) can thus be rewritten as

$$(w_1 - w_2)(\beta - \gamma) = \gamma \left[(p_1 - k_1) - (p_2 - k_2) \right], \tag{6}$$

which implies that the difference in wholesale prices must be inversely proportional to the difference in markups. It follows that the more efficient firm ($n = 1$), which will have the larger markup in equilibrium, must be given a strictly lower marginal wholesale price ($w_1 < w_2$) if total industry surplus is to be maximized (cf. also Inderst and Shaffer 2009).[15]

Reducing Outside Options. When downstream firms have access to valuable outside options, we show that the *opposite* prediction holds. Condition (2) implies that in addition to considering the marginal impact of w_n on total industry surplus, the incumbent supplier must also consider the marginal impact of w_n on the outside option of firm n'. We have already shown that in order to reduce this outside option, the supplier has an incentive to lower w_n below what it would charge if it were an unconstrained monopolist. Given the cost differences downstream, however, there is no reason to believe that it would lower its marginal wholesale price equally for both firms. Thus, it is important to consider the effect a given wholesale price reduction would have on the outside options of the two firms, and to ask for which firm this effect would be stronger (note that firm 1's outside option would thus decrease by more than firm 2's outside option if $d\pi_1(\widehat{\mathbf{k}}_1)/dw_2 > d\pi_2(\widehat{\mathbf{k}}_2)/dw_1$).

Determining for which firm the "outside option effect" would be stronger turns out to be straightforward once it is recognized that the more efficient firm always has the lower marginal operating cost k_n in equilibrium (i.e., $c_1 < c_2$ implies $k_1 < k_2$ in equilibrium). It follows from this that the effect will be stronger for the more efficient firm if and only if it is also stronger for the firm with the lower marginal operating cost, which holds when[16]

$$\frac{d^2\pi_n}{dk_n dk_{n'}} < 0 \text{ for } n' \neq n. \tag{7}$$

[15] To see this, suppose that $k_n < k_{n'}$, so that firm n's operating cost is lower. Then, firm n will have the lower price in equilibrium, $p_n < p_{n'}$, which implies that it will have the larger markup $p_n - k_n > p_{n'} - k_{n'}$ (this follows from the first-order condition $(p_n - k_n)\frac{\partial q_n}{\partial p_n} + q_n = 0$, where $\frac{\partial q_n}{\partial p_n} = \beta$). In particular, when $w_n = w$, so that, together with $c_1 < c_2$, this implies $k_1 < k_2$, the right-hand side of (6) would be strictly positive, while the left-hand side would be zero. To equalize the two sides, it must hold that $w_1 < w_2$.

[16] Note that (7) is calculated at arbitrary values k_n and $k_{n'}$, not just at equilibrium values.

Condition (7) is commonly used in the literature and is satisfied by many functional specifications (cf. Athey and Schmutzler, 2001), including the case of linear demands.

When condition (7) holds, a reduction in the rival firm's marginal operating cost will have a larger negative effect on a firm's profit when the firm has a lower marginal operating cost (i.e., the reduction in the more efficient firm's outside option will be greater). Intuitively, when k_n is smaller, making firm n more competitive, firm n sells at a higher per-unit markup (cf. our previous discussion). It follows that when the firm's rival becomes more competitive following a reduction of its own marginal operating cost, the resulting decrease in firm n's demand is more costly in terms of lost profits, compared to a situation in which firm n has a higher marginal operating cost and thus a lower per-unit markup. This suggests that the lower wholesale price should go to the less efficient firm.

Optimal Discriminatory Wholesale Prices. We now explore the implications of the discussion above and consider which is stronger, the incentive that arises from (6) (which suggests that a lower wholesale price should be given to the more efficient firm) or the incentive that arises from (7) (which, assuming it holds, suggests that a lower wholesale price should be given to the less efficient firm). In general, it is not possible to say which one will dominate. However, it turns out that in the case of linear demands, the trade-off is always resolved in favor of the latter: the optimal marginal wholesale price will be *higher* for the more efficient firm (i.e., $w_1 > w_2$) when the incumbent supplier is constrained.

Proposition 2 *Consider the optimal non-linear contract of a supplier that is constrained by the downstream firms' option of switching to a different source of supply. On the one hand, the supplier has an incentive to give the more efficient downstream firm a lower marginal wholesale price in order to increase total industry surplus, which can then be extracted via the fixed parts of its contract. On the other hand, when condition (7) is satisfied, the supplier also has an incentive to do the opposite, as giving an advantage to a less efficient firm has a larger negative effect on the outside option of its rival. In the case of linear demands, the latter incentive is sufficiently strong that marginal wholesale prices are always higher in equilibrium for the more efficient and thus larger downstream firm.*

Proof. See Appendix.

With linear demands, the effect that we newly identify in this paper is sufficiently strong that it makes the supplier want to handicap the more efficient firm. This reduces total industry surplus. To see why, recall our observation that a firm with a lower marginal cost of operating, k_n, will have a strictly higher markup, $p_n - k_n$, in equilibrium. This means that the more efficient firm's cost advantage will not adequately be reflected in a reduction in prices, and thus a shift in sales at the margin from the less efficient firm to the more efficient firm will increase industry surplus.[17] It follows that, all else equal, industry surplus will be larger if the less efficient firm receives a higher marginal wholesale price. This is indeed the outcome when the supplier is unconstrained. Instead, by setting $w_1 > w_2$, the constrained supplier makes the allocative inefficiency worse. Although total industry surplus is thereby reduced, the supplier obtains a larger overall share of the profit.[18]

Note finally that Proposition 2 focuses on the determination of the marginal wholesale price w_n because the choice of t_n is not relevant for downstream competition and prices. However, w_n is not the same as the average wholesale price W_n, where W_n is given by

$$W_n = w_n + \frac{t_n}{q_n}. \tag{8}$$

Although the less efficient downstream firm obtains a lower marginal price when demand is linear, this does not imply that it will be able to purchase its input from the incumbent supplier at overall more favorable conditions (i.e., it should not be taken to suggest that $W_2 < W_1$ necessarily follows from $w_2 < w_1$) because this need not be true in general.[19] Rather, as noted in the Introduction, a main contribution of our analysis is to show how a supplier that has some scope to optimally manage different distribution channels can instead gain by making smaller, less efficient buyers more competitive "at the margin". We will return to a comparison of the average and marginal wholesale prices in Section 6.

[17] Note that we consider symmetric demand, which allows us to abstract from differences in demand elasticities when prices are symmetric.

[18] As the opposite, $w_1 < w_2$, would result when the supplier was unconstrained, it may be asked how these two cases are linked. Note, however, that as the alternative supply option becomes increasingly attractive, it does not become irrelevant for both, i.e., the less and the more efficient firm, at the same time.

[19] It is also important to note that our set-up abstracts from other sources of size-related advantages in procuring input. For instance, Katz (1987) and Inderst and Valletti (2009a) show that lump-sum switching costs can give rise to size advantages because larger buyers can distribute these costs over a larger volume.

5 Changing Competition

We now explore the model's insights and predictions with respect to how varying the degree of competition in the downstream market affects equilibrium prices, and with respect to how these prices will be affected by the closeness of substitutes to the supplier's input.

Threat of Demand-Side Substitution. We first discuss a reduction in $\widehat{m}$. Clearly, this leads to an increase in the value of the outside option of downstream firms. Consequently, the supplier's offer must leave each firm with higher profits. As we show next, a change in the attractiveness of the outside option also affects marginal wholesale prices and, thereby, ultimately final goods' prices. This may at first not be immediate. After all, it is not obvious why the supplier, when choosing its contracts (t_n, w_n), would be expected to place less weight on maximizing industry profits when the threat of demand-side substitution increases. Why would it not just reduce the fixed component t_n in its contracts, thereby paying the downstream firms directly for the increase in the value of their outside option?

The key to understanding why it would not just reduce t_n comes from condition (7). Note first that a downstream firm which operates under its outside option becomes more competitive when its respective marginal cost, $\widehat{m}+c$, decreases. From (7), such a deviating firm, which rejects the supplier's offer, is hurt *more* when the supplier lowers the marginal wholesale price, $w_{n'} = w$, of the firm's rival. Consequently, once $\widehat{m}$ decreases, the (negative) effect that a marginal decrease of w has on the outside option of all downstream firms is larger. Given the trade-off in the first-order condition (2) for w_n, this induces the supplier to place more weight on the reduction of the firms' outside options and less on the maximization of industry profits. Appealing again for simplicity to strict quasiconcavity of the supplier's program, the model thus predicts that the incumbent's wholesale prices would be expected to decrease in the face of an increasingly attractive alternative source of supply — even though the outside option is not used in equilibrium and even though the incumbent uses nonlinear contracts. We restate this in the following Proposition.

Proposition 3 *If $\widehat{m}$ decreases (i.e., if the downstream firms' cost of obtaining the input from another source decreases), the supplier would respond by offering a lower marginal wholesale price, w_n. It follows that all downstream prices p_n would be lower as a result.*

Downstream Competition. We consider next a change in downstream competition. As is standard, we do so by considering both an increase in the number of rival downstream firms and a reduction in product differentiation. As we saw previously in the case of heterogeneous downstream firms, the characterization of marginal wholesale prices generally depends on higher-order derivatives of the demand system. To abstract from this, it is convenient to focus on linear demand (so that all higher-order derivatives are zero). Nevertheless, we can provide some general intuition for our comparative-static results.

Consider first a change in the number of downstream firms N. In this case, the key thing to notice is that now in each first-order condition for the respective wholesale price w_n, the marginal effect on the outside option of all other $N-1$ firms shows up. For each of these firms n', this represents the change in own demand due to the induced price changes of all other firms multiplied by the firm's (off-equilibrium) margin, $\widehat{p}_{n'} - \widehat{k}_{n'}$. Similarly, consider a reduction in product differentiation. Then, the impact that a lower and thus more competitive marginal wholesale price w_n for one firm has on the outside option of all other firms n' is also intuitively larger. (Note that in the absence of competition, it is even not possible for w_n to affect the value of rivals' outside options). While these two effects work towards strictly lower marginal wholesale prices for all firms when downstream competition increases (when either the number of firms increases or their products become less differentiated), there is also a countervailing force. As we show explicitly in the considered linear examples, an *unconstrained* monopolist would then want to increase the marginal wholesale price, so as to further dampen downstream competition. As it turns out, the novel effect, which works through the value of outside options, is again stronger than this countervailing force, so that a more competitive downstream market indeed results in lower prices, even though the supplier offers observable non-linear contracts.

5.1 Hotelling Competition

Consider a model of Hotelling competition with two firms. We assume demand is uniformly distributed over the unit interval with the two firms located at the extremes. Each consumer has valuation $v > 0$ and transportation costs are denoted by $\tau > 0$. The demand function when all consumers buy and both firms sell positive quantities is then

$$q_n = \frac{1}{2} - \frac{1}{2\tau}(p_n - p_{n'}). \tag{9}$$

Note that the properties of q_n are standard. It is decreasing in firm n's own price, increasing in firm n''s price, and equal to 1/2 when the final goods' prices are the same (in that case, each firm has 50% of the market). Substituting this demand function into the first-order conditions from the proof of Proposition 2, we obtain the marginal wholesale prices[20]

$$w_n = \widehat{m} + \frac{1}{2}\left[3\tau - \frac{1}{3}(c_n - c_{n'})\right], \tag{10}$$

and the resulting induced final goods' prices[21]

$$p_n = \widehat{m} + \frac{5}{2}\tau + c_n - \frac{7}{18}(c_n - c_m). \tag{11}$$

The characterization of optimal prices confirms our previous results. The minus sign in front of the term $\frac{1}{3}(c_n - c_{n'})$ in the expression for w_n implies that the more efficient downstream firm does indeed receive a higher marginal wholesale price from the supplier (cf. Proposition 2). And it is straightforward to show that for all $\widehat{m}$ such that the market is covered and both firms have positive market shares, marginal wholesale prices are indeed lower than what an unconstrained monopolist supplier would charge (cf. Proposition 1). Note finally that the expressions in (10) and (11) also relate the marginal wholesale and final goods' prices to the degree of competition τ in the downstream market and the constraint $\widehat{m}$ that the supplier faces (where the latter results confirm Proposition 3).

Proposition 4 *With Hotelling competition, when the market is covered and both firms sell positive quantities, the marginal wholesale price w_n and final price p_n are increasing in τ and $\widehat{m}$. Thus, for example, if τ decreases (i.e., if downstream competition were to become more intense), or if $\widehat{m}$ decreases (i.e., if the cost of obtaining the input elsewhere were to decrease), the supplier would respond by offering a lower marginal wholesale price.*

Taken together, our setting with non-linear contracts and a constrained incumbent supplier, when applied to the workhorse model of Hotelling competition, thus has the feature that supply-side constraints (as expressed by a change in $\widehat{m}$) as well as demand-side constraints (as expressed by a change in τ) affect both wholesale prices and final goods' prices. In particular, wholesale and final goods' prices decrease as either downstream firms or the supplier become less differentiated compared to their respective competitors.

[20] Note that for this characterization to apply, the consumers' utility from purchasing the product must be sufficiently high that, under the characterized equilibrium prices, the market is indeed fully covered.

[21] Details of the calculations for the Hotelling model can be found in Appendix B.

Note that with symmetry, so that $c_1 = c_2$, the expressions in (10) and (11) simplify to

$$w_n = w = \widehat{m} + \frac{3}{2}\tau$$

and

$$p_n = p = \widehat{m} + \frac{5}{2}\tau + c.$$

As is well known, the margin for each downstream firm, $p - c - w$, is then simply τ. As competition increases, both the supplier's and the downstream firms' margins decrease.

Comparison to Benchmarks. To conclude our analysis of the Hotelling model, we compare the explicit characterization of w_n and p_n above to the two benchmark cases that we discussed in the Introduction (recall that in the first benchmark, contracts are unobservable, whereas in the second benchmark, the incumbent supplier is unconstrained).

Regarding the first benchmark case, there can be an extreme opportunism problem when contracts are non-linear and unobservable. In the commonly assumed case of "passive beliefs" (cf. McAfee and Schwartz, 1994; Rey and Verge, 2004), for example, wholesale prices equal the supplier's marginal cost, which in our setting implies $w_n = 0$.[22] In this case, final goods' prices strictly decrease when τ decreases, while marginal wholesale prices are unaffected. Note that marginal wholesale prices are also unaffected when competition from another source of supply increases, as the incumbent supplier is its own worst competitor.

In the second benchmark case, w_n is chosen to maximize total industry surplus $\Omega(\mathbf{w})$. In this case, if the market is fully covered, we obtain the (monopolizing) wholesale prices[23]

$$w_n^{Mon} = v - \frac{3}{2}\tau - \frac{1}{4}(c_n + 3c_{n'})$$

and the resulting induced final goods' prices

$$p_n^{Mon} = v - \frac{1}{2}\tau + \frac{1}{4}(c_n - c_{n'}).$$

In this case, the difference in the marginal wholesale prices between firms 1 and 2 is $(c_1 - c_2)/2$, which is strictly negative when $c_1 < c_2$ (i.e., when firm 1 is more efficient than firm 2). In contrast, the respective difference was strictly positive for the constrained supplier

[22] Marginal-cost pricing also arises in the contract equilibrium setting in O'Brien and Shaffer (1992).

[23] To obtain these expressions, it is convenient to solve first for the *retail* prices that maximize $q_1(p_1 - c_1) + q_2(p_2 - c_2)$, where q_n is given by (9). (The market is covered by at least one product when $p_1 + p_2 \leq 2v - \tau$.) This yields p_n^{Mon}. Requiring then that these prices are obtained from $p_n = \tau + (2k_n + k_{n'})/3$ yields w_n^{Mon}.

(cf. expression (10)). Further, as transportation costs decrease, making the downstream firms closer substitutes, both wholesale and final goods' prices increase. Again, this is the opposite of what we obtain for the constrained supplier (cf. expression (10) and (11)).

Admittedly, with an unconstrained supplier and Hotelling competition, the fact that the optimal final goods' price p_n^{Mon} is inversely related to τ is somewhat mechanic, provided that the market remains covered. In that case, to ensure that all consumers will continue to buy the product as τ increases, final goods' prices must fall, which in turn requires that the supplier's marginal wholesale price w_n^{Mon} must fall as well. However, as we show in the next subsection, the case of an unconstrained supplier yields predictions that are opposite to those of our model where the supplier is constrained even when total demand is elastic.

5.2 Elastic Total Demand

We next consider a linear demand system in which total demand is elastic (unlike in the Hotelling model where demand was assumed to be inelastic) and $N \geq 2$. In particular, using the symmetric, linear-quadratic specification of the representative consumer's utility that is found in Shubik and Levitan (1980), we obtain for good n the demand function

$$q_n = \frac{1}{N}\left[1 - p_n - \theta\left(p_n - \frac{\sum_{n' \in N} p_{n'}}{N}\right)\right] \quad (12)$$

and the indirect demand function

$$p_n = 1 - \frac{N+\theta}{1+\theta}q_n - \frac{\theta}{1+\theta}\sum_{n' \neq n} q_{n'}.$$

This demand system has the attractive property that when changing the degree of substitution, θ, the sum of the individual quantities does not change when firms charge symmetric prices.[24] The same is true when the number of firms N increases. Hence, the degree of competition along both dimensions can be varied without affecting the size of the market.

In order to obtain explicit expressions when there are more than two downstream firms, we focus on the symmetric case: $c_n = c$. And, to make production profitable, we stipulate that $c < 1$.[25] Given these restrictions, we derive in the proof of Proposition 5 an explicit characterization of the equilibrium final prices and profits as a function of the marginal

[24] Goods are independent if $\theta = 0$ and become increasingly substitutable as θ increases.

[25] This restriction on the downstream firms' marginal costs is needed because the overall market size is equal to one and we have stipulated, for convenience only, that the supplier's own marginal cost is zero.

wholesale prices. It is useful to note that in the symmetric case with $w_n = w$, we obtain

$$p_n = p = \frac{1}{2+\theta-\frac{1}{N}\theta}\left[1+(c+w)\left(1+\theta-\frac{1}{N}\theta\right)\right] \tag{13}$$

and

$$\pi_n = \pi = \frac{1}{N}\frac{1+\theta-\frac{\theta}{N}}{\left(2+\theta-\frac{1}{N}\theta\right)^2}(1-c-w)^2. \tag{14}$$

For a given marginal wholesale price w, it follows that both prices and profits strictly decrease as either N or θ increase. Further, it follows that, $p \to c + w$ as $\theta \to \infty$. We analyze below how these prices change once we take into account the adjustment of w.[26]

Benchmarks. It is now convenient to set the stage by deriving the comparative statics for the two respective benchmarks. Regarding the first benchmark, $w_n = 0$ for the same reasons as before when contracts are unobservable and beliefs are passive. In this case, final prices strictly decrease when goods become less differentiated (higher θ) or when the number of firms increases (higher N), while the marginal wholesale prices are not affected.

Regarding the second benchmark, an unconstrained supplier will optimally choose $w_n = w$ to maximize total industry surplus. This yields the (monopolizing) wholesale prices

$$w^{Mon} = \frac{1}{2}\theta\frac{N-1}{N}\frac{1}{1+\theta-\frac{1}{N}\theta}(1+c)$$

and the resulting induced final goods' prices

$$p^{Mon} = \frac{1}{2}(1+c).$$

As can be seen from these expressions, the monopoly price p^{Mon} is independent of downstream competition (and thus does not vary with either θ or N).[27] This outcome holds because, as in the Hotelling case, the marginal wholesale price strictly increases when downstream competition intensifies (i.e., w^{Mon} strictly increases when either θ or N increase). In the case of independent downstream firms ($\theta = 0$), the supplier would choose $w^{Mon} = 0$. In the case of perfect competition downstream ($\theta = \infty$), the supplier would choose $w^{Mon} = p^{Mon}$. For intermediate levels of competition, the supplier would choose w^{Mon} between 0 and p^{Mon}, compensating for higher intra-brand competition in the downstream market by pushing up the marginal wholesale price in order to dampen competition.

[26] Incidentally, with the demand system (12), for a given marginal wholesale price w, the symmetric final price p does not converge to $c + w$ as $N \to \infty$, although clearly downstream profits satisfy $\pi \to 0$.

[27] The calculations are straightforward and obtained from the expressions in the proof of Proposition 5.

Characterization. Making use of the first-order conditions in (2), the constrained supplier's profit-maximization problem can be solved for the symmetric optimal marginal wholesale price $w_n = w$.[28] This price can then be substituted into (13) to obtain the symmetric equilibrium final goods' price $p_n = p$. Doing so yields the following comparative-static results (where the comparative statics on $\widehat{m}$ follow already from Proposition 3).

Proposition 5 *With Shubik-Levitan demands, when the downstream firms are equally efficient, $c_n = c$, the marginal wholesale and final goods' prices have the following properties:*
i) The marginal wholesale price w and final price p are increasing in $\widehat{m}$. If the cost of the alternative supply were to increase (decrease), the supplier would respond by raising (lowering) its wholesale price, thereby inducing a higher (lower) final price p.
ii) The final price p is decreasing in θ and N. Final prices decrease (increase) as the downstream market becomes more (less) competitive. This is so whether the goods become less (more) differentiated or the number of competitors increases (decreases).

Proof. See Appendix.

The comparative-static results in Proposition 5 follow from the same logic as in the previously analyzed model with Hotelling competition. The only difference is that here the market demand is elastic, whereas in the Hotelling model, the market demand is inelastic. Nevertheless, in both models, prices in the marketplace decrease both as the value of the outside option increases (the supplier becomes more constrained) or as the downstream market becomes more competitive (the goods become more substitutable or the number of firms increases). These results hold even though contracts are observable and nonlinear.

We can push the results in the Shubik-Levitan case further by noting that $\lim_{\theta \to \infty} p = \widehat{m} + c$.[29] That is, as the goods become essentially undifferentiated, final prices converge to the downstream firms' marginal operating costs under the *alternative* supply option. Once again, this result holds despite the ability of the supplier to use non-linear contracts. It also follows from this result that as the supplier's cost advantage over the alternative supply source, $\widehat{m}$, goes to zero, the outcome becomes perfectly competitive, with $p = c$.

[28] We relegate an explicit characterization of the expression for w_n to the proof of Proposition 5.

[29] This follows immediately from inspecting expression (24) in the proof of Proposition 5. Because this expression is always equal to $1 - 2p - c$ (cf. the derivation in the proof), it is easily verified that this can only be the case when $p - (\widehat{m} + c) \to 0$. Otherwise, expression (5) would not be bounded as $\theta \to \infty$.

Recall that generally there is a trade-off in the adjustment of the marginal wholesale price as competition intensifies. While, as we discussed above, a more competitive wholesale price for one firm has a larger impact on the outside option of its rivals, there is also more scope to dampen downstream competition by increasing wholesale prices. With linear demand, it turns out that as products become less differentiated, the ultimate effect on downstream competition is such that retail prices are always unambiguously lower. However, at least for the limit case when products become increasingly less differentiated, there is also a more general intuition for why then marginal wholesale prices must converge to the cost of the alternative source of supply, so that there is no longer an additional dampening of downstream competition. We discuss this next.

As products become less and less differentiated, i.e., as $\theta \to \infty$ in the previous analysis, there simply remains no scope for the incumbent supplier to profitably dampen competition. To see this, note first that from $\widehat{m} > 0$ the supplier can always pocket the surplus that is achieved when the product is supplied competitively downstream while downstream firms procure from him at $w = \widehat{m}$. When the supplier charges a strictly higher marginal wholesale price $w > \widehat{m}$, thereby dampening competition, this could create additional surplus, which could then be shared among the supplier and all N downstream firms. However, when products end up becoming (almost) non-differentiated, the crux is that any downstream firms could then conquer the whole market by turning to the alternative source of supply at marginal cost $\widehat{m}$. A deviating downstream firm would then excessively free-ride on the dampening effect of higher marginal wholesale prices for all other rivals, who offer almost the same product and face strictly higher marginal wholesale prices. In fact, as is easily seen, any strictly positive gap $w > \widehat{m}$ becomes thereby no longer sustainable when products become sufficiently less differentiated.

As noted previously, our set-up allows one to capture constraints on both the upstream and downstream markets and offers intuitively appealing predictions. This has implications for applied work. In terms of competition policy, for example, a reduction of competitive pressure in our set-up, in either the upstream or the downstream market, gives rise to a change in both the input prices and the thereby induced final prices. These predictions contrast with the predictions of the previously discussed benchmark of an unconstrained supplier, whether or not contracts are observable.

6 Discussion

Renegotiations. The core contribution of the paper is to develop a simple setting of vertical contracting in which a supplier uses its marginal wholesale prices strategically to extract a larger share of profits from competing downstream firms. Marginal wholesale prices affect industry profits both on equilibrium and off equilibrium. It is the latter effect which is novel in our contribution and which is behind our comparative-static results.

Our model is kept purposely simple — the supplier makes take-it-or-leave-it offers to downstream firms — without the possibility of renegotiation. This embodies the following two assumptions off equilibrium. First, if a downstream firm rejects the supplier's offer, there is no renegotiation of the contracts that were accepted by the other downstream firms. Second, there is also no attempt by the supplier to make a new offer to the downstream firm that rejected its offer. We now discuss how both of these assumptions could be relaxed.

When allowing for continuing negotiations after a rejection, one must specify what delay of an individual agreement would mean for production and sales at *all* firms. In this regard, it seems reasonable to assume that the other downstream firms and even the rejecting buyer would continue to be active in the market while the renegotiations proceed.

To this end, we extend our model by supposing that time runs discretely, $\tau = 1, 2,..$, and that all players discount future cash flows by the same discount factor δ. We further assume that firms produce and sell in each period (with per-period payoffs that are captured by our previous notation), and that the following (stage) game unfolds. First, the supplier makes offers (t_n, w_n) to each of the N buyers. Second, each buyer accepts or rejects its respective offer (rejection means it purchases from its alternative supplier). Third, each buyer competes (in the current period) under its respective supply arrangement. To rule out implicit collusion, we consider only outcomes which are equilibria of the stage game.

We proceed in two steps. First, suppose contracts only last for one period. Then, it should be clear that, in a stationary equilibrium, our previous characterization fully applies to the outcome in each period. Next, suppose contracts last for multiple periods. Suppose that (off-equilibrium) one buyer does not accept the contract, so that for the first period after the rejection, only $N-1$ buyers procure from the incumbent supplier. That is, after the rejection by one buyer, there is production and competition for a single period, with the rejecting buyer procuring from its alternative source and earning its outside option.

When the rejecting buyer anticipates that he consistently receives the same offer, while other contracts are not renegotiated, it is indeed (weakly) optimal for him to accept the remade offer in the continuation game.[30]

However, note that the possibility to renegotiate contracts *would* affect our results if, somewhat artificially, we restricted the supplier not to make a new offer to a buyer who rejected its contract – because then marginal wholesale prices would no longer serve the purpose of strategically affecting the outside option of other buyers. This can be seen most clearly for the case in which there are only two buyers. In this case, if one buyer were to reject its offer, and by assumption could no longer be approached, the other buyer's contract would no longer serve the purpose of reducing the first buyer's outside option. The supplier and second buyer would instead want to renegotiate their contract so as to give the respective downstream firm a "first-mover" advantage vis-á-vis its competitor (a strategy known as "strategic delegation"). That said, we would expect that, in many instances, a rejecting buyer would in fact be approachable by the supplier even when it temporarily procures from an alternative source.

Two-Part Tariff Contract As in much of the literature, we specified so far that the supplier offers downstream firms a two-part tariff contract, thereby using two instruments: The fixed part t_n to extract profits from downstream firms and the marginal wholesale price w_n to govern their price-setting behavior. Recall now that the key novelty in our setting is the trade-off between joint industry profit maximization, namely through relatively high wholesale prices, and surplus extraction, for which the value of each downstream firm's outside option is decreased by lowering rivals' wholesale prices. This suggests that the supplier would benefit from a richer set of contracts, so that ultimately different wholesale prices would apply on- and off-equilibrium. This in turn might ensure higher industry profits when all downstream firms agree and, at the same time, greater punishment for a downstream firm that rejects the offer. Arguably, with price competition such a menu would be futile when downstream firms' decision to accept or reject an offer was not observed by rivals. Hence, our analysis could be readily modified in this way.[31] In what

[30] We do not claim that this constitutes the unique subgame perfect equilibrium for the continuation game after a single buyer rejected. We must leave a full analysis of a game with possible production and renegotiation of long-term contracts in each period to future work.

[31] Precisely, denote just for now (with a slight abuse of notation) by $\widehat{\pi}_n(\widehat{\mathbf{k}}_n)$ the off-equilibrium profits of firm n when n rejects the supplier's offer. When the rejection not observed, profits for this firm are

follows we argue, however, how our results survive even when all moves are observed and when, at the same time, the supplier can use a richer contractual set.

Precisely, we now allow the supplier to offer a menu of contracts to each downstream firm. The menu is designed so that the respective firm n chooses (t_n, w_n) when all firms accept and $(\widehat{t}_n, \widehat{w}_n)$ when one firm rejects the supplier's offer. Given symmetry and as the latter is off-equilibrium only, we do not need to make a further distinction. Also, note that we do do allow contracts to condition directly on the set of accepting and rejecting firms. Instead, the respective choice from the menu must be made incentive compatible. As we show, for this reason the supplier can not do better with a menu. In fact, his profits would clearly only increase when $\widehat{w}_n < w_n$, so that firm n would become more aggressive off-equilibrium than on-equilibrium. The respective pair of contracts is, however, not incentive compatible! This follows directly from our core condition (7). To see this, note that when one firm, say firm n', deviates, it will become more aggressive than under the supplier's equilibrium offer, which follows as $\widehat{m} < w_{n'}$. From (7) this implies that a firm n that accepts the supplier's offer would now rather prefer the on-equilibrium wholesale price w_n and not $\widehat{w}_n$, provided that $\widehat{w}_n < w_n$ - and provided that the firm is supposed to prefer (t_n, w_n) over $(\widehat{t}_n, \widehat{w}_n)$ when all other firms accept as well. In other words, precisely when an accepting firm is meant to choose the "more aggressive" offer $\widehat{w}_n < w_n$ it in fact prefers the "less aggressive" offer w_n. Therefore, the optimal menu of the supplier will be

obtained by keeping all $p_{n''}$ other than $p_{n'}$ fixed. The first-order condition for the supplier now equates $\frac{d}{dw_n}\Omega(\mathbf{k})$ with $\frac{d}{dw_n}\sum_{n' \neq n} \widehat{\pi}_{n'}(\widehat{\mathbf{k}}_{n'})$, where now, using the envelope theorem,

$$\frac{d\widehat{\pi}_{n'}(\widehat{\mathbf{k}}_{n'})}{dw_n} = (p_{n'} - c_{n'} - \widehat{m}) \sum_{n'' \neq n'} \frac{\partial q_{n'}}{\partial p_{n''}} \frac{dp_{n''}}{dw_n} > 0.$$

Here, $\widehat{p}_{n'}$ denotes the price of n' when n' rejects and we use that with strategic substitutes $\frac{dp_{n''}}{dw_n} > 0$.

degenerate, as in our previous characterization.[32]

Average vs. Marginal Wholesale Prices. At the end of Section 4, we introduced the concept of a firm's average wholesale price W_n, as opposed to its marginal wholesale price w_n. One can also distinguish between marginal operating costs $k_n = c_n + w_n$ and average operating costs $K_n = c_n + W_n$. With linear demands, we found that a firm with a lower c_n would pay a higher marginal wholesale price w_n. To complete the analysis, for the Hotelling model (cf. Section 5.1), we now compare the firms' respective average costs.

Before doing so, however, recall that our analysis abstracts from various alternative sources of buyer power, which a downstream firm may lever into better purchasing conditions. Both on and off equilibrium, a more efficient downstream firm procures a larger volume, which may give rise to additional purchasing efficiencies. For instance, a buyer could invest, e.g., through more extended search, to make his outside option more attractive, which is more profitable to do so when it has a larger volume to procure. We abstract from these possibilities, which is why the preceding and subsequent comparative analysis of purchasing conditions is not intended to provide a full-fledged picture of buyer power.

In Appendix B, we show that the more efficient firm pays a higher average wholesale price. However, we also show that the more efficient firm still enjoys both a lower marginal cost of operation, $k_n = c_n + w_n$, as well as a lower average cost of operation, $K_n = c_n + W_n$.

Other Applications. We have seen how the incentives of a supplier to use marginal wholesale prices to decrease the outside option of competing downstream firms — even at the expense of sacrificing industry profit — distinguishes the case of an unconstrained supplier from that of a constrained supplier. And we have seen how these incentives can

[32] For a formal illustration, suppose for expositional convenience that there are only two firms and that firm $n = 2$ possibly deviates, so that we have to consider incentive compatibility of the respective contracts (t_1, w_1) and $(\widehat{t}_1, \widehat{w}_1)$:

$$\pi_1(c_1 + w_1, c_2 + w_2) - t_1 \geq \pi_1(c_1 + \widehat{w}_1, c_2 + w_2) - \widehat{t}_1$$

and

$$\pi_1(c_1 + \widehat{w}_1, c_2 + \widehat{m}) - t_1 \geq \pi_1(c_1 + w_1, c_2 + \widehat{m}) - t_1.$$

Adding up the two constraints, we have after some transformation the requirement

$$\int_{c_2+\widehat{m}}^{c_2+w_2} \left[\frac{\partial \pi_1(c_1 + w_1, k_2)}{\partial k_2} - \frac{\partial \pi_1(c_1 + \widehat{w}_1, k_2)}{\partial k_2} \right] dk_2 \geq 0.$$

From (7) this is only feasible when $w_1 \leq \widehat{w}_1$.

give rise to different comparative-static predictions. Moving beyond our focus on wholesale price determination, it would seem the framework we have set out could potentially be applied to other issues in vertical contracting as well. In what follows, we discuss how it might be applied, for example, to shed insight into the profitability of vertical mergers.

Recall the two benchmark cases. When an unconstrained supplier employs observable non-linear contracts, industry profits are maximized via arms-length contracting and there is no need or role for vertical integration. Indeed, partial vertical integration, where the supplier merges with some but not all of the downstream firms, would be counterproductive because transfer prices to the merged entities would then be at cost, which would induce the non-merged firms to be too aggressive in their pricing. In contrast, when contracts are unobservable, supplier opportunism prevents industry profits from being maximized via arms-length contracting. In this case, vertical integration — whether partial or full — can be profitable because it can mitigate the observability problem, resulting in higher prices. This is one of the insights from Hart and Tirole's (1990) work, and it provides an explanation of how vertical mergers can be privately profitable and yet socially undesirable.

Things are different in our model with a constrained supplier. In the absence of vertical integration, wholesale prices, and the thereby induced final prices, fall short of maximizing industry profits for the reasons we have discussed. In contrast, with full vertical integration, there is no need to worry about the downstream firms' outside options, and as a result, prices and industry profits will be higher. In this sense, the predictions of the model are similar to those from Hart and Tirole's (1990) model. But, unlike in Hart and Tirole's (1990) model, welfare need not be lower. In fact, when total demand is inelastic (cf. the Hotelling case in Section 5.1), welfare is actually higher under full vertical integration because this improves allocative efficiency relative to the case where the constrained supplier's optimal wholesale prices would handicap the more efficient downstream firm.[33]

The case of partial vertical integration is more nuanced. In this case, for example, when the supplier is only integrated with firm 1 but not with its duopolistic competitor, firm 2, the determination of the wholesale price w_2 no longer serves the objective of decreasing firm 1's outside option. All else being equal, this should push the choice of w_2 up. Further,

[33] In the Hotelling case, given a price difference $p_2 - p_1$ and thus a "critical consumer" location $\widehat{x} = q_1$, aggregate "shoe leather costs" are given by $\tau \left[\int_0^{\widehat{x}} x dx + \int_{\widehat{x}}^1 (1-x) dx \right]$, which have to be added to aggregate production costs $q_1 c_1 + q_2 c_2$. Total costs are minimized when $\widehat{x} = q_1 = 1/2 + (c_2 - c_1)/(2\tau)$, which is obtained exactly under an integrated monopoly (or, likewise, when $w_n = w_n^{Mon}$, as derived in Section 5.1).

as is well known, the determination of w_2 now serves the purpose of dampening competition through increasing the vertically integrated firm's opportunity costs of subsequently choosing a low final price p_1. This is so because firm 1 is now no longer an "agent" of the supplier who can be controlled by an *observable* contract. Instead, it is always supplied competitively. We leave the analysis of the impact of a partial vertical merger on consumer surplus and welfare, as well as that of the profitability of such a merger, to future work.

7 Concluding Remarks

This paper introduces a framework to model the joint determination of prices in an upstream and downstream market. We assume that an incumbent supplier is constrained by the ability of the downstream firms to switch to an alternative source of supply. Importantly, we allow the supplier to offer non-linear contracts. Because we also assume these contracts are observable, in principle the supplier could use marginal wholesale prices to dampen intra-brand competition so as to thereby maximize total industry surplus. However, our first result is that this is not optimal. By inducing more downstream competition, namely by reducing the marginal wholesale price for all supplied firms, the incumbent supplier can increase its profit by extracting a larger fraction of a smaller industry surplus. This follows because by making each downstream firm more competitive, the profits that would be obtained from switching suppliers are reduced for all other downstream firms.

The focus of our analysis lies in the comparative statics of the determined wholesale and final prices. In a first step, we analyze how our model gives rise to price discrimination in the upstream market. We identify two opposing forces. To generate a larger industry surplus, the supplier should offer more efficient and thus ultimately larger downstream firms a *more* competitive contract. However, the negative impact on a firm's outside option when rivals are made more competitive is also larger when the respective firm is more efficient. This suggests that the supplier should offer more efficient firms a *less* competitive contract. We show that, with linear demands, the second effect dominates. The supplier can gain from partially ironing out the cost disadvantage of the less efficient firms. We discussed how our theory of wholesale price determination could be enriched by other theories of (size-related) buyer power, so as to obtain a richer picture of size-related discounts that is more commensurable with observed practice in different industries.

In an application to linear demand, we explicitly derive comparative statics results in terms of the constraints that firms face in the upstream and the downstream markets. We show how, in contrast to other benchmark models from the literature, our set-up with non-linear contracts and a binding constraint for the supplier generates monotonic comparative statics results that intuitively map such competitive constraints into a change in both wholesale and final prices. We argue that, with respect to applications to competition policy, this set-up should enrich the modeling choices that are available to both theorists and practitioners. In this respect, we proposed questions for future research, such as the interaction of vertical mergers and the strategic use of wholesale prices to affect the value of downstream firms' outside options and, thereby, the sharing of total industry surplus.

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9 Appendix A: Omitted Proofs

Proof of Proposition 2. In a slight abuse of notation, where the terms "with a hat" are understood to relate to prices and costs when n' rejects the supplier's offer, we have

$$\frac{d\pi_{n'}(\widehat{\mathbf{k}}_{n'})}{dw_n} = -\frac{d\widehat{p}_n}{dw_n}(\widehat{p}_{n'} - c_{n'} - \widehat{m})\frac{\partial \widehat{q}_{n'}}{\partial \widehat{p}_n}.$$

With linear demand, we can express this more simply as

$$\frac{d\pi_{n'}(\widehat{\mathbf{k}}_{n'})}{dw_n} = -\frac{d\widehat{p}_n}{dk_n}(\widehat{p}_{n'} - c_{n'} - \widehat{m})\gamma.$$

(Note that it is more instructive to express the derivative of the downstream price with respect to our expression of overall marginal cost $k_n = c_n + w_n$, instead of with respect to w_n.) Together with the derivative of total industry surplus, this yields, from combining the two first-order conditions,

$$\begin{aligned} & \beta\left[\frac{dp_n}{dk_n} - \frac{dp_n}{dk_{n'}}\right](w_1 - w_2) \qquad (15)\\ = \;& \gamma\left[\frac{dp_n}{dk_n} - \frac{dp_n}{dk_{n'}}\right][(p_1 - c_1) - (p_2 - c_2)] \\ & + \frac{dp_n}{dk_n}\gamma\left[(\widehat{p}_2 - c_2 - \widehat{m}) - (\widehat{p}_1 - c_1 - \widehat{m})\right]. \end{aligned}$$

The right-hand side of this can be rearranged to read as

$$-\gamma\frac{dp_n}{dk_{n'}}[(p_1 - c_1) - (p_2 - c_2)] + \gamma\frac{dp_n}{dk_n}[(p_1 - \widehat{p}_1) - (p_2 - \widehat{p}_2)].$$

For linear demand we can further use that

$$p_n - \widehat{p}_n = (w_n - \widehat{m})\frac{dp_n}{dk_n},$$

so that

$$(p_1 - \widehat{p}_1) - (p_2 - \widehat{p}_2) = \frac{dp_n}{dk_n}(w_1 - w_2)$$

as well as

$$(p_2 - p_1) = (k_2 - k_1)\left(\frac{dp_n}{dk_n} - \frac{dp_n}{dk_{n'}}\right).$$

Then, substituting this into (15), we have the requirement that

$$\begin{aligned} & (w_1 - w_2)\left[(\beta + \gamma\frac{dp_n}{dk_{n'}})\left(\frac{dp_n}{dk_n} - \frac{dp_n}{dk_{n'}}\right) - \gamma\left(\frac{dp_n}{dk_n}\right)^2\right] \\ = \;& \gamma\frac{dp_n}{dk_{n'}}(c_2 - c_1)\left[\left(\frac{dp_n}{dk_n} - \frac{dp_n}{dk_{n'}}\right) - 1\right]. \end{aligned}$$

We now substitute for the derivatives $\frac{dp_n}{dk_n}$ and $\frac{dp_n}{dk_{n'}}$, which are readily obtained as

$$\frac{dp_n}{dk_n} = \frac{2\beta^2}{4\beta^2-\gamma^2} \text{ and } \frac{dp_n}{dk_{n'}} = -\frac{\beta\gamma}{4\beta^2-\gamma^2}.$$

With this at hand, we finally obtain after some transformations that

$$(w_1 - w_2) = (c_2 - c_1)\frac{\gamma^2}{2\beta}\frac{2\beta^2-\beta\gamma-\gamma^2}{4\beta^3-2\beta\gamma^2-\gamma^3}, \tag{16}$$

which, from $\beta < 0$ and $|\beta| \geq \gamma$, implies $w_1 > w_2$ as long as $c_1 < c_2$. **Q.E.D.**

Proof of Proposition 5. Denote $p_\varnothing := \sum_n p_n/N$ and $w_\varnothing := \sum_n w_n/N$. Recall that $c_n = c$ in this case. To derive equilibrium final prices, we have to maximize for each n the respective profits

$$\pi_n = \frac{1}{N}\left[1 - p_n - \theta\left(p_n - \frac{\sum_{n'\in N} p_{n'}}{N}\right)\right](p_n - w_n - c).$$

From the first-order condition we obtain, after making use of the average price $p_\varnothing$,

$$p_n = \frac{1 + \theta(p_\varnothing - p_n) + (c + w_n)\left(1 + \theta - \frac{1}{N}\theta\right)}{2 + \theta - \frac{1}{N}\theta}.$$

Aggregating over all n firms, this yields the system of optimal prices

$$p_n(\mathbf{k}) = \frac{1}{2+\theta-\frac{1}{N}\theta}\left[1 + (c+w_n)\left(1+\theta-\frac{1}{N}\theta\right) + (w_\varnothing - w_n)\theta\frac{1+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}\right]. \tag{17}$$

To calculate equilibrium profits, we use next from the first-order condition $d\pi_n/dp_n = 0$ that, after substituting for $\frac{dq_n}{dp_n}$,

$$q_n = (p_n - w_n - c)\frac{1}{N}\left[1 + \theta\left(1 - \frac{1}{N}\right)\right].$$

Substituting this back into π_n yields

$$\pi_n(\mathbf{k}) = \frac{1}{N}\frac{1+\theta-\frac{\theta}{N}}{\left(2+\theta-\frac{1}{N}\theta\right)^2}\left[1 - c - w_\varnothing - (\theta+1)(w_n - w_\varnothing)\frac{2+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}\right]^2. \tag{18}$$

In light of subsequent calculations, it is further useful to write this alternatively as

$$\begin{aligned}\pi_n(\mathbf{k}) \quad = \quad & \frac{1}{N}\frac{1+\theta-\frac{\theta}{N}}{\left(2+\theta-\frac{1}{N}\theta\right)^2} \\ & \left[1 - c - \frac{w_n}{N}\left((\theta+1)\frac{\left(2+\theta-\frac{1}{N}\theta\right)}{\left(2+2\theta-\frac{1}{N}\theta\right)}(N-1)+1\right) + \frac{\sum w_{n'}}{N}\theta\frac{\left(1+\theta-\frac{1}{N}\theta\right)}{\left(2+2\theta-\frac{1}{N}\theta\right)}\right]^2.\end{aligned}$$

We derive next total industry profits, $Nq(p-c)$, from which we obtain

$$\frac{d}{dw}\Omega(\mathbf{k})\bigg|_{w_n=w} = \frac{1+\theta-\frac{1}{N}\theta}{2+\theta-\frac{1}{N}\theta}\left(1+c-2p\right). \tag{19}$$

We can substitute p from (13).

From (18) the outside option of some firm n, provided that all rivals face $w_{n'}=w$, is given, with a slight simplification of notation, by

$$\begin{aligned}\widehat{\pi}_n &= \frac{1}{N}\frac{1+\theta-\frac{\theta}{N}}{\left(2+\theta-\frac{1}{N}\theta\right)^2}\\ &\left[1-c-\frac{\widehat{m}}{N}\left((\theta+1)\frac{\left(2+\theta-\frac{1}{N}\theta\right)}{\left(2+2\theta-\frac{1}{N}\theta\right)}(N-1)+1\right)+w\frac{N-1}{N}\theta\frac{\left(1+\theta-\frac{1}{N}\theta\right)}{\left(2+2\theta-\frac{1}{N}\theta\right)}\right]^2.\end{aligned}$$

At an interior equilibrium for w, and noting that the program is strictly concave, it holds that

$$\frac{d}{dw}\Omega(\mathbf{k})_{w_n=w} = N\frac{d\widehat{\pi}}{dw}, \tag{20}$$

so that, together with (19), we have the requirement that

$$\begin{aligned}&\left(\frac{1+\theta-\frac{1}{N}\theta}{2+\theta-\frac{1}{N}\theta}\right)\left(\frac{\theta\frac{N-1}{N}(1-c)-2w\left(1+\theta-\frac{1}{N}\theta\right)}{2+\theta-\frac{1}{N}\theta}\right)\\ =\ & 2\frac{N-1}{N}\theta\left(\frac{1+\theta-\frac{1}{N}\theta}{\left(2+\theta-\frac{1}{N}\theta\right)^2\left(2+2\theta-\frac{1}{N}\theta\right)}\right)\cdot\\ &\left[1-c-\frac{\widehat{m}}{N}\left((\theta+1)\frac{\left(2+\theta-\frac{1}{N}\theta\right)}{\left(2+2\theta-\frac{1}{N}\theta\right)}(N-1)+1\right)+w\frac{N-1}{N}\theta\frac{1+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}\right].\end{aligned}$$

This finally can be solved for w to obtain

$$w = \frac{N-1}{N^2}\theta\frac{\left[\theta(1-c)-2\widehat{m}\frac{1+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}\left((\theta+1)(N-1)\left(2+\frac{N-1}{N}\theta\right)+\left(2+\theta+\frac{N-1}{N}\theta\right)\right)\right]}{\left(1+\frac{N-1}{N}\theta\right)\left[\left(2(1+\theta)-\frac{1}{N}\theta\right)+\left(\frac{N-1}{N}\theta\right)^2\frac{1+\theta-\frac{1}{N}\theta}{2(1+\theta)-\frac{1}{N}\theta}\right]}. \tag{21}$$

While the comparative result in $\widehat{m}$ follows immediately, substituting w to obtain p and then differentiating with respect to θ or N turns out to be too unwieldy. We, therefore, proceed somewhat indirectly.

For this we return to the supplier's objective function, but suppose now that the control variable is the equilibrium final price p. Note that any given p is supported by a wholesale price of

$$w = \frac{p(2+\theta-\frac{1}{N}\theta)-1}{1+\theta-\frac{1}{N}\theta} - c. \tag{22}$$

Instead of (20), we thus consider now the first-order condition

$$\frac{d}{dp}\Omega = N\frac{d\widehat{\pi}}{dw}\frac{dw}{dp}, \tag{23}$$

where we have somewhat abbreviated the notation. Note now first that the derivative of industry profits on the left-hand side of (23) equals $1-2p+c$, which is independent of θ. A sufficient condition for the assertion to hold is thus from (23) that for any p the right-hand side is strictly *increasing* in θ.

After substituting for w from (22), we obtain for the right-hand side of (23), after some further transformation, the expression

$$\frac{2(N-1)}{N}\theta\frac{1+\theta-\frac{1}{N}\theta}{\left(2+\theta-\frac{1}{N}\theta\right)\left(2+2\theta-\frac{1}{N}\theta\right)}\cdot \tag{24}$$
$$\left[\begin{array}{c} p\frac{(2+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}\frac{N-1}{N}\theta-\frac{\widehat{m}}{N}(\theta+1)(N-1)\frac{2+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}-c\frac{N-1}{N}\theta\frac{1+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta} \\ +\left(1-c-\frac{m}{N}\right)\end{array}\right].$$

In the rest of the proof, we show that (24) is indeed strictly increasing in θ. For this we provide sufficient conditions by analyzing the different terms in (24) in turn. Note first that the term in rectangular brackets is strictly positive. To see next that the multiplier, which comprises the first line in (24), is increasing in θ, note that, using a further transformation,

$$\frac{d}{d\theta}\left(\frac{1/\theta+1-\frac{1}{N}}{2/\theta+1-\frac{1}{N}}\right)>0 \text{ and } \frac{d}{d\theta}\left(\frac{1}{2/\theta+2-\frac{1}{N}}\right)>0.$$

We turn next to the term in rectangular brackets in (24). To show monotonicity in θ, we clearly have to deal only with the first line. This can be further transformed to

$$c\left(\frac{\theta}{2+2\theta-\frac{1}{N}\theta}\right)-\frac{N-1}{N}\widehat{m}\left(\frac{2+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}\right)+(p-\widehat{m}-c)\frac{N-1}{N}\theta\left(\frac{2+\theta-\frac{1}{N}\theta}{2+2\theta-\frac{1}{N}\theta}\right). \tag{25}$$

Take now the three terms in (25) in turn. First, we already know that the term multiplied by c is strictly increasing in θ. For the second term, which is multiplied by $\widehat{m}$, note that

$$\frac{d}{d\theta}\left(\frac{2/\theta+1-\frac{1}{N}}{2/\theta+2-\frac{1}{N}}\right)<0.$$

Regarding the last term, note that $p-\widehat{m}-c>0$, while it is immediate that the respective multiplier is strictly increasing in θ. This concludes the comparative analysis in θ.

With respect to a change in N, we can now be brief by following the preceding argument. We thus need to show now that the right-hand side of (24) is strictly increasing in N. To show this first for the multiplier, i.e., for the first line in (24), note that this transforms to

$$2\theta\left(\frac{(1+\theta)N-\theta}{(2+\theta)N-\theta}\right)\left(\frac{N-1}{2(1+\theta)N-\theta}\right), \tag{26}$$

where we can show for each of the two terms that they are indeed strictly increasing in N. We next transform the term in rectangular brackets, which is strictly positive, to obtain

$$1-\widehat{m}\left(\frac{(2+\theta)N}{2(1+\theta)N-\theta}\right)+(p-c)\frac{N-1}{N}\left(\frac{(1+\theta)N-\theta}{2(1+\theta)N-\theta}\right)+p\left(\frac{N-1}{2(1+\theta)N-\theta}\right). \tag{27}$$

Here, the term multiplied by $-\widehat{m}$ is strictly decreasing in N. The term multiplied by $p-c>0$ is, next, strictly increasing in N, as this holds for both parts. Finally, once again the term multiplied by p is strictly increasing in N, as used also for (26). **Q.E.D.**

10 Appendix B: Calculations for the Hotelling Case

Solving the model of Hotelling competition, we obtain for the price of $n=1$

$$p_1=\frac{2}{3}k_1+\frac{1}{3}k_{2'}+\tau$$

and for the firm's downstream profits

$$\begin{aligned}\pi_1 &= \frac{1}{2\tau}(\tau+\frac{1}{3}(k_2-k_1))^2,\\ \widehat{\pi}_1 &= \frac{1}{2\tau}(\tau+\frac{1}{3}(k_2-\widehat{k}_1))^2.\end{aligned}$$

Expressions for $n=2$ are symmetric. (Again, in a slight abuse of notation we denote by $\widehat{\pi}_1$ the profits when only firm $n=1$ turns to the alternative source of supply.) Equilibrium marginal wholesale prices can be obtained immediately from combining the respective first-order conditions in (2). (Alternatively, we can use the expressions from Proposition 2, such as (16), after noting that, with Hotelling competition, $\beta=1$ and $\gamma=1$.) **Q.E.D.**

To support the discussion of average wholesale prices, W_n, and average total costs, K_n, in Section 6, we derive the respective expressions for the Hotelling case (cf. Section 5.1) under the assumed restriction that, both on and off equilibrium, the downstream firms are active and the market is fully covered. On equilibrium, we thus require that $0 < q_1 < 1$, which after substituting for the equilibrium wholesale and final prices, holds if[34]

$$0 < \frac{1}{\tau}\left(\frac{\tau}{2} + \frac{1}{9}(c_2 - c_1)\right) < 1.$$

Given that $c_1 \leq c_2$, this is satisfied if

$$\tau > \frac{2}{9}(c_2 - c_1). \tag{28}$$

Denote next the (off-equilibrium) quantity that prevails when firm $n = 1$ rejects the supplier's offer by $\widehat{q}_1$. We then have likewise that $0 < \widehat{q}_1 < 1$ if

$$\tau > \frac{5}{9}(c_2 - c_1). \tag{29}$$

Finally, if firm $n = 2$ rejects, then off-equilibrium both firms will make positive sales if

$$\tau > \frac{5}{27}(c_2 - c_1). \tag{30}$$

As is easily seen, condition (30) is the strictest of these three conditions.

We ask next how W_1 and W_2 compare. Note first that, after some transformations,

$$W_n = p_n - c_n - \frac{\widehat{\pi}_n}{q_n},$$

so that, after substituting for p_n,

$$W_1 > W_2 \Leftrightarrow \frac{\widehat{\pi}_1}{q_1} - \frac{\widehat{\pi}_2}{q_2} < \frac{7}{9}(c_2 - c_1). \tag{31}$$

Using next that

$$\frac{\widehat{\pi}_n}{q_n} = \frac{\left(\frac{3}{2}\tau - \frac{5}{18}(c_n - c_{n'})\right)^2}{\tau - \frac{2}{9}(c_n - c_{n'})},$$

we have that $W_1 > W_2$ holds if and only if

$$\tau^2 > \frac{1}{27}(c_2 - c_1)^2.$$

This is implied by condition (30).

Finally, making use of condition (31), we have that

$$K_1 < K_2 \Leftrightarrow \frac{\widehat{\pi}_1^*}{q_1^*} - \frac{\widehat{\pi}_2^*}{q_2^*} > -\frac{2}{9}(c_2 - c_1),$$

which transforms into condition

$$\tau^2 > \frac{1}{72}(c_2 - c_1)^2.$$

This is again implied by condition (30).

[34] Note that we assume that consumers' utility (gross of "transportation cost"), v, is sufficiently high.