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Price Discrimination in Input Markets: Quantity Discounts and Private Information

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CESifo Working Paper No. 4202
Category 11: Industrial Organisation
April 2013

Presented at CESifo Area Conference on Applied Microeconomics, March 2013

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Abstract

We consider a monopolistic supplier's optimal choice of wholesale tariffs when downstream firms are privately informed about their retail costs. Under discriminatory pricing, downstream firms that differ in their ex ante distribution of retail costs are offered different tariffs. Under uniform pricing, the same wholesale tariff is offered to all downstream firms. In contrast to the extant literature on price discrimination with nonlinear wholesale tariffs, we find that banning discriminatory wholesale contracts often improves welfare. This also holds if the manufacturer is not an unconstrained monopolist. Moreover, uniform pricing increases downstream investments in cost reduction in the long run.

JEL-Code: D430, L110, L420.

Keywords: asymmetric information, input markets, quantity discounts, price discrimination, screening, vertical contracting.

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April 11, 2013
We thank Anette Boom, Frago Kourandi, Matthias Kräkel, Patrick Legros, Laurent Linnemer, Takeshi Murooka, Peng Peng, Markus Reisinger, Claudia Salim, Klaus M. Schmidt, Patrick Schmitz, and Nikolaos Vettas for helpful comments and suggestions. Furthermore, we benefited from comments made by conference audiences at the CESifo Conference Applied Microeconomics (Munich), EARIE (Stockholm), SFB Meeting (Tutzing), ANR-DFG Workshop on Market Power in Vertically Related Markets (Paris) as well as seminar audiences at the University of Toulouse, Humboldt University—Berlin, Université Libre de Bruxelles, Otto Beisheim School of Management—Vallendar, ETH Zurich, and the University of Bamberg. Herweg gratefully acknowledges financial support from the Deutsche Forschungsgemeinschaft through SFB/TR-15. All errors are of course our own.

1. Introduction

Third-degree price discrimination is a widely used business practice in intermediate-good markets, i.e., manufacturers often apply different conditions to identical transactions with different retailers.[1] The pros and cons of this pricing practice have been discussed among legal and economic scholars since the 1930's and are still debatable. Whether price discrimination by a large manufacturer represents an abuse of its dominant position is a crucial question in many antitrust decisions on both sides of the Atlantic ocean.[2] Most contributions to the economic literature on the welfare effects of price discrimination focus on linear wholesale tariffs (Katz, 1987; DeGraba, 1990; Yoshida, 2000; O'Brien, 2002; Valletti, 2003; Inderst and Valletti, 2009). A common pricing practice in business-to-business relations, however, are quantity rebate schemes, which is hardly surprising in the face of the well-known double marginalization problem.[3] Regarding the welfare effects of price discrimination, the extant literature that allows for nonlinear wholesale tariffs—by and large—agrees upon a ban on price discrimination being detrimental for social welfare (O'Brien and Shaffer, 1994; Rey and Tirole, 2007; Inderst and Shaffer, 2009; Arya and Mittendorf, 2010).[4]

This clearcut theoretical prediction is at odds with the legal practice in the EU as well as in the US, where antitrust authorities regard quantity discounts as a justifiable pricing strategy of manufacturers as long as they are non-discriminatory. For instance, in the *Michelin I* judgment from 1981, the European Commission did not contest the quantity rebate scheme itself, but its alleged discriminatory nature with "comparable amounts purchased almost never result[ing] in the same or comparable discount being granted." (Recital 42 of Commission decision 81/969/EEC)[5] In contrast to the extant theoretical literature, but in line with the usual legal practice, we derive conditions such that banning discriminatory nonlinear wholesale tariffs is socially desirable. The novelty of our paper is to allow for privately informed downstream firms.[6]

We investigate the welfare effects of banning discriminatory nonlinear wholesale tariffs in a

[1] In the following, the term *price discrimination* is used exclusively to refer to third-degree price discrimination, i.e., to situations where the manufacturer offers different wholesale tariffs (which may be more complex than linear tariffs) to its retailers.

[2] For an overview of landmark antitrust cases in the EU see Russo, Schinkel, Günster, and Carree (2010).

[3] Empirical evidence for non-linear contracts being employed in vertical relations is presented—for instance—by Slade (1998) for the Canadian market of gasoline retailing and by Ferrari and Verboven (2012) for magazine distribution in Belgium.

[4] Building on the Rey-Tirole model and assuming that the manufacturer competes against a competitive fringe, Caprice (2006) shows that a ban on price discrimination leads to an increase in welfare if the fringe is sufficiently efficient.

[5] Likewise, in the *European sugar industry* decision from 1973, the Commission ruled that "the granting of a rebate which does not depend on the amount bought [...] is an unjustifiable discrimination [...]." (Recital II-E-1 of Commission decision 73/109/EC) Other decisions include the Eurofix—Bauco/Hilti case, where the commission objected that the reduction of discounts was not linked primarily to any objective criteria such as quantity. (Commission decision 88/138/EEC)

[6] We are not the first to consider privately informed downstream firms in a model of vertical relations. While other models of vertical relations, e.g., Rey and Tirole (1986) or Majumdar and Shaffer (2012), allow for downstream firms having private information regarding their stochastic retail cost, these papers do not discuss third-degree price discrimination. Price discrimination with privately informed buyers is also analyzed by Bang, Kim, and Yoon (2011). They, however, neither analyze the welfare effects of a ban on price discrimination nor do they consider nonlinear tariffs.

model with two downstream firms that have private information regarding their own retail cost, which is either high or low. Ex ante, downstream firms differ in the distribution of their retail cost and this is known by a monopolistic manufacturer. If third-degree price discrimination is permitted, the manufacturer offers to downstream firms with different distributions of retail costs a different menu of quantity-transfer pairs. Under uniform pricing, on the other hand, the same menu is offered to both downstream firms. When deciding whether to accept the manufacturer's offer, each downstream firm is privately informed about the realization of its retail cost. Thus, the manufacturer offers nonlinear tariffs not only to reduce double marginalization but also to screen downstream firms according to retail efficiency.

We consider a model with two downstream firms, each of which serves an independent market. The quantities procured by low-cost retailers turn out to be independent of the pricing regime because under both regimes there is no distortion at the top. The quantities procured by high-cost retailers, on the other hand, are distorted downward and the magnitude of this distortion depends on the pricing regime. Under price discrimination, the high-cost type of the ex ante more efficient firm—more likely to be a low cost producer—procures a lower quantity than the high-cost type of the ex ante less efficient firm. The quantity procured by ex post high-cost retailers under uniform pricing is bracketed by the quantities assigned to high-cost retailers under price discrimination. Therefore, in expectations, banning price discrimination harms the market which is served by the ex ante less efficient firm, whereas the other market, which is served by the ex ante more efficient firm, benefits. Due to these opposing effects, general welfare results are hard to obtain. Nevertheless, we show that uniform pricing is optimal from a welfare point of view as long as price discrimination does not lead to an expansion of (expected) total output. For the case of linear demand and provided that all markets are being served under either pricing regime, price discrimination does not lead to an expansion of total output and thus is detrimental for welfare. This output criterion is known from the literature analyzing third-degree price discrimination in final-good markets with linear tariffs and without asymmetric information (Schmalensee, 1981).[7] For the case of homogeneous Cournot competition downstream, Schmalensee's observation, together with the fact that the less efficient downstream firm receives a discount under price discrimination, directly implies that banning price discrimination in input markets improves welfare if wholesale contracts are linear (Katz, 1987; DeGraba, 1990).[8]

In our model, it can be optimal for the manufacturer not to serve a high-cost retailer in order to cut back on information rents. In consequence, if the average probability of high-cost production is low but the ex ante less efficient firm is nevertheless quite likely to produce at high cost, then high-cost production takes place only under price discrimination and only in the ex ante less efficient market. Here, price discrimination leads to more markets being served in

[7] A series of articles elaborates on Schmalensee's insight, see Varian (1985), Schwartz (1990), Malueg (1993), Aguirre, Cowan, and Vickers (2010).

[8] As shown by Yoshida (2000), if firms differ in their efficiency to transform the input into the final good, an increase in total output is a sufficient condition for price discrimination to reduce welfare.

expectations and unambiguously improves welfare. This finding resembles the classic Chicago school argument in favor of price discrimination (Bork, 1978).[9]

By allowing downstream firms to invest in process innovation, DeGraba (1990) identifies another channel through which uniform pricing can improve welfare. By extending our model to a long-run analysis in the spirit of DeGraba (1990), we show that if downstream firms can invest in the (expected) efficiency of production, uniform pricing results in higher investment incentives, thereby potentially leading to overall higher welfare. This conjecture is confirmed for the case of linear demand downstream.

A widespread assumption in the literature on price discrimination in input markets is that the manufacturer is an unconstrained monopolist who can make take-it-or-leave it offers to its retailers. Two exceptions are Inderst and Valletti (2009) and O'Brien (2002), both of whom focus on linear wholesale contracts. In Inderst and Valletti (2009) the manufacturer is constrained by the threat of demand-side substitution. O'Brien (2002) assumes that wholesale prices are determined by bilateral negotiations between the manufacturer and downstream firms. Both contributions show that relaxing the assumption of an unconstrained monopolistic manufacturer can give rise to circumstances where the welfare implications of price discrimination are reversed. In order to show robustness of our findings we introduce upstream competition in a similar vein to Inderst and Valletti (2009). Focusing on the cases where the retailers procure the inputs from the manufacturer in equilibrium, we show that banning price discrimination often improves welfare even in the presence of an alternative source of supply. While outside the scope of our paper, an important concern of antitrust authorities is whether price discrimination is used by manufacturers in order to exclude potential rivals upstream, so called primary-line injuries. How a manufacturer can use discriminatory tariffs in order to exclude a rival is at the heart of the analysis of Giardino-Karlinger and Motta (2012), who consider a model with network effects and inelastic demand. In our model, in contrast, there are no network effects and demand is elastic, which implies that double marginalization is an issue.

The article closest related to this paper is Inderst and Shaffer (2009), who assume that the manufacturer offers observable two-part tariffs to the retailers. Focusing on asymmetric downstream firms, discriminatory contracts are shown to amplify differences in downstream firms' competitiveness. A ban on price discrimination tends to raise all final-good prices and thus to reduce total output. In consequence, banning price discrimination reduces consumer surplus and welfare. Similarly, Arya and Mittendorf (2010) show a ban on discriminatory two-part tariffs to be always welfare harming when downstream firms are asymmetric in the sense that one operates in multiple markets while the other downstream firm is active only in a single market. While in Inderst and Shaffer (2009) as well as in Arya and Mittendorf (2010) the manufacturer is perfectly informed about the downstream firms' asymmetries this is not the case in our model. We show that introducing asymmetric information can turn these previous welfare

[9] That price discrimination can lead to more (input) markets being served is also shown by Herweg and Müller (2012) for linear wholesale tariffs.

findings upside down.

Due to our focus on separate markets, it is of no relevance for an individual retailer whether he knows the supply conditions of the other retailers. If retailers operate in the same market, on the other hand, a crucial modeling assumption is whether retailers can observe their rivals contracts. If contracts are unobservable, the manufacturer faces a commitment problem when price discrimination is permitted and the outcome optimal from the integrated structure's point of view cannot be obtained. Uniform pricing restores the manufacturer's commitment power which implies that banning price discrimination reduces welfare—cf. Rey and Tirole (2007). This commitment issue—which first was raised by Hart and Tirole (1990), O'Brien and Shaffer (1992, 1994), and McAfee and Schwartz (1994)—is completely absent in our analysis.

With downstream firms operating in separate markets the question of the policy relevance of our findings is immediately at hand because both Art. 102(c) TFEU as well as the Robinson-Patman Act consider discriminatory pricing as an abuse of a dominant position only if a downstream firm is placed at a competitive disadvantage.[10] Nevertheless, the European Commission and the Community courts have largely applied Art. 102(c) TFEU to manufacturers' pricing practices which have little to do with putting their retailers at a competitive disadvantage—most notably to ban geographic price discrimination across member states (Geradin and Petit, 2005). Fighting geographic price discrimination is of high relevance for competition policy in the EU. As stated in Art. 18 TFEU, one of the most basic principles of the Treaty of the EU is the avoidance of discrimination based on national grounds. The landmark case on geographic price discrimination is United Brands (Commission decision 76/353/EEC). United Brands Company (UBC) sold bananas to distributors/ripeners from various Member States at significantly different prices, with the prices charged from Danish distributors exceeding the prices charged from Irish distributors by 138%. According to the Commission UBC's pricing practice constituted an abuse of its dominant position. Similarly, Tetra Pak, one of the world's leading companies for the packaging of liquids in cartons, charged considerably different prices across Member States (Tetra Pak II, Commission decision 92/163/EEC). The Commission and the CFI concluded that Tetra Pak's business strategy was an abuse of its dominant position and an infringement of Art. 102(c) TFEU.[11]

The rest of the paper is organized as follows. In Section 2, we introduce our basic model with a monopolistic input supplier. This model is analyzed in Section 3. In Section 4, we conduct a long-run analysis by allowing downstream firms to invest in a reduction of production cost

[10] In the US the standard of proof for competitive harm is relatively low. According to the commonly applied Morton Salt rule the existence of a substantial price difference for a substantial period of time is sufficient; actual proof of retailers competing for the same customers is not required. (FTC v. Morton Salt Co., 334 U.S. 37) In the recent Volvo case, however, the Supreme Court for the first time required actual proof of retailers competing for the same customers in order to establish competitive harm, thereby overruling the decision of a lower court. (Volvo Trucks North America, Inc. v. Reeder-Simco GMC, Inc. (04-905), 546 U.S. 164, 2006). For a more elaborate discussion of this point see Luchs, Geylani, Dukes, and Srinivasan (2010).

[11] Sometimes cases of geographic price discrimination are also considered as an infringement of Art. 101.1 TFEU. Notable examples are Glaxo Wellcome (Commission decision 2001/791/EC) in the pharmaceutical industry and Souris/Topps (Commission decision COMP/C-3/37.980) in the toy industry.

before contracting takes place. After considering a continuous type distribution for downstream firms in Section 5, Section 6 augments the basic model by assuming that the manufacturer is constrained by the threat of demand-side substitution. We conclude in Section 7. All proofs of Sections 3–5 are relegated to the Appendix A, while the Appendix B provides additional material to Section 6.

2. The Model

Consider a vertically related industry where the upstream market is monopolized by manufacturer M. The manufacturer produces an essential input that is supplied to the downstream sector. For simplicity, we assume that the manufacturer produces quantity q at constant marginal cost, $K > 0$. There are two downstream firms, $i \in \{1, 2\}$, that can transform one unit of the input into one unit of the final good.

We assume that downstream firms operate in separate and independent markets, i.e., each downstream firm is a local monopolist.[12] Downstream markets are identical in size and characterized by the inverse demand function $P(q)$, which is strictly decreasing, twice differentiable where $P > 0$, and satisfies the assumption $2P'(q) < \min\{0, -qP''(q)\}$ where $P > 0$.[13]

Downstream firm i produces at constant marginal cost and without fixed costs. The marginal cost of production is either high or low, $c_i \in \{c_L, c_H\}$ with $0 \leq c_L < c_H < P(0) - K$. The last inequality guarantees that the joint-surplus maximizing quantity of a vertically integrated firm is strictly positive.

A downstream firm's type—i.e., its marginal cost of production—is private information. The manufacturer only knows the probability α_i with which downstream firm i produces at low marginal cost. Ex ante firm 1 is more likely to produce at low marginal cost than firm 2, i.e., $0 < \alpha_2 < \alpha_1 < 1$.[14]

The manufacturer can make take-it-or-leave-it offers to the downstream firms, where the wholesale tariff offered to downstream firm i takes the form of a list of quantity-transfer combinations. With only two ex post types, the manufacturer cannot benefit from specifying more than two items per list. So the tariff offered to firm i is $\Gamma_i = \langle (q_{Li}, t_{Li}), (q_{Hi}, t_{Hi}) \rangle$, specifying a quantity $q \in \mathbb{R}_{\geq 0}$ and a transfer from firm i to the manufacturer, $t \in \mathbb{R}$, for each feasible cost type.[15] We assume free disposal, i.e., when having purchased quantity q' of the input,

[12] With downstream firms operating in independent markets our model is equivalent to a model where the manufacturer sells directly to final consumers. We frame it as an input market setting because, on the one hand, non-discrimination laws are typically applicable to contracts between firms at different nodes of a supply chain, and, on the other hand, nonlinear contracts are common in business-to-business relations.

[13] This assumption is weaker than the standard assumption $P'(q) < \min\{0, -qP''(q)\}$, which is typically imposed for the case of Cournot competition downstream (Vives, 1999; Inderst and Valletti, 2009).

[14] Our model can also be interpreted as a model of demand uncertainty where each downstream firm produces with constant marginal cost c_L. With probability α_i downstream firm i faces high demand $P(q)$, otherwise it faces low demand $\tilde{P}(q) = \max\{P(q) - (c_H - c_L), 0\}$.

[15] This simple form of tariffs is indeed optimal under price discrimination. Under uniform pricing, on the other hand, the manufacturer benefits from offering a direct mechanism, which specifies quantity-transfer pairs depending on both firms' type announcements. Such a direct mechanism would implement the same allocation

downstream firm i can produce any quantity $q \in [0, q']$ of the final output at cost $c_i q$.

The sequence of events is as follows: first, nature draws the cost type for each downstream firm $i \in \{1, 2\}$, which thereafter is privately observed by the respective downstream firm. Next, the manufacturer makes a take-it-or-leave-it offer to each downstream firm. Under price discrimination the manufacturer offers each downstream firm a possibly different tariff, whereas under uniform pricing one and the same tariff applies to both firms. A downstream firm either chooses one of the two offered quantity-transfer pairs or it rejects the manufacturer's offer. In case of rejection, the downstream firm obtains its reservation profit, which is normalized to zero. If the downstream firm accepts a quantity-transfer pair (q, t), it decides how much of this acquired input to transform into the final good, and sells the produced output to consumers.

With the set of ex post types (potential ex post profits) being identical for both downstream firms in our model, the quantity discounts offered by the manufacturer under uniform pricing are available to both firms ex ante and in this sense practically available. If the firms' type spaces are different, say because one firm operates in a significantly larger market than the other firm, then the quantities assigned to the firm operating in the large market might never be attractive to the firm operating in the small market. If this is the case, the manufacturer can use a quantity rebate scheme in order to implement third-degree price discrimination indirectly. This is not feasible in our model, which therefore provides a clean comparison of a situation where price discrimination is permitted to a situation where price discrimination is not only forbidden but also not feasible indirectly via sophisticated quantity rebate schemes.

3. THE ANALYSIS

Let $q^*(c) = \arg\max_{q \geq 0}\{(P(q) - c)q\}$ denote the quantity optimally produced by a downstream firm that operates at marginal cost c. It is readily verified that $q^*(\cdot)$ is strictly decreasing in c. Due to free disposal, downstream firm i's maximum profit when faced with quantity-transfer tuple (q, t) is $\pi(q, c_i) - t$, where

$$\pi(q, c_i) = [P(\min\{q, q^*(c_i)\}) - c_i] \min\{q, q^*(c_i)\}. \tag{1}$$

Thus, downstream firm i's gross profit $\pi(q, c_i)$ is strictly increasing and strictly concave in q on $[0, q^*(c_i))$ and constant for $q \geq q^*(c_i)$. Moreover, $\pi(q, c_i)$ satisfies the following single-crossing property:

as an indirect mechanism with pre-contracting communication. Regarding indirect mechanisms, qualitatively similar results can be obtained when the manufacturer offers a three-part tariff to each downstream firm:

$$\Gamma_i(q) = \begin{cases} L_i + \hat{w}_i q & \text{for } q \leq \bar{q}_i \\ L_i + \hat{w}_i \bar{q}_i + \tilde{w}_i(\bar{q}_i - q) & \text{for } q > \bar{q}_i \end{cases}.$$

As we show in the Appendix B, for linear demand the quantities procured under the optimal three-part tariffs are exactly the same as the quantities optimally specified in the quantity-transfer lists we consider, which implies that the welfare findings are also identical.

Lemma 1. *A low-cost downstream firm benefits more from an increase in the quantity of the input than a high-cost downstream firm: for all* $0 \leq q' < q'' \leq q^*(c_L)$ *it holds that*

$$\pi(q'', c_L) - \pi(q', c_L) > \pi(q'', c_H) - \pi(q', c_H).$$

Furthermore, let $q^{JS}(c) = \arg\max_{q \geq 0}\{(P(q) - c)q - Kq\}$ denote the optimal quantity produced by a vertically integrated structure comprising of the manufacturer and a downstream firm with marginal cost c.

3.1. Optimal Wholesale Tariffs

Discriminatory offers.—If not restricted to offering the same wholesale tariffs to both downstream firms, the manufacturer solves two independent maximization problems. When contracting with a downstream firm that produces at low costs with probability α, the manufacturer offers a wholesale tariff $\Gamma = \langle(q_L, t_L), (q_H, t_H)\rangle$ in order to maximize expected upstream profits,

$$\alpha[t_L - Kq_L] + (1 - \alpha)[t_H - Kq_H] \ , \tag{2}$$

subject to Γ being incentive compatible and individually rational,

$$\pi(q_L, c_L) - t_L \geq \pi(q_H, c_L) - t_H \ , \tag{IC$_L$}$$
$$\pi(q_H, c_H) - t_H \geq \pi(q_L, c_H) - t_L \ , \tag{IC$_H$}$$
$$\pi(q_L, c_L) - t_L \geq 0 \ , \tag{IR$_L$}$$
$$\pi(q_H, c_H) - t_H \geq 0 \ . \tag{IR$_H$}$$

As usual, incentive compatibility requires that the low-cost type obtains a higher quantity than the high-cost type, $q_H \leq q_L$. Moreover, due to free disposal in the optimum we must have $q_H \leq q^*(c_H)$ and $q_L \leq q^*(c_L)$. Thus, the optimal contract satisfies the following monotonicity constraint:

$$q_H \leq \min\{q_L, q^*(c_H)\} \leq \max\{q_L, q^*(c_H)\} \leq q^*(c_L). \tag{MON}$$

By standard arguments, the transfers t_H and t_L are uniquely determined by the two binding constraints, (IR$_H$) and (IC$_L$). Hence, the manufacturer chooses quantities q_L and q_H to maximize

$$\begin{aligned}\Pi^D(q_L, q_H) \ = \ \alpha\,\{[P(q_L) - c_L]q_L - q_H(c_H - c_L) - Kq_L\} \\ + (1 - \alpha)\,\{[P(q_H) - c_H]q_H - Kq_H\}\end{aligned} \tag{3}$$

subject to the monotonicity requirement (MON). Define

$$\hat{\alpha} := \frac{P(0) - c_H - K}{P(0) - c_L - K} \in (0, 1). \tag{4}$$

Proposition 1. *Under discriminatory wholesale tariffs, a low-cost firm obtains the joint surplus maximizing quantity, $q_L^D = q^{JS}(c_L)$, whereas the quantity assigned to a high-cost firm is distorted downwards. If a firm is very likely to produce at low costs, $\alpha \geq \hat{\alpha}$, then the quantity assigned to its high-cost type equals zero. If $\alpha < \hat{\alpha}$, then $q_H^D(\alpha) > 0$ is defined by*

$$P(q_H^D(\alpha)) - c_H + P'(q_H^D(\alpha))q_H^D(\alpha) = K + \frac{\alpha}{1-\alpha}(c_H - c_L). \tag{5}$$

Intuitively, as the probability of dealing with a low-cost downstream firm becomes smaller, the manufacturer chooses the quantity offered to the high-cost type closer to the joint-surplus maximizing quantity $q^{JS}(c_H)$. If, on the other hand, the probability of contracting with a low-cost downstream firm is sufficiently high, the manufacturer prefers to offer a zero quantity to the high-cost type. This eliminates information rents and in turn allows the manufacturer to extract all the surplus from the interaction with a low-cost type. A low-cost firm is always assigned the joint-surplus maximizing quantity, which is the well-known no distortion at the top result. It is worthwhile to point out that if the difference in possible retail costs is not too high, both cost types are rather likely to be served by the manufacturer.

Uniform pricing.—The requirement that both downstream firms have to be offered the same tariff, i.e., $\Gamma_1 = \Gamma_2$, leaves the incentive compatibility and individual rationality constraints unchanged. The manufacturer chooses quantities q_L and q_H in order to maximize

$$\begin{aligned}\Pi^U(q_L, q_H) \;=\; &\alpha_\Sigma \left\{[P(q_L) - c_L]q_L - q_H(c_H - c_L) - Kq_L\right\} \\ &+ (2-\alpha_\Sigma)\left\{[P(q_H) - c_H]q_H - Kq_H\right\},\end{aligned} \tag{6}$$

where $\alpha_\Sigma := \alpha_1 + \alpha_2$. In order to characterize the optimal tariff under uniform pricing, let

$$\hat{\alpha}_1(\alpha_2) := 2\hat{\alpha} - \alpha_2 \tag{7}$$

denote the value of α_1 that, for a given value of α_2, results in an average probability of contracting with a low-cost firm equal to $\hat{\alpha}$.

Proposition 2. *Under a uniform wholesale tariff, a low-cost firm obtains the joint surplus maximizing quantity, $q_L^U = q^{JS}(c_L)$, whereas the quantity assigned to a high-cost firm is distorted downwards. If the average probability of both downstream firms to produce at low costs is relatively high, $\alpha_1 \geq \hat{\alpha}_1(\alpha_2)$, then the quantity assigned to a high-cost type equals zero. If $\alpha_1 < \hat{\alpha}_1(\alpha_2)$, then $q_H^U(\alpha_\Sigma) > 0$ is defined by*

$$P(q_H^U(\alpha_\Sigma)) - c_H + P'(q_H^U(\alpha_\Sigma))q_H^U(\alpha_\Sigma) = K + \frac{\alpha_\Sigma/2}{1-\alpha_\Sigma/2}(c_H - c_L). \tag{8}$$

Comparison of pricing regimes.—The degree of the downward distortion in a high-cost type's quantity is determined by the respective firm's individual probability of producing at low cost under price discrimination and by the average probability of contracting with a low-cost firm under uniform pricing. The following lemma orders the different quantities assigned to high-cost types.

Lemma 2. *The quantity offered to high-cost firms under uniform pricing is bracketed by the quantities offered to the high-cost firms under price discrimination:*

$$q_H^D(\alpha_1) \leq q_H^U(\alpha_\Sigma) \leq q_H^D(\alpha_2) < q^{JS}(c_H). \tag{9}$$

3.2. Welfare

We now turn to the welfare implications of banning price discrimination. Welfare under pricing regime $r \in \{D, U\}$, which is stochastic ex ante, is defined as the sum of consumer and producer surplus, $W^r = \sum_{i=1}^{2}\{\int_0^{q_i^r} P(z)dz - (c_i + K)q_i^r\}$. Let the difference in expected welfare between the discriminatory pricing regime and the uniform pricing regime be $\Delta W := E[W^D] - E[W^U]$.

To delineate the importance of asymmetric information, we first consider a benchmark case with symmetric information.

Proposition 3. *Suppose downstream firm 1 produces at low costs with certainty, $\alpha_1 = 1$, and downstream firm 2 produces at high cost with certainty, $\alpha_2 = 0$. Then, permitting price discrimination improves welfare, i.e., $\Delta W > 0$.*

With symmetric information, if price discrimination is allowed, it is optimal for the manufacturer to offer each downstream firm the joint surplus maximizing quantity—irrespective of its cost type—and to fully extract downstream profits via the transfer. Under uniform pricing this is not optimal and the manufacturer faces a metering problem similar to the screening problem under asymmetric information. The efficient firm 1 obtains the joint surplus maximizing quantity but the quantity assigned to the less efficient firm 2 is distorted downwards. With even the joint-surplus maximizing quantities being too low from a welfare perspective it is readily obtained that banning price discrimination is strictly welfare harming.[16]

Under asymmetric information ΔW depends only on the quantities produced by high-cost retailers because there is no distortion at the top under either regime. Formally,

$$\begin{aligned}\Delta W &:= \Delta W(\alpha_1, \alpha_2)\\ &= \sum_{i=1}^{2}(1-\alpha_i)\left[\int_{q_H^U(\alpha_1+\alpha_2)}^{q_H^D(\alpha_i)} P(z)dz - (c_H + K)(q_H^D(\alpha_i) - q_H^U(\alpha_1+\alpha_2))\right]. \end{aligned} \tag{10}$$

Thus, we can distinguish the following four cases, as depicted in Figure 1:

(I) If both downstream firms are relatively unlikely to produce at low costs, $\alpha_2 < \alpha_1 < \hat{\alpha}$, then high-cost production takes place in both markets under either pricing regime, i.e., $0 < q_H^D(\alpha_1) < q_H^U(\alpha_\Sigma) < q_H^D(\alpha_2)$.

[16] An alternative benchmark with symmetric information is the following: downstream firms' costs are stochastic but contracting takes place ex ante before the cost types are realized. Under price discrimination both firms sell the joint surplus maximizing quantities irrespective of the realized cost type. Under uniform pricing the manufacturer again faces a metering problem. As a consequence the quantities sold by high-cost downstream firms are distorted downward and banning price discrimination, again, is detrimental for welfare.

(II) If firm 1 is relatively likely and firm 2 is relatively unlikely to produce at low costs, $\alpha_2 < \hat{\alpha} \leq \alpha_1 < \hat{\alpha}_1(\alpha_2)$, then high-cost production takes place in both markets under uniform pricing, while under price discrimination high-cost production takes place only in market 2, i.e., $0 = q_H^D(\alpha_1) < q_H^U(\alpha_\Sigma) < q_H^D(\alpha_2)$.

(III) If firm 1 is very likely and firm 2 is relatively unlikely (but not too unlikely) to produce at low costs, $\alpha_2 < \hat{\alpha} \leq \hat{\alpha}_1(\alpha_2) \leq \alpha_1$, then high-cost production takes place only under price discrimination and only in market 2, i.e., $0 = q_H^D(\alpha_1) = q_H^U(\alpha_\Sigma) < q_H^D(\alpha_2)$.

(IV) If both firms are relatively likely to produce at low costs, $\hat{\alpha} \leq \alpha_2 < \alpha_1$, then high-cost production does not take place under either pricing regime, i.e., $0 = q_H^D(\alpha_1) = q_H^U(\alpha_\Sigma) = q_H^D(\alpha_2)$.

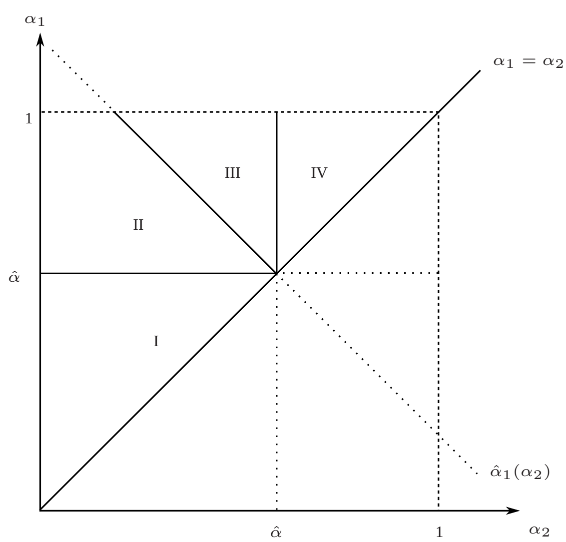

Figure 1: Welfare comparison.

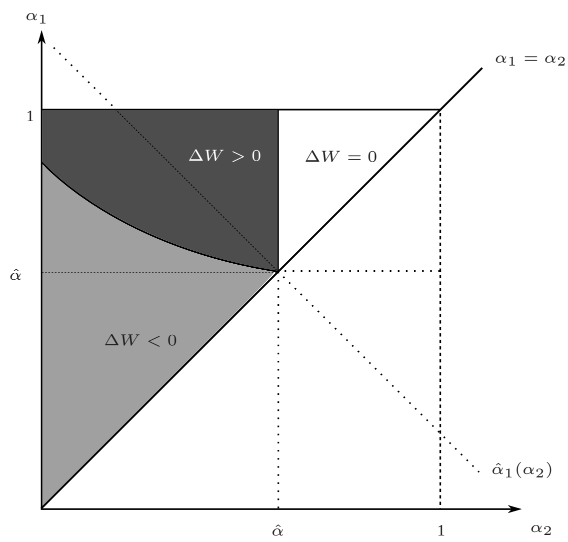

Figure 2: Linear demand.

In case (IV), with the manufacturer never serving a high-cost downstream firm irrespective of the pricing regime, we have $\Delta W = 0$. Therefore, in what follows, we focus on the interesting cases (I) - (III).

Before characterizing the welfare consequences of banning price discrimination it is worthwhile to point out how the different parties are affected by this policy. Clearly, the manufacturer is harmed if price discrimination is banned. Moreover, in expectations, consumers in market 1 benefit while consumers in market 2 are harmed. Finally, note that a downstream firm's ex ante expected profit is equal to its expected information rent, which is increasing in the quantity assigned to its high-cost type. Therefore, from an ex ante perspective, downstream firm 1 benefits while downstream firm 2 is harmed by a ban on price discrimination.

In order to state the main finding of this section, define the expected change in quantity as $\Delta Q := E[Q^D] - E[Q^U]$, with Q^r denoting the aggregate quantity of the final good.

Proposition 4. *Suppose that high-cost production takes place at least in market 2 under price discrimination, i.e.,* $\alpha_2 < \hat{\alpha}$.

(i) If high-cost production takes place under uniform pricing, $\alpha_1 < \hat{\alpha}_1(\alpha_2)$, then permitting price discrimination harms welfare whenever it does not lead to a strict expansion in expected total output, i.e., $\Delta Q \leq 0 \implies \Delta W < 0$.

(ii) If high-cost production takes place only under price discrimination, $\alpha_1 \geq \hat{\alpha}_1(\alpha_2)$, then permitting price discrimination improves welfare, i.e., $\Delta W > 0$.

In case (III)—part (ii) of Proposition 4—to cut back on information rents, M assigns a zero quantity to the high-cost type of firm 1 under price discrimination and to high-cost downstream firms in general under uniform pricing. Thus, price discrimination leads to more markets being served (in expectation), thereby benefiting welfare in the spirit of the classic Chicago school argument against non-discrimination clauses.

In cases (I) and (II)—part (i) of Proposition 4—it is not clear which pricing regime results in higher expected welfare due to opposing effects. In the case of high-cost production, the quantity sold in market 2 is lower whereas the quantity sold in market 1 is higher under uniform pricing than under price discrimination—market 1 is not even served under price discrimination in case (II). Even though a general welfare result cannot be derived in these cases, we can establish a sufficient condition—resembling Schmalensee's (1981) output test—for uniform pricing to improve welfare: if price discrimination does not lead to an expansion of expected total output, expected welfare decreases if price discrimination is permitted.[17]

The above discussion leads us to conjecture that banning price discrimination can be welfare enhancing, which is further supported by analyzing case (II) in more detail.

Corollary 1. *If high-cost production takes place under uniform pricing but only in market 2 under price discrimination, $\hat{\alpha} < \alpha_1 < \hat{\alpha}_1(\alpha_2)$, then permitting price discrimination becomes more likely to be welfare harming as firm 1 becomes more likely to be a high-cost type, i.e., $d\Delta W/d\alpha_1 > 0$.*

Corollary 1 suggests that banning price discrimination can switch from being welfare harming to being welfare enhancing as the probability of firm 1 to be the low-cost type decreases. We will show below that this conjecture holds true for a linear demand function.

Even if price discrimination is legally banned, one might argue that in practice the manufacturer might get away with discriminatory wholesale tariffs as long as none of the downstream firms files a complaint. First of all, note that high-cost types obtain their reservation profits independent of the pricing regime. Moreover, as we have argued above, in the case of low-cost production downstream firm 1 would benefit from the enforcement of the nondiscrimination clause whereas downstream firm 2 would suffer. Therefore, if a downstream firm brings a case, then it must be the low-cost type of firm 1. In case of a complaint, however, the enforcement of

[17] In analogy to Varian (1985), we can establish also a lower bound regarding the change in expected welfare: $\Delta W > \sum_{i=1}^{2}(1-\alpha_i)[P(q_H^D(\alpha_i)) - (c_H + K)](q_H^D(\alpha_i) - q_H^U(\alpha_\Sigma))$. An immediate implication is that price discrimination improves welfare if (from the perspective of a vertically integrated firm) the profitability of the output under price discrimination exceeds the profitability of the output under uniform pricing *valued at the discriminatory prices*.

the nondiscrimination clause is welfare neutral at best: while the quantity in low-cost markets is unaffected, the quantity in market 2 in case of high-cost production is reduced, which harms welfare. As we will argue in Section 5, this rather negative observation is an artifact of the two-type case.

3.3. An Application with Linear Demand

Suppose demand is linear, $P(q) = \max\{0, 1-q\}$, and assume that $c_H + K < 1$. In this case, $q^{JS}(c_H) = \frac{1-c_H-K}{2}$, $q_H^D(\alpha) = \max\{0, q^{JS}(c_H) - \frac{\alpha}{1-\alpha}\frac{c_H-c_L}{2}\}$, and $q_H^U(\alpha_\Sigma) = \max\{0, q^{JS}(c_H) - \frac{\alpha_\Sigma/2}{1-\alpha_\Sigma/2}\frac{c_H-c_L}{2}\}$. Letting $\alpha_1^W(\alpha_2)$ be implicitly defined by $\Delta W(\alpha_1^W(\alpha_2), \alpha_2) \equiv 0$, tedious but straightforward calculations yield the following result.

Proposition 5. *Suppose that high-cost production takes place at least in market 2 under price discrimination, i.e., $\alpha_2 < \hat{\alpha}$. Then, permitting price discrimination harms welfare if and only if firm 1 is likely to produce at high cost, i.e., $\Delta W < 0 \iff \alpha_1 < \alpha_1^W(\alpha_2)$.*

Proposition 5 is illustrated in Figure 2. If the antitrust authority need not be overly concerned about the possibility of one or the other market not being served under either pricing regime (for $\hat{\alpha}$ large), then—at least for linear demand—banning price discrimination is socially desirable. The area where both markets are served irrespective of the pricing regime is quite large if the difference in retail costs between a high-cost and a low-cost firm is relatively low. Hence, if differences in ex post retail costs are not overly large and if the demand function is sufficiently linear in the relevant range of prices, banning price discrimination—the usual legal practice in the EU—improves welfare.

The finding that banning price discrimination often is welfare improving is in contrast to findings in the extant literature on third-degree price discrimination under nonlinear wholesale tariffs. Inderst and Shaffer (2009), for instance, consider a manufacturer who is perfectly informed about the retail costs of two asymmetric downstream firms. For the case of separate markets—Proposition 6 of Inderst and Shaffer—they show that banning price discrimination unambiguously reduces welfare, which parallels our symmetric information benchmark (cf. Proposition 3). With symmetric information price discrimination allows the manufacturer to achieve the vertically integrated outcome, which can be considered as a second best. This second-best outcome is not achieved under uniform pricing, where the quantity procured by the inefficient firm is distorted downward due to the additional incentive constraint. With asymmetric information, in contrast, the manufacturer is constrained by incentive compatibility under either pricing regime. As a result, the quantities procured by high-cost downstream firms are distorted downwards under both pricing regimes. In general it is unclear which pricing regime leads to the larger average distortion. Proposition 5 shows that the average distortion is higher under price discrimination than under uniform pricing if demand is linear, leading to a ban on price discrimination being welfare improving. Put differently, our finding shows that the strong welfare result of Inderst and Shaffer does not carry over to the case of asymmetric information.

Finally, the welfare assessment in Proposition 5 allows us to address the usefulness of the output test proposed in Proposition 4(i). Remember that this output test embodies a sufficient condition for price discrimination to be welfare harming. The relevant question to ask therefore is for what part of the dark-gray shaded area in Figure 2 the expected overall quantity is weakly smaller under price discrimination than under uniform pricing. When all markets are always served, case (I), then $\Delta Q = 0$ and we can conclude that a ban on price discrimination is welfare improving. In case (II), when the high-cost type of firm 1 is not served under price discrimination, price discrimination always leads to an expansion of expected aggregate output. Thus, in case (II), the output test does not help to specify which pricing regime is superior from a welfare point of view.

4. Long-Run Analysis

For linear wholesale prices, DeGraba (1990) pointed out a further channel through which differences in the pricing regimes can translate into differences in welfare: with the more efficient downstream firm being discriminated against, price discrimination leads to lower incentives for downstream firms to invest in a more efficient retail technology, thereby harming welfare not only in the short run but also in the long run. In this section, we show that a ban on price discrimination increases downstream firms' incentives to invest in cost reduction also when nonlinear wholesale contracts are in place.

Specifically, suppose that initially both downstream firms produce at high cost with certainty. At some preliminary stage 0, before the manufacturer makes its offers, both downstream firms can simultaneously invest in R&D. If the research of a downstream firm is successful, this downstream firm produces at low cost c_L; otherwise, this downstream firm continues to operate at high cost c_H. If a downstream firm incurs investment cost $\psi(\alpha)$, its research is successful with probability $\alpha \in [0, 1]$, where $\psi(0) = \psi'(0) = 0$ and $\psi''(\cdot) \geq 0$. Thus, in a sense, α reflects a downstream firm's research intensity. The investment in R&D is observed by the manufacturer. Whether the research was successful, however, is private information of each downstream firm. We focus on symmetric equilibria in pure strategies.[18] In order to obtain a clear-cut finding with respect to the difference in investment incentives under the two pricing regimes, we impose the following

Assumption 1. *Downstream marginal revenue is concave:* $3P''(q) + qP'''(q) \leq 0$, *whenever* $P > 0$.

Investment Incentives.—Remember that transfers charged by the manufacturer are pinned down by (IR$_H$) and (IC$_L$). Given R&D intensities α_i and α_j, downstream firm i's expected profit at the investment stage under pricing regime $r \in \{D, U\}$ is

$$\pi_0^r(\alpha_i) = \alpha_i(c_H - c_L)q_H^r(\alpha_i, \alpha_j) - \psi(\alpha_i), \tag{11}$$

[18] For the case of zero investment cost, $\psi(\alpha_i) \equiv 0$, we focus on symmetric equilibria in undominated strategies.

where $q_H^r(\alpha_i, \alpha_j)$ denotes the quantity offered to firm i's high-cost type under pricing regime r. Taking the derivative of (11) with respect to α_i yields the following first-order condition:

$$q_H^r(\alpha_i, \alpha_j)(c_H - c_L) + \alpha_i(c_H - c_L)\frac{\partial q_H^r(\alpha_i, \alpha_j)}{\partial \alpha_i} = \psi'(\alpha_i). \tag{12}$$

On the one hand, a higher investment makes it more likely that the downstream firm produces at low costs, and thus obtains a positive information rent. On the other hand, the information rent decreases in a downstream firm's investment, because the quantity assigned to a high-cost firm is decreasing in the investment level. Under price discrimination the expected information rent of firm i depends only on its own investment level, whereas under uniform pricing it depends on the average investment level of both firms. Thus, the manufacturer reacts more strongly to an increased investment of firm i—and cuts back this firm's information rent more severely—under price discrimination than under uniform pricing. In consequence, permitting discriminatory wholesale contracts stifles downstream firms' incentives to invest in a reduction of their production costs.[19]

Proposition 6. *Suppose that Assumption 1 holds, so that downstream marginal revenue is concave. Then, a downstream firm's investment into cost reduction is higher under uniform pricing than under price discrimination, i.e.,* $0 < \alpha^D < \alpha^U$.

Welfare.—With investment incentives being higher under uniform pricing than under price discrimination, it seems likely that in the long run banning price discrimination is socially beneficial. The next finding establishes this conjecture for a specification with linear demand.

Proposition 7. *Suppose that demand is linear and there are no investment costs, i.e.,* $P(q) = \max\{1 - q, 0\}$ *and* $\psi(\alpha) \equiv 0$ *for all* $\alpha \in [0, 1]$. *Then, in the long run, welfare is higher under uniform pricing than under price discrimination.*

In the long run, with $\alpha^D < \alpha^U < \hat{\alpha}$, both cost types of both downstream firms are always served. Moreover, with investment incentives being higher under uniform pricing than under price discrimination, a firm is more likely to produce at low cost under uniform pricing. This effect supports welfare under uniform pricing compared to price discrimination. With higher investment incentives under uniform pricing, however, the downward distortion in quantity for a high-cost firm is stronger which reduces welfare under uniform pricing compared to price discrimination. According to Proposition 7 the direct effect due to an increased probability of producing at low costs outweighs the indirect effect of a higher quantity distortion, thereby making a ban on price discrimination socially desirable in the long-run.

[19]Following DeGraba (1990) we consider symmetric firms which implies that no discrimination takes place on the equilibrium path. Nevertheless, when discrimination is possible (off equilibrium) this has an effect on the downstream firms' investment incentives.

5. Continuous Distribution of Downstream Costs

In this section, we allow for the marginal cost of downstream firm $i \in \{1, 2\}$ being continuously distributed, i.e., $c \in [c_L, c_H] \equiv \mathcal{C}$ with $0 \leq c_L < c_H$. Firm i's cost is ex ante distributed according to c.d.f. $F_i(c)$ with density $f_i(c) > 0$ for all $c \in \mathcal{C}$. The cost distributions of the two firms are different in the sense that there exist values of $c \in \mathcal{C}$ such that $F_1(c)/f_1(c) \neq F_2(c)/f_2(c)$. The manufacturer, who knows the firms' ex ante cost distributions but not effective retail costs, offers downstream firm i a quantity-transfer list $\Gamma_i \equiv \langle (q_i(c), t_i(c)) \rangle_{c \in \mathcal{C}}$, specifying a quantity $q_i(c) \in \mathbb{R}_{\geq 0}$ and a transfer $t_i(c)$ for each feasible cost type. For this continuous-type case, we focus on linear demand $P(q) = \max\{1 - q, 0\}$. The manufacturer's expected profit is given by

$$\Pi = \sum_{i=1}^{2} \left\{ \int_{c_L}^{c_H} [t_i(c) - K q_i(c)] f_i(c) \, dc \right\}. \tag{13}$$

As before the manufacturer has to satisfy the individual rationality and incentive constraints: for all $i \in \{1, 2\}$ and $c \in \mathcal{C}$,

$$q_i(c)[1 - q_i(c) - c] - t_i(c) \geq 0 \tag{IR}$$

$$c \in \arg\max_{\tilde{c} \in \mathcal{C}} \{q_i(\tilde{c})[1 - q_i(\tilde{c}) - c] - t_i(\tilde{c})\}. \tag{IC}$$

If price discrimination is banned, the manufacturer has to comply with the non-discrimination constraint $\Gamma_1 = \Gamma_2$. Note that for the manufacturer it is more profitable to contract with low-cost downstream firms. This implies that the usual monotonicity requirement, which is necessary to satisfy incentive compatibility, here requires that $q_i(c)$ and $t_i(c)$ are non-increasing. In order to avoid bunching, we impose the following assumption in the spirit of the monotone hazard rate property.

Assumption 2. *For all $c \in \mathcal{C}$ it holds that $F_i(c)/f_i(c)$, with $i \in \{1, 2\}$, and $[F_1(c)+F_2(c)]/[f_1(c) + f_2(c)]$ are non-decreasing.*

Note that Assumption 2, which guarantees that optimal quantity schedules are strictly decreasing, is satisfied if both density functions are weakly decreasing.

Moreover, we focus on cases where—irrespective of the pricing regime—the manufacturer serves all types of downstream firms, which corresponds to case (I) in the previous analysis.

Assumption 3. $c_H + K < 1 - [\min\{f_1(c_H), f_2(c_H)\}]^{-1}$.

Lemma 3. *Suppose that Assumptions 2 and 3 hold, so that the optimal quantity schedules are all strictly decreasing in the cost type and all cost types procure a strictly positive quantity. Then, there exist cost realizations for which the quantities assigned to the two firms under discrimination differ, i.e., there are $c \in \mathcal{C}$ such that $q_i^D(c) < q_j^D(c)$ for $i, j \in \{1, 2\}$ and $i \neq j$. For all these cost realization the quantity offered under uniform pricing is strictly bracketed by the two discriminatory quantities, i.e., $q_i^D(c) < q^U(c) < q_j^D(c)$.*

According to Lemma 3, one market benefits from price discrimination whereas the other market is harmed compared to uniform pricing for a given cost realization. Nevertheless, we obtain a clear welfare result.

Proposition 8. *Suppose that Assumptions 2 and 3 hold, so that the optimal quantity schedules are all strictly decreasing in the cost type and all cost types procure a strictly positive quantity. Then, permitting price discrimination harms welfare, i.e.,* $\Delta W < 0$.

In the two-type case we have argued that if a downstream firm has an incentive to bring a case, the enforcement of a nondiscrimination clause is welfare neutral at best. As the next finding shows, with a continuum of cost types, if a firm has an incentive to bring a case, the enforcement of a uniform tariff can improve welfare.

Observation 1. *Suppose* $f_1(c)$ *crosses* $f_2(c)$ *once from above at* $\tilde{c} \in (c_L, c_H)$*, so that firm 1 is more likely to produce at low-cost levels than firm 2. If the manufacturer offers different tariffs to the downstream firms, then the ex ante efficient firm* 1 *has an incentive to bring a case when its costs are relatively high—in particular for* $c \in [\tilde{c}, c_H)$*. Moreover, if the lawsuit is successful, output in market* 1 *increases which increases welfare in market* 1.

6. Demand-Side Substitution

As was recently shown by Inderst and Valletti (2009) and Caprice (2006), the implications of price discrimination in input markets for pricing decisions and welfare may be reversed if the assumption of a monopolistic input supplier is relaxed. As we will show next, the main effect of downstream firms having an outside option in our model is to shift rents from the manufacturer to the downstream firms. As a result, by and large, our findings are robust toward relaxing the assumption of a monopolistic input supplier.[20]

Consider the same model as before, but suppose that a downstream firm, when rejecting the manufacturer's offer, can turn to an alternative source of input supply. If a firm with marginal cost $c \in \{c_L, c_H\}$ acquires its input from the alternative supply, then its profits are $\pi^A(c)$, with $0 \leq \pi^A(c_H) < \pi^A(c_L)$.[21,22] We assume that the alternative supply is not too attractive in the sense that the joint surplus generated by the manufacturer and either type of downstream firm exceeds that downstream firm's profit obtained under the alternative supply.

Assumption 4. *For all* $c \in \{c_L, c_H\}$ *it holds that* $\pi(q^{JS}(c), c) - Kq^{JS}(c) > \pi^A(c)$.

Define

$$\phi := \frac{\pi^A(c_L) - \pi^A(c_H)}{c_H - c_L}, \tag{14}$$

[20] A detailed derivation of the results presented in this section is to be found in Appendix B.

[21] Here, the manufacturer faces a screening problem with a type-dependent outside option. This class of problems is thoroughly analyzed, for instance, by Jullien (1996, 2000).

[22] For instance, if a competitive fringe supplies the input at per-unit wholesale price w^A, then $\pi^A(c) = \max_q\{q[P(q) - c - w^A]\}$.

which declares how much more a low-cost firm benefits from the alternative input supply than a high-cost firm, relative to the low-cost firm's cost advantage. In order to stick close to our basic model, we keep c_L and c_H fixed and assume that any variation in ϕ arises due to changes in $\pi^A(c_L)$ or $\pi^A(c_H)$.

For reasons of tractability, we focus on situations where under the optimal contract it is never the upward incentive constraint that is binding, i.e., we do not consider *countervailing incentives* in the sense of Lewis and Sappington (1989).[23] Moreover, we restrict attention to circumstances where the manufacturer serves both types of downstream firms, which allows to draw welfare implications irrespective of the particular form the alternative supply takes. A sufficient condition for the optimal contract to satisfy these properties is

Assumption 5. $\phi \in [\tilde{\phi}, q^{JS}(c_H)]$*, where* $\pi(\tilde{\phi}, c_H) - \pi^A(c_H) - K\tilde{\phi} \equiv 0$.

While the existence of an alternative supply leaves the incentive compatibility constraints unchanged, the individual rationality constraints now reflect type-dependent outside options:

$$\pi(q_L, c_L) - t_L \geq \pi^A(c_L) \; , \tag{IR$_L^A$}$$

$$\pi(q_H, c_H) - t_H \geq \pi^A(c_H) \; . \tag{IR$_H^A$}$$

For pricing regime $r \in \{D, U\}$, define $\alpha^r(\phi)$ as the critical probability of low-cost production at which the quantity assigned to a high-cost type in the case without type-dependent outside options equals ϕ. Moreover, let $\alpha_1^U(\alpha_2;\phi) := \alpha^U(\phi) - \alpha_2$ and note that $\alpha_1^U(\alpha^D(\phi);\phi) = \alpha^D(\phi)$. The following result shows that our previous findings are robust toward relaxing the assumption of an unconstrained manufacturer.

Proposition 9. *Suppose that Assumptions 4 and 5 hold, so that under the optimal contract countervailing incentives do not prevail and neither downstream firm procures its input from the alternative supply. Moreover, suppose that firm 2 is likely to produce at high cost,* $\alpha_2 < \alpha^D(\phi)$*.*

(i) If firm 1 is rather likely to produce at high cost, $\alpha_1 < \alpha_1^U(\alpha_2;\phi)$*, then permitting price discrimination harms welfare whenever it does not lead to a strict expansion in expected total output, i.e.,* $\Delta Q \leq 0 \implies \Delta W < 0$*.*

(ii) If firm 1 is rather likely to produce at low cost, $\alpha_1^U(\alpha_2;\phi) \leq \alpha_1$*, then permitting price discrimination improves welfare, i.e.,* $\Delta W > 0$*.*

In comparison to our baseline model, instead of high-cost firms not being served at all, now high-cost firms are offered a "rather low" quantity equal to ϕ if contracting with a low-cost firm is sufficiently likely. Otherwise, however, the intuition behind the welfare result of Proposition 9 is basically the same as the one behind Proposition 4. In particular, banning price discrimination can be beneficial for welfare also in situations where the manufacturer is not an unconstrained monopolist.[24] This becomes apparent when investigating the case of linear demand.

[23] Cf. also Tirole (1988, p.154).

[24] Moreover, just like in the case without alternative supply, if high-cost production takes pace in both markets only under uniform pricing, $\alpha^D(\phi) < \alpha_1 < \alpha_1^U(\alpha_2;\phi)$, then ΔW is strictly increasing in α_1.

Corollary 2. *Suppose that Assumptions 4 and 5 hold, so that under the optimal contract countervailing incentives do not prevail and neither downstream firm procures its input from the alternative supply. Furthermore, suppose demand is linear,* $P(q) = \max\{1 - q, 0\}$*. Then, if firm 1 is likely to produce at high cost,* $\alpha_1 < \alpha^D(\phi)$*, permitting price discrimination harms welfare, i.e.,* $\Delta W < 0$*.*

According to Corollary 2, if the potential differences in retail costs are low, a ban on price discrimination improves welfare at least for linear demand. In order to see this, notice that $\alpha^D(\phi) = [q^{JS}(c_H) - \phi]/[q^{JS}(c_L) - \phi]$ approaches 1 as c_H tends to c_L.

7. Conclusion

In this paper, we analyze a vertically related industry with asymmetric information between the upstream and the downstream sector. The main purpose is to inquire into the welfare effects of banning third-degree price discrimination in intermediate-good markets when nonlinear pricing schemes are feasible. This question is of immediate practical interest because from a legal perspective, quantity discounts are commonly regarded as a justifiable pricing strategy of manufacturers as long as they are not discriminatory in the sense of applying different conditions to identical transactions with different trading partners.

While there has been considerable back and forth in the academic literature regarding the question whether banning price discrimination in input markets constitutes a desirable course of policy when wholesale prices are linear, among the few exceptions which consider nonlinear wholesale pricing schemes the predominant opinion is that banning price discrimination is detrimental for welfare. In contrast to these findings, we show that even if nonlinear pricing schemes are feasible, the reservation toward discriminatory pricing practices embodied in legal enactments may well be warranted when downstream firms have private information.

A weak point of our analysis is the focus on separate markets, which rules out potential competitive effects. We believe, however, that our findings carry over to situations where downstream firms compete in differentiated products—at least if the degree of differentiation is sufficiently large. We refrain from analyzing competition downstream because, with our focus on fairly general wholesale contracts, it is far from straightforward how to model competition in a tractable manner.

Many real-life trading relationships are long-lived. If a downstream firm's retail costs vary from period to period but are correlated over time, the manufacturer's assessment of the distribution of retail costs can become more precise over time and as a result the asymmetric information problem is reduced. To achieve incentive compatibility in early periods, however, becomes more costly, which increases the asymmetric information problem in early periods of the business relationship. To explore the repeated interaction between a manufacturer and privately informed retailers is a fascinating topic for future research.

A. Proofs of Propositions and Lemmas

Proof of Lemma 1. First, suppose $q' < q'' < q^*(c_H)$. Then

$$\begin{aligned} &\pi(q'', c_L) - \pi(q', c_L) > \pi(q'', c_H) - \pi(q', c_H) \\ &\iff [P(q'') - c_L]q'' - [P(q') - c_L]q' > [P(q'') - c_H]q'' - [P(q') - c_H]q' \\ &\iff q' < q''. \end{aligned} \tag{A.1}$$

Next, suppose $q' < q^*(c_H) \leq q'' \leq q^*(c_L)$. Then

$$\begin{aligned} &\pi(q'', c_L) - \pi(q', c_L) > \pi(q'', c_H) - \pi(q', c_H) = \pi(q^*(c_H), c_H) - \pi(q', c_H) \\ &\iff [P(q'') - c_L]q'' - [P(q') - c_L]q' > [P(q^*(c_H)) - c_H]q^*(c_H) - [P(q') - c_H]q' \\ &\iff [P(q'') - c_L]q'' - [P(q^*(c_H)) - c_L]q^*(c_H) + [P(q^*(c_H)) - c_L]q^*(c_H) \\ &\qquad - [P(q') - c_L]q' > [P(q^*(c_H)) - c_H]q^*(c_H) - [P(q') - c_H]q' \\ &\iff \pi(q'', c_L) - \pi(q^*(c_H), c_L) + (c_H - c_L)(q^*(c_H) - q') > 0, \end{aligned} \tag{A.2}$$

where the last inequality holds by $q' < q^*(c_H) \leq q'' \leq q^*(c_L)$ and $\pi(q, c_L)$ being strictly increasing in q on $[0, q^*(c_L))$.
Last, suppose $q^*(c_H) \leq q' < q'' \leq q^*(c_L)$. Then

$$\pi(q'', c_L) - \pi(q', c_L) > \pi(q'', c_H) - \pi(q', c_H) = \pi(q^*(c_H), c_H) - \pi(q^*(c_H), c_H) = 0 \tag{A.3}$$

holds because $\pi(q, c_L)$ is strictly increasing in q on $[0, q^*(c_L))$. □

Proof of Proposition 1. It is readily verified that $\Pi^D(q_L, q_H)$ is strictly concave. From the first-order condition $\partial\Pi^D/\partial q_L = 0$ we obtain that $q_L^D = q^{JS}(c_L)$. Moreover, a high-cost type is served if and only if

$$\left.\frac{\partial \Pi^D}{\partial q_H}\right|_{q_H=0} > 0 \iff \alpha < \hat{\alpha}. \tag{A.4}$$

If $\alpha < \hat{\alpha}$, then $q_H^D(\alpha)$ is characterized by the first-order condition $\partial\Pi^D/\partial q_H = 0$, cf. (5), and we have $0 < q_H^D(\alpha) < q^{JS}(c_H)$. Finally, note that q_L^D and $q_H^D(\alpha)$ satisfy the constraint (MON). □

Proof of Proposition 2. The result follows directly from the proof of Proposition 1 if we replace α by $\alpha_\Sigma/2$ and recognize that $\alpha_\Sigma/2 < \hat{\alpha}$ is equivalent to $\alpha_1 < \hat{\alpha}_1(\alpha_2)$. □

Proof of Lemma 2. The desired statement follows from Propositions 1 and 2 together with the definition of $q^{JS}(c)$ and the fact that

$$\alpha_2 < \alpha_1 \implies \frac{\alpha_2}{1-\alpha_2} < \frac{\alpha_1 + \alpha_2}{2 - \alpha_1 - \alpha_2} < \frac{\alpha_1}{1-\alpha_1}. \tag{A.5}$$

□

Proof of Proposition 3. With $\alpha_1 = 1$ and $\alpha_2 = 0$ the manufacturer de facto knows that $c_1 = c_L$ and $c_2 = c_H$. First, suppose that price discrimination is feasible. If the manufacturer contracts with a downstream firm that operates at marginal cost c, then—with incentive compatibility not being an issue—the manufacturer chooses $(q(c), t(c))$ in order to maximize $t(c)-Kq(c)$ subject to $\pi(q(c), c) - t(c) \geq 0$. In the optimum the participation constraint must be binding such that the manufacturer's quantity choice effectively maximizes joint surplus. In consequence, $q^D(c) = q^{JS}(c)$.

Next, under uniform pricing the manufacturer chooses $(q(c_L), t(c_L))$ and $(q(c_H), t(c_H))$ in order to

$$\max \sum_{c\in\{c_L,c_H\}} [t(c) - Kq(c)] \qquad \text{s.t.} \qquad (\text{IR}_L)\text{ , }(\text{IR}_H)\text{ , }(\text{IC}_L)\text{ , }(\text{IC}_H), \tag{A.6}$$

where the constraints are those introduced in Subsection 3.1. The transfers are pinned down by the two binding constraints, (IR$_H$) and (IC$_L$). Thus, the manufacturer chooses quantities $q(c_L)$ and $q(c_H)$ according to

$$\max\ [P(q(c_L)) - c_L - K]q(c_L) + [P(q(c_H)) - c_H - K - (c_H - c_L)]q(c_H). \tag{A.7}$$

Clearly, there is no distortion at the top, $q^U(c_L) = q^{JS}(c_L)$. If $P(0) - c_H - K > c_H - c_L$, then $q^U(c_H)$ is characterized by

$$P'(q^U(c_H))q^U(c_H) + P(q^U(c_H)) - c_H - K = c_H - c_L. \tag{A.8}$$

and $0 < q^U(c_H) < q^{JS}(c_H)$. If $P(0) - c_H - K \leq c_H - c_L$, then $q^U(c_H) = 0$.

Regarding welfare, note that the outcome in low-cost market 1 does not depend on the pricing regime. The quantity in high-cost market 2, on the other hand, is distorted below $q^{JS}(c_H)$ under uniform pricing. With $q^{JS}(c_H)$ being too low from a welfare perspective, banning price discrimination therefore is unambiguously detrimental for welfare , i.e., $\Delta W > 0$. $\square$

Proof of Proposition 4. We prove each part of the proposition in turn. To cut back on notation, define $q^D_{Hi} := q^D_H(\alpha_i)$ for $i \in \{1, 2\}$, and $q^U_H := q^U_H(\alpha_\Sigma)$.

(i) Note that the expected total output under price discrimination and under uniform pricing is given by

$$E[Q^D] = \alpha_1 q^{JS}(c_L) + (1-\alpha_1)q^D_{H1} + \alpha_2 q^{JS}(c_L) + (1-\alpha_2)q^D_{H2} \tag{A.9}$$

and

$$E[Q^U] = \alpha_1 q^{JS}(c_L) + (1-\alpha_1)q^U_H + \alpha_2 q^{JS}(c_L) + (1-\alpha_2)q^U_H, \tag{A.10}$$

respectively. Thus, $\Delta Q := E[Q^D] - E[Q^U]$ is given by

$$\Delta Q = (1-\alpha_2)[q^D_{H2} - q^U_H] - (1-\alpha_1)[q^U_H - q^D_{H1}]. \tag{A.11}$$

The change in expected welfare can be rewritten as

$$\Delta W = (1-\alpha_2)\int_{q_H^U}^{q_{H2}^D} P(z)dz - (1-\alpha_1)\int_{q_{H1}^D}^{q_H^U} P(z)dz - (c_H + K)\Delta Q. \tag{A.12}$$

Since $P'(q) < 0$, we can find an upper bound for the first term and a lower bound for the second term (see Varian, 1985). Hence, the change in expected welfare is bounded from above by

$$\Delta W < (1-\alpha_2)P(q_H^U)\left[q_{H2}^D - q_H^U\right] - (1-\alpha_1)P(q_H^U)\left[q_H^U - q_{H1}^D\right] - (c_H+K)\Delta Q. \tag{A.13}$$

Rearranging the above inequality yields

$$\Delta W < [P(q_H^U) - (c_H + K)]\Delta Q.$$

We conclude by noting that $[P(q_H^U) - (c_H + K)] > 0$ because $q^{JS}(c_H) > q_H^U$.

(ii) With $\hat{\alpha}_1(\alpha_2) \le \alpha_1$, we have $q_{H1}^D = q_H^U = 0 < q_{H2}^D$. According to (10), the difference in expected welfare under the two pricing regimes is

$$\Delta W = (1-\alpha_2)\left[\int_0^{q_{H2}^D} P(z)dz - (c_H+K)q_{H2}^D\right]. \tag{A.14}$$

From the first-order condition (5) together with $P'(\cdot) < 0$ whenever $P(\cdot) > 0$ it follows that

$$\begin{aligned} &P(q_{H2}^D) - (c_H+K) = -P'(q_{H2}^D)q_{H2}^D + \frac{\alpha}{1-\alpha}(c_H - c_L) > 0 \\ \implies &\left[P(q_{H2}^D) - (c_H+K)\right] q_{H2}^D > 0 \\ \implies &\int_0^{q_{H2}^D} P(z)dz - (c_H+K)q_{H2}^D > 0, \end{aligned} \tag{A.15}$$

which establishes the desired result. □

Proof of Corollary 1. In case (II), with $\alpha_2 < \hat{\alpha} < \alpha_1 < \hat{\alpha}_1(\alpha_2)$, we have $q_{H1}^D = 0 < q_H^U < q_{H2}^D$. Note that $dq_{H1}^D/d\alpha_1 = 0$. Differentiation of (10) w.r.t. α_1 yields

$$\frac{d\Delta W}{d\alpha_1} = \left[\int_0^{q_H^U} P(z)dz - (c_H+K)q_H^U\right] - (2-\alpha_\Sigma)\frac{dq_H^U}{d\alpha_1}\left[P(q_H^U) - (c_H+K)\right] \tag{A.16}$$

With q_H^U being defined by (8), we have $dq_H^U/d\alpha_1 < 0$. Moreover, with $P'(\cdot) < 0$ whenever $P(\cdot) > 0$, from (8) it follows that

$$\begin{aligned} P(q_H^U) - (c_H+K) = -P'(q_H^U)q_H^U + \frac{\alpha_\Sigma}{2-(\alpha_\Sigma)}(c_H-c_L) > 0 \\ \implies \int_0^{q_H^U} P(z)dz - (c_H+K)q_H^U > 0. \end{aligned} \tag{A.17}$$

Taken together, these observations allow us to conclude that $d\Delta W/d\alpha_1 > 0$. □

Proof of Proposition 5. With ΔW being given by

$$\Delta W = \sum_{i=1}^{2}(1-\alpha_i)(q_H^D(\alpha_i) - q_H^U(\alpha_\Sigma))\left[(1-c_H-K) - \frac{q_H^D(\alpha_i)+q_H^U(\alpha_\Sigma)}{2}\right], \quad \text{(A.18)}$$

we consider in turn each of the three relevant cases identified in the main text: (I) $\alpha_2 < \alpha_1 < \hat{\alpha}$; (II) $\alpha_2 < \hat{\alpha} \leq \alpha_1 < \hat{\alpha}_1(\alpha_2)$; and (III) $\alpha_2 < \hat{\alpha} < \hat{\alpha}_1(\alpha_2) \leq \alpha_1$. To cut back on notation, define $q_{Hi}^D := q_H^D(\alpha_i)$ for $i \in \{1,2\}$, $q_H^U := q_H^U(\alpha_\Sigma)$, $q_H^{JS} := q^{JS}(c_H)$, and $\Delta_c := c_H - c_L$.

(I) With $\alpha_2 < \alpha_1 < \hat{\alpha}$ we have $q_{Hi}^D = q_H^{JS} - \frac{\alpha_i}{1-\alpha_i}\frac{\Delta_c}{2}$ and $q_H^U = q_H^{JS} - \frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}$. Noting that $\Delta Q = [\sum_{i=1,2}(1-\alpha_i)q_{Hi}^D] - (2-\alpha_\Sigma)q_H^U = 0$, $\Delta W < 0$ follows from Proposition 4(i).

(II) With $\alpha_2 < \hat{\alpha} \leq \alpha_1 < \hat{\alpha}_1(\alpha_2)$, we have $q_{H1}^D = 0$, $q_{H2}^D = q_H^{JS} - \frac{\alpha_2}{1-\alpha_2}\frac{\Delta_c}{2}$ and $q_H^U = q_H^{JS} - \frac{\alpha_\Sigma}{2-(\alpha_\Sigma)}\frac{\Delta_c}{2}$. The difference in expected welfare thus equals

$$\Delta W = (1-\alpha_2)q_{H2}^D\left\{1 - \frac{1}{2}q_{H2}^D - (c_H+K)\right\} - (2-\alpha_\Sigma)q_H^U\left\{1-\frac{1}{2}q_H^U - (c_H+K)\right\}. \quad \text{(A.19)}$$

Let $\alpha_1^W(\alpha_2)$ be implicitly defined by

$$\Delta W(\alpha_1^W(\alpha_2), \alpha_2) \equiv 0. \quad \text{(A.20)}$$

Differentiation of (A.20) with respect to α_2 reveals that

$$\begin{aligned}\frac{d\alpha_1^W(\alpha_2)}{d\alpha_2}&\left[-(2-\alpha_\Sigma)\frac{dq_H^U}{d\alpha_\Sigma}\left\{1-q_H^U-(c_H+K)\right\} + q_H^U\left\{1-\frac{1}{2}q_H^U-(c_H+K)\right\}\right]\\ &= -(1-\alpha_2)\frac{dq_{H2}^D}{d\alpha_2}(\left\{1-q_{H2}^D-(c_H+K)\right\} + q_{H2}^D\left\{1-\frac{1}{2}q_{H2}^D-(c_H+K)\right\}\\ &\quad + (2-\alpha_\Sigma)\frac{dq_H^U}{d\alpha_\Sigma}\left\{1-q_H^U-(c_H+K)\right\} - q_H^U\left\{1-\frac{1}{2}q_H^U-(c_H+K)\right\} \quad \text{(A.21)}\end{aligned}$$

Substituting for q_{H2}^D and q_H^U, and noting that $\frac{dq_{H2}^D}{d\alpha_2} = -\frac{1}{(1-\alpha_2)^2}\frac{\Delta_c}{2}$ and $\frac{dq_H^U}{d\alpha_\Sigma} = -\frac{2}{(2-\alpha_\Sigma)^2}\frac{\Delta_c}{2}$ yields

$$\begin{aligned}\frac{d\alpha_1^W(\alpha_2)}{d\alpha_2}&\left[\frac{2}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\left\{q_H^{JS}+\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\right.\\ &\quad\left.+\left\{q_H^{JS}-\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\left\{\frac{3}{2}q_H^{JS}+\frac{1}{2}\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\right]\\ &= \left[\frac{1}{1-\alpha_2}\frac{\Delta_c}{2}\left\{q_H^{JS}+\frac{\alpha_2}{1-\alpha_2}\frac{\Delta_c}{2}\right\}\right.\\ &\quad\left.+\left\{q_H^{JS}-\frac{\alpha_2}{1-\alpha_2}\frac{\Delta_c}{2}\right\}\left\{\frac{3}{2}q_H^{JS}+\frac{1}{2}\frac{\alpha_2}{1-\alpha_2}\frac{\Delta_c}{2}\right\}\right]\\ &\quad-\left[\frac{2}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\left\{q_H^{JS}+\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\right.\\ &\quad\left.+\left\{q_H^{JS}-\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\left\{\frac{3}{2}q_H^{JS}+\frac{1}{2}\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\right] \quad \text{(A.22)}\end{aligned}$$

A first important observation is that each term in square brackets is strictly positive, which implies that $d\alpha_1^W(\alpha_2)/d\alpha_2 > -1$. Moreover, all the terms with q_H^{JS} on the RHS of (A.22) cancel out, which allows us to rewrite (A.22) as follows:

$$\begin{aligned}\frac{d\alpha_1^W(\alpha_2)}{d\alpha_2}\Bigg[\frac{2}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\left\{q_H^{JS}+\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\\ +\left\{q_H^{JS}-\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\left\{\frac{3}{2}q_H^{JS}+\frac{1}{2}\frac{\alpha_\Sigma}{2-\alpha_\Sigma}\frac{\Delta_c}{2}\right\}\Bigg]\\ =\left(\frac{\Delta_c}{2}\right)^2\left\{\frac{\alpha_2(2-\alpha_2)}{(1-\alpha_2)^2}-\frac{\alpha_\Sigma[4-\alpha_\Sigma]}{(2-\alpha_\Sigma)^2}\right\}.\end{aligned} \quad \text{(A.23)}$$

Straightforward manipulation of the RHS yields

$$\left(\frac{\Delta_c}{2}\right)^2\left\{\frac{\alpha_2(2-\alpha_2)}{(1-\alpha_2)^2}-\frac{\alpha_\Sigma[4-\alpha_\Sigma]}{(2-\alpha_\Sigma)^2}\right\}=\frac{1}{2}\left(\frac{\Delta_c}{2}\right)^2\frac{\alpha_\Sigma^2-4\alpha_\Sigma+4\alpha_2(2-\alpha_2)}{(1-\alpha_2)^2(2-\alpha_\Sigma)^2}. \quad \text{(A.24)}$$

Since $\alpha_\Sigma^2-4\alpha_\Sigma+4\alpha_2(2-\alpha_2)<0$ if and only if $\alpha_1\in(\alpha_2,4-3\alpha_2)$, the RHS of (A.23) is strictly negative. Therefore, with the term in square brackets on the LHS of (A.23) being strictly positive, we must have $d\alpha_1^W(\alpha_2)/d\alpha_2<0$. Taken together, the above observations imply

$$\frac{d\alpha_1^W(\alpha_2)}{d\alpha_2}\in(-1,0). \quad \text{(A.25)}$$

Last, note that $\alpha_1^W(\hat\alpha)=\hat\alpha$. To see this, note that for $\alpha_1=\alpha_2$ we have $q_{H2}^D=q_H^U$, and in consequence

$$\Delta W=-(1-\alpha_2)q_{H2}^D\left\{1-\frac{1}{2}q_{H2}^D-(c_H+K)\right\}=-(1-\alpha_2)q_{H2}^D\left\{\frac{3}{2}q_H^{JS}+\frac{1}{2}\frac{\alpha_2}{1-\alpha_2}\frac{\Delta_c}{2}\right\}. \quad \text{(A.26)}$$

With $q_H^{JS}>0$, for $\Delta W=0$ we must have $q_{H2}^D=0$, which holds for $\alpha_2=\hat\alpha$. Together with $d\alpha_1^W(\alpha_2)/d\alpha_2\in(-1,0)$ this last observation implies $\alpha_1^W(\alpha_2)\in(\hat\alpha,\hat\alpha_1(\alpha_2))$. The result then follows immediately from Corollary 1.

(III) $\Delta W>0$ follows from Proposition 4(ii).

Taken together, the above observations establish the desired result. □

Proof of Proposition 6. First, we show that the equilibrium investment levels are indeed characterized by the respective first-order conditions. Thereafter, we show that $\alpha^D<\alpha^U$.

Consider price discrimination first. Firm i's expected profit at the contracting stage does not depend on firm j's investment intensity α_j such that $\pi_0^D(\alpha_i;\alpha_j)=\pi_0^D(\alpha_i)$. The information rent left to a low-cost downstream firm is zero if its investment level is too high, i.e., $\pi_0^D(\alpha_i)=-\psi(\alpha_i)\le 0$ for $\alpha_i\ge\hat\alpha$. Moreover, $d\pi_0^D(\alpha)/d\alpha|_{\alpha=0}=q_H^{JS}(0)(c_H-c_L)>0$. Thus, $\alpha^D\in(0,\hat\alpha)$. Finally, note that $\pi_0^D(\cdot)$ is a continuously differentiable function and thus α^D is characterized by the first-order condition

$$q_H^D(\alpha^D)(c_H-c_L)+\frac{\alpha^D}{(1-\alpha^D)^2}\,\frac{(c_H-c_L)^2}{2P'(q_H^D(\alpha^D))+q_H^D(\alpha^D)P''(q_H^D(\alpha^D))}=\psi'(\alpha^D). \quad \text{(A.27)}$$

Under uniform pricing the profit of downstream firm i depends also on the rival's investment level α_j. If $\alpha_j = 0$, then firm i chooses a strictly positive investment level because $\partial\pi_0^U(\alpha_i;0)/\partial\alpha_i|_{\alpha_i=0} > 0$. For $r = U$, implicitly differentiating (11) with respect to α_j reveals

$$\frac{d\alpha_i}{d\alpha_j}\left\{2\frac{\partial q_H^U(\alpha_\Sigma)}{\partial\alpha_i} + \alpha_i\frac{\partial^2 q_H^U(\alpha_\Sigma)}{\partial\alpha_i^2} - \frac{\psi''(\alpha_i)}{(c_H - c_L)}\right\} = -\frac{\partial q_H^U(\alpha_\Sigma)}{\partial\alpha_j} - \alpha_i\frac{\partial^2 q_H^U(\alpha_\Sigma)}{\partial\alpha_i\partial\alpha_j}. \quad \text{(A.28)}$$

Given $q_H^U > 0$, from (8) in combination with $2P' < \min\{0, -qP''\}$ it follows that

$$\frac{\partial q_H^U(\alpha_\Sigma)}{\partial\alpha_i} = \frac{\partial q_H^U(\alpha_\Sigma)}{\partial\alpha_j} = \frac{2(c_H - c_L)}{(2-\alpha_\Sigma)^2\left[2P'(\cdot) + P''(\cdot)q_H^U(\alpha_\Sigma)\right]} < 0. \quad \text{(A.29)}$$

Moreover, by Assumption 1,

$$\frac{\partial^2 q_H^U(\alpha_\Sigma)}{\partial\alpha_i^2} = \frac{\partial^2 q_H^U(\alpha_\Sigma)}{\partial\alpha_i\alpha_j} =$$
$$\frac{2(c_H - c_L)\left\{2\left[2P'(\cdot) + P''(\cdot)q_H^U(\alpha_\Sigma)\right] - (2-\alpha_\Sigma)\left[3P''(\cdot) + P'''(\cdot)q_H^U(\alpha_\Sigma)\right]\frac{\partial q_H^U(\alpha_\Sigma)}{\partial\alpha_i}\right\}}{(2-\alpha_\Sigma)^3\left[2P'(\cdot) + P''(\cdot)q_H^U(\alpha_\Sigma)\right]^2}$$
$$\leq 0. \quad \text{(A.30)}$$

This allows us to conclude that firm i's best-response function is weakly decreasing—*weakly* decreasing because it might be the case that firm i chooses $\alpha_i = 1$ for values of α_j sufficiently close to zero or $\alpha_i = 0$ for values of α_j sufficiently close to one. With downstream firms being ex ante symmetric, their best-response functions are symmetric. Existence of a symmetric Nash equilibrium with equilibrium investment level $\alpha^U \in (0,1)$ then follows from best-response functions being continuous and firm i choosing an investment level strictly less than 1 for α_j sufficiently high. To see the latter point, note the following: (i) if $2\hat{\alpha} < 1$, then $\alpha_i = 0$ is a best response to $\alpha_j \in [2\hat{\alpha}, 1]$ because a higher investment by firm i does not change the quantity allocation, $q_H^U(\alpha_i + \alpha_j) = 0$, but comes at higher cost; (ii) if $1 < 2\hat{\alpha}$, then $\partial\pi_0^U(\alpha_i;1)/\partial\alpha_i|_{\alpha_i=2\hat{\alpha}-1} = \alpha_i(c_H - c_L)^2/(2-\hat{\alpha})^2P'(0) - \psi'(\alpha_i) < 0$, such that firm i's best response is smaller than $2\hat{\alpha} - 1$, which itself is smaller than 1 because $\hat{\alpha} < 1$ for $c_H < c_L$. Last, note that any symmetric equilibrium under uniform pricing must have $\alpha^U < \hat{\alpha}$: if $\alpha^U \geq 2\hat{\alpha}$, then firm i's best response to $\alpha_j = \alpha^U$ is not $\alpha_i = \alpha^U$ but $\alpha_i = 0$; if $\alpha^U \in [\hat{\alpha}, 2\hat{\alpha})$, then firm i can profitably deviate to α_i slightly below $2\hat{\alpha} - \alpha^U$, which results in strictly positive expected profits because $q_H^U(\alpha_i + \alpha^U) > 0$. Hence, α^U is implicitly defined by

$$q_H^U(2\alpha^U)(c_H - c_L) + \frac{\alpha^U}{2(1-\alpha^U)^2}\,\frac{(c_H - c_L)^2}{2P'(q_H^U(2\alpha^U)) + q_H^U(2\alpha^U)P''(q_H^U(2\alpha^U))} = \psi'(\alpha^U). \quad \text{(A.31)}$$

Comparing the equalities (A.27) and (A.31) immediately reveals that $\alpha^D \neq \alpha^U$. Note that for $\alpha^U = \alpha^D$, we would have $q_H^U = q_H^D$. Suppose, in contradiction, that $\alpha^U < \alpha^D$, which implies that $q_H^U > q_H^D$. Let $MR'(q) \equiv 2P'(q) + qP''(q)$, so that $MR(q)$ denotes the marginal revenue of a downstream firm. With $\psi'(\alpha^U) \leq \psi'(\alpha^D)$, by hypothesis, it has to hold that

$$q_H^D(c_H - c_L) + \frac{\alpha^D}{(1-\alpha^D)^2}\,\frac{(c_H - c_L)^2}{MR'(q_H^D)} \geq q_H^U(c_H - c_L) + \frac{\alpha^U}{2(1-\alpha^U)^2}\,\frac{(c_H - c_L)^2}{MR'(q_H^U)},$$

or equivalently,

$$(c_H - c_L)(q_H^U - q_H^D) + \frac{\alpha^U}{2(1-\alpha^U)^2}\,\frac{(c_H - c_L)^2}{MR'(q_H^U)} - \frac{\alpha^D}{(1-\alpha^D)^2}\,\frac{(c_H - c_L)^2}{MR'(q_H^D)} \leq 0. \tag{A.32}$$

The above inequality is violated because (a) by hypothesis $\alpha^U < \alpha^D$ and $q_H^U > q_H^D$, and (b) by Assumption 1 $MR'(q)$ is non-increasing. This completes the proof. □

Proof of Proposition 7. For $\psi(\alpha) \equiv 0$ and $P(q) = \max\{1 - q, 0\}$, where the latter implies $MR'(q) = -2$, it is straightforward to show that the investment level under price discrimination is given by

$$\alpha^D = 1 - \frac{\sqrt{2q^{JS}(c_L)\,(c_H - c_L)}}{2q^{JS}(c_L)} \in (0,1), \tag{A.33}$$

with $q^{JS}(c_L) = (1/2)(1 - c_L - K)$. The symmetric investment level under uniform pricing amounts to

$$\alpha^U = 1 - \frac{c_H - c_L + \sqrt{c_H - c_L}\sqrt{c_H - c_L + 16q^{JS}(c_L)}}{8q^{JS}(c_L)} \in (\alpha^D, 1). \tag{A.34}$$

With our focus on equilibria in undominated strategies, there is a unique equilibrium, which is symmetric. In order to see this, let $\alpha_i^R(\alpha_j)$ be the reaction function of firm i. The slope of the reaction function

$$\frac{d\alpha_i^R}{d\alpha_j} = -\frac{2 + \alpha_i - \alpha_j}{4 - 2\alpha_j} \in (-1, -1/2), \tag{A.35}$$

Thus, there is only a symmetric equilibrium because the absolute value of the slope of the reaction function is always less than one.

The difference in expected welfare between price discrimination and uniform pricing is

$$\Delta W = \frac{1}{16}(c_H - c_L)\Bigg[(\sqrt{c_H - c_L})^2 + 3\sqrt{c_H - c_L}\sqrt{c_H - c_L + 16q^{JS}(c_L)} \\ - 10\sqrt{2}\sqrt{(c_H - c_L)q^{JS}(c_L)}\Bigg]. \tag{A.36}$$

Thus, $\Delta W < 0$ if and only if

$$\sqrt{c_H - c_L} + \sqrt{9(c_H - c_L) + 144q^{JS}(c_L)} - \sqrt{200q^{JS}(c_L)} < 0, \tag{A.37}$$

which holds because $c_H < 1 - K$. □

Proof of Lemma 3. First, we analyze the manufacturer's screening problem for the continuous distribution of downstream types. Noting that neither the individual rationality constraints nor the incentive compatibility constraints depend on the pricing regime, we begin with drawing out the implications of these constraints for the optimal wholesale tariff. To cut back on notation, we suppress the subscript i indicating the downstream firm.

Define

$$V(c) \equiv q(c)[1 - q(c) - c] - t(c). \tag{A.38}$$

Using a revealed preference argument for types $c, \hat{c} \in \mathcal{C}$ and $\hat{c} > c$, we obtain

$$q(c) \geq \frac{V(c) - V(\hat{c})}{\hat{c} - c} \geq q(\hat{c}). \tag{A.39}$$

The above chain of inequalities implies that $V'(c) = -q(c)$ except for points of discontinuity. Moreover, from (A.39) we immediately obtain that the incentive compatible quantity and transfer schedules, $q(c)$ and $t(c)$, are non-increasing. Using the insights from above, the transfer $t(c)$ can be stated as

$$t(c) = q(c)[1 - q(c) - c] - \int_c^{c_H} q(z)\ dz \tag{A.40}$$

because $V(c) = V(c_H) + \int_c^{c_H} q(z)\ dz$ and $V(c_H) = 0$ in the optimum.

Discriminatory Offers.—With downstream firms operating in separate markets, the manufacturer solves two isolated maximization problems. After integrating by parts, the manufacturer's problem regarding firm $i = 1, 2$ can be stated as follows:

Program D1:

$$\max_{\langle q(c)\rangle_{c\in\mathcal{C}}} \int_{c_L}^{c_H} \left(q(c)[1 - q(c) - c - K] - q(c)\frac{F_i(c)}{f_i(c)} \right) f_i(c)\ dc$$

$$\text{subject to:} \quad q(c) \quad \text{is non-increasing}$$

Ignoring the monotonicity constraint for the moment, point-wise maximization yields

$$q_i^D(c) = \frac{1}{2}\left[1 - c - K - \frac{F_i(c)}{f_i(c)}\right]. \tag{A.41}$$

By Assumptions 2 and 3, the quantity schedule $q_i^D(c)$ is strictly decreasing and assigns a positive quantity to all types.

Uniform Pricing.—Being restricted to offer the same wholesale tariff to both downstream firms, the manufacturer maximizes

$$\int_{c_L}^{c_H} [t(c) - Kq(c)][f_1(c) + f_2(c)]\ dc, \tag{A.42}$$

subject to the (IC) and (IR) constraints. Since the constraints are the same as under price discrimination, the incentive compatible transfer schedule is still characterized by (A.40). Integrating by parts yields

$$\int_{c_L}^{c_H} \int_c^{c_H} q(z)\ dz[f_1(c) + f_2(c)]\ dc = \int_{c_L}^{c_H} q(c)[F_1(c) + F_2(c)]\ dc, \tag{A.43}$$

such that the manufacturer faces the following problem:

Program U:

$$\max_{\langle q(c)\rangle_{c\in\mathcal{C}}} \int_{c_L}^{c_H} \left(q(c)[1-q(c)-c-K] - q(c)\frac{F_1(c)+F_2(c)}{f_1(c)+f_2(c)} \right) [f_1(c)+f_2(c)]\, dc$$
$$\text{subject to: } \; q(c) \; \text{ is non-increasing}$$

Ignoring the monotonicity constraint for the moment, point-wise maximization yields

$$q^U(c) = \frac{1}{2}\left[1 - c - K - \frac{F_1(c)+F_2(c)}{f_1(c)+f_2(c)}\right]. \tag{A.44}$$

By Assumptions 2 and 3, the quantity schedule $q^U(c)$ is strictly decreasing and assigns a positive quantity to all types.

Based on the above insights, we now can prove Lemma 3. According to (A.41), if $q_1^D(c) < q_2^D(c)$, then $F_1(c)/f_1(c) > F_2(c)/f_2(c)$. In combination with (A.44), $q_1^D(c) < q^U(c) < q_2^D(c)$ is equivalent to

$$\frac{F_1(c)}{f_1(c)} > \frac{F_1(c)+F_2(c)}{f_1(c)+f_2(c)} > \frac{F_2(c)}{f_2(c)} \iff \frac{F_1(c)}{f_1(c)} > \frac{F_2(c)}{f_2(c)}, \tag{A.45}$$

which establishes the desired result. □

Proof of Proposition 8. Inserting (A.41) and (A.44) into

$$\mathbb{E}[W^D] = \sum_{i=1}^{2}\left\{\int_{c_L}^{c_H} \left[q_i^D(c) - (1/2)(q_i^D(c))^2 - (c+K)q_i^D(c)\right] f_i(c)\, dc\right\} \tag{A.46}$$

and

$$\mathbb{E}[W^U] = \int_{c_L}^{c_H} \left[q^U(c) - (1/2)(q^U(c))^2 - (c+K)q^U(c)\right] (f_1(c)+f_2(c))\, dc, \tag{A.47}$$

respectively, reveals

$$\begin{aligned} \Delta W = \frac{1}{8}\Bigg\{ &\int_{c_L}^{c_H} f_1(c)\left[1-(c+K)-\frac{F_1(c)}{f_1(c)}\right]\left[\frac{F_1(c)f_2(c)-F_2(c)f_1(c)}{f_1(c)[f_1(c)+f_2(c)]}\right] dc \\ &+ \int_{c_L}^{c_H} f_2(c)\left[1-(c+K)-\frac{F_2(c)}{f_2(c)}\right]\left[\frac{F_2(c)f_1(c)-F_1(c)f_2(c)}{f_2(c)[f_1(c)+f_2(c)]}\right] dc\Bigg\}. \end{aligned} \tag{A.48}$$

Simplifying the above expression yields

$$\Delta W = -\frac{1}{8}\int_{c_L}^{c_H} \frac{[F_1(c)f_2(c)-F_2(c)f_1(c)]^2}{f_1(c)f_2(c)[f_1(c)+f_2(c)]}\, dc < 0, \tag{A.49}$$

which establishes the desired result. □

Proof of Observation 1. Note that given our assumption $F_1(c) > F_2(c)$ for all $c \in (c_L, c_H)$. First, we characterize a firm's profit in equilibrium for a given pricing regime $r \in \{D, U\}$. This allows us to calculate a firm's change in profits for a given cost realization if we move from one regime to the other. Finally, we will derive bounds for these changes that establish the Result.

Let $V_i^r(c) = \int_c^{c_H} q_i^r(z)\, dz$ denote the utility of firm $i \in \{1, 2\}$ under pricing regime r given its retail cost is equal to c. Under price discrimination, we have

$$V_i^D(c) = \int_c^{c_H} \frac{1-c-K}{2}\, dz - \frac{1}{2}\int_c^{c_H} \frac{F_i(c)}{f_i(c)}\, dz. \tag{A.50}$$

Likewise, under uniform pricing,

$$V_i^U(c) = \int_c^{c_H} \frac{1-c-K}{2}\, dz - \frac{1}{2}\int_c^{c_H} \frac{F_i(c)+F_j(c)}{f_i(c)+f_j(c)}\, dz. \tag{A.51}$$

Retailer i strictly prefers a ban on price discrimination if $\Delta V_i(c) < 0$, where

$$\Delta V_i(c) := V_i^D(c) - V_i^U(c) = \frac{1}{2}\int_c^{c_H} \left[\frac{f_i(c)F_j(c) - f_j(c)F_i(c)}{[f_i(c)+f_j(c)]f_i(c)}\right] dz. \tag{A.52}$$

Let us consider the ex ante efficient firm 1. Suppose firm 1's cost are relatively high, $c \in [\tilde{c}, c_H)$ and thus $f_1(\cdot) \leq f_2(\cdot)$. Hence,

$$\Delta V_1(c) < \frac{1}{2}\int_c^{c_H} \left[\frac{f_2(z)[F_2(z) - F_1(z)]}{[f_1(z)+f_2(z)]f_1(z)}\right] dz < 0. \tag{A.53}$$

Finally, to prove the last statement of the result, note that $q_1^D(c) < q^U(c)$ iff

$$\frac{F_1(c)+F_2(c)}{f_1(c)+f_2(c)} - \frac{F_1(c)}{f_1(c)} < 0. \tag{A.54}$$

As we have shown above, the inequality is satisfied for $c \in (\tilde{c}, c_H)$. □

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B. Supplementary Material

B.1. Proofs and Supplementary Material to Section 6

Before providing the proofs of Proposition 9 and Corollary 2, we first derive the quantities offered by the M under either pricing regime. In order to state the discussion as concise a possible, define α^r, with $r \in \{D, U\}$ denoting the pricing regime, as follows: $\alpha^D = \alpha_i$ for $i \in \{1, 2\}$ under price discrimination and $\alpha^U = \alpha_\Sigma$ under uniform pricing.[25] Moreover, we define $\hat{q}^r(\alpha^r)$ as the quantity that solves the first-order condition (5) and (8) for $r = D$ and $r = U$, respectively.

Proposition 10. *Suppose that Assumptions 4 and 5 hold and that M serves both types of downstream firms. The optimal wholesale mechanism under pricing regime $r \in \{D, U\}$ allocates quantities*

(i) $q_L^r(\alpha^r) = q^{JS}(c_L)$ *and* $q_H^r(\alpha^r) = \hat{q}^r(\alpha^r)$ *if* $\phi \leq q^{JS}(c_H)$ *and* $\alpha^r \leq \alpha^r(\phi)$*;*

(ii) $q_L^r(\alpha^r) = q^{JS}(c_L)$ *and* $q_H^r(\alpha^r) = \phi$ *if* $\phi \leq q^{JS}(c_H)$ *and* $\alpha^r \geq \alpha^r(\phi)$*;*

(iii) $q_L^r(\alpha^r) = q^{JS}(c_L)$ *and* $q_H^r(\alpha^r) = q^{JS}(c_H)$ *if* $q^{JS}(c_H) \leq \phi \leq q^{JS}(c_L)$*.*

Proof. The manufacturer maximizes

$$\Pi = \alpha^r[t_L - kq_L] + \delta^r[t_H - kq_H] \tag{B.1}$$

subject to (IR$_H^A$), (IC$_H$), (IR$_L^A$), and (IC$_L$). If discriminatory offers are allowed, then $\delta^D = 1 - \alpha_i$ with regard to downstream firm $i \in \{1, 2\}$. Under uniform wholesale tariffs, we have $\delta^U = 2 - \alpha_\Sigma$. The presence of the alternative supply gives rise to a screening problem with type-dependent participation constraints. Following the analysis in Laffont and Martimort (2002), under Assumption 5, we have to distinguish three cases: (IR$_H^A$) and (IC$_L$) are binding; (IR$_H^A$) and (IR$_L^A$) are binding; (IR$_H^A$), (IC$_L$), and (IR$_L^A$) are binding. We analyze each of these cases in turn. Figure 3 illustrates the following discussion for the discriminatory pricing regime.

First, consider the relaxed optimization problem where, under pricing regime $r \in \{D, U\}$, M maximizes (B.1) subject only to (IR$_H^A$) and (IC$_L$). For a given allocation (q_L, q_H), the optimal transfers make both constrains bind:

$$\begin{aligned} t_H^r &= \pi(q_H, c_H) - \pi_H^A, \\ t_L^r &= \pi(q_L, c_L) - \pi(q_H, c_L) + \pi(q_H, c_H) - \pi_H^A. \end{aligned}$$

Except for being shifted downward by the amount π_H^A, the transfers are the same as in the standard case without alternative supply. In consequence, the optimal allocation is the same as in Section 3: $q_L^r(\alpha^r) = q^{JS}(c_L)$, and $q_H^r(\alpha^r) = \hat{q}^r(\alpha^r)$ for $\alpha^r \leq \hat{\alpha}^r$, where $\hat{\alpha}^D = \hat{\alpha}$ and $\hat{\alpha}^U = 2\hat{\alpha}$, and zero otherwise. With the allocation satisfying the monotonicity constraint

[25] We are aware of the slight abuse in notation regarding Section 4, but we believe that there is little cause for confusion.

(MON), (IC$_H$) is satisfied trivially because (IC$_L$) holds with equality. Thus, this allocation and the associated transfers solve M's original problem as long as the (IR$_L^A$) constraint is satisfied, or, equivalently, as long as

$$\pi(q^{JS}(c_L), c_L) - t_L^r \geq \pi_L^A \iff \phi \leq q_H^r(\alpha^r). \tag{B.2}$$

Note that $\hat{q}^r(\alpha^r)$ is a strictly decreasing function with $\hat{q}^r(0) = q^{JS}(c_H)$ and $\hat{q}^r(\hat{\alpha}^r) = 0$. In consequence, (IR$_L^A$) holds if $\phi \leq q^{JS}(c_H)$ and $\alpha^r \leq \alpha^r(\phi) \in [0, \hat{\alpha}^r]$, where $\alpha^r(\phi)$ is implicitly defined as

$$\hat{q}^r(\alpha^r(\phi)) \equiv \phi. \tag{B.3}$$

Existence and uniqueness of $\alpha^r(\phi)$ follow from the intermediate value theorem together with $\hat{q}^r(\alpha^r)$ being a continuous and strictly decreasing function on $[0, \hat{\alpha}^r]$.

Next, consider the relaxed problem where M maximizes (B.1) subject only to (IR$_H^A$) and (IR$_L^A$). For a given allocation (q_L, q_H), the optimal transfers make both constrains bind:

$$t_L^r = \pi(q_L, c_L) - \pi_L^A \tag{B.4}$$

$$t_H^r = \pi(q_H, c_H) - \pi_H^A \tag{B.5}$$

Inserting these transfers into (B.1) reveals that M's goal is to maximize the joint surplus. Hence, the quantities implemented are $q_L^r(\alpha^r) = q^{JS}(c_L)$ and $q_H^r(\alpha^r) = q^{JS}(c_H)$. Obviously, the above wholesale mechanism satisfies the monotonicity constraint (MON). For this solution to the relaxed problem also to be a solution to the original problem, it needs to be checked that the mechanism is also incentive compatible. The incentive constraint of the low-cost firm, (IC$_L$), is satisfied if

$$\pi(q^{JS}(c_L), c_L) - t_L \geq \pi(q^{JS}(c_H), c_L) - t_H \iff q^{JS}(c_H) \leq \phi. \tag{B.6}$$

A high-cost firm truthfully reveals its type, i.e. (IC$_H$) is satisfied, if

$$\pi(q^{JS}(c_H), c_H) - t_H \geq \pi(q^{JS}(c_L), c_H) - t_L \iff q^{JS}(c_L) \geq \phi. \tag{B.7}$$

Thus, for $\phi \in [q^{JS}(c_H), q^{JS}(c_L)]$ the above wholesale mechanism is optimal under the original problem.

Last, consider the relaxed problem where M maximizes (B.1) subject to (IR$_H^A$), (IR$_L^A$), and (IC$_L$). For $\phi \leq q^{JS}(c_H)$ and $\alpha^r \leq \alpha^r(\phi)$, on the one hand, and for $\phi \in [q^{JS}(c_H), q^{JS}(c_L)]$, on the other hand, the solution to this problem is given by the solution to the respective less heavily constrained optimization problem considered before, where only two of the constraints were binding in the optimum. For $\phi < q^{JS}(c_H)$ and $\alpha^r > \alpha^r(\phi)$, however, in the optimum all three constraints must be binding. Thus, transfers under pricing regime $r \in \{D, U\}$ as functions of the implemented allocation (q_L, q_H) are given by:

$$t_H^r = \pi(q_H, c_H) - \pi_H^A \tag{B.8}$$

$$t_L^r = \pi(q_L, c_L) - \pi_L^A \tag{B.9}$$

$$t_L^r - t_H^r = \pi(q_L, c_L) - \pi(q_H, c_L). \tag{B.10}$$

Solving the above equations (B.8)–(B.10) for q_H yields

$$q_H^r(\alpha^r) = \frac{\pi_L^A - \pi_H^A}{c_H - c_L} = \phi. \tag{B.11}$$

With q_H being fixed by (B.11), M chooses q_L in order to maximize

$$t_L^r - kq_L = \pi(q_L, c_L) - \pi_L^A - kq_L \ , \tag{B.12}$$

which is achieved by $q_L^r(\alpha^r) = q^{JS}(c_L)$. The above allocation clearly satisfies the monotonicity constraint (MON), and (IC$_H$) trivially holds because (IC$_L$) is satisfied with equality. Thus, the above wholesale mechanism also is a solution to the original problem for $\phi < q^{JS}(c_H)$ and $\alpha^r > \alpha^r(\phi)$. This establishes the desired result. □

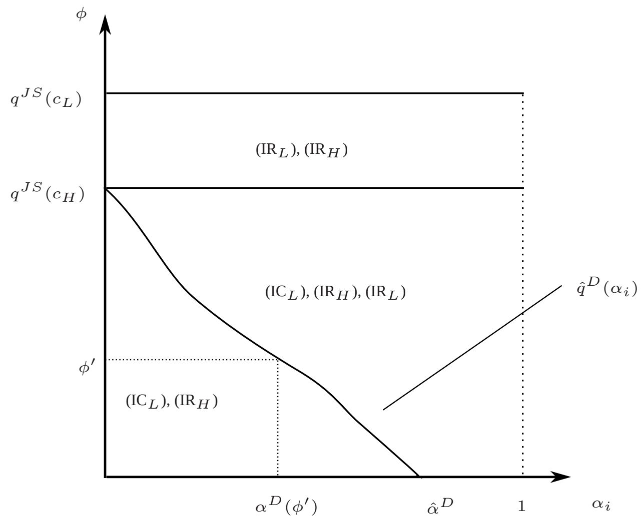

Figure 3: Binding constraints when M serves both types.

Proof of Proposition 9. For the moment, assume that M wants to serve both types of downstream firms. We will provide a detailed account of the circumstances under which M prefers to serve only one type of downstream firm at the end of this Appendix.

While M offers $q^{JS}(c_L)$ to any low-cost downstream firm, the quantity offered to a high-cost downstream firm depends on both the pricing regime and its ex ante efficiency. Remember that $\alpha^U(\phi)$ is implicitly defined by $\hat{q}^U(\alpha^U(\phi)) = \phi$. Under price discrimination the high-cost type of firm i is offered quantity $q_H^D(\alpha_i) = \hat{q}^D(\alpha_i)$ if $\alpha_i \leq \alpha^D(\phi)$ and quantity $q_H^D(\alpha_i) = \phi$ otherwise. Under uniform pricing M offers $q_H^U(\alpha_\Sigma) = \hat{q}^U(\alpha_\Sigma)$ if $\alpha_\Sigma \leq \alpha^U(\phi)$ and $q_H^U(\alpha_\Sigma) = \phi$ otherwise. With $\alpha_1^U(\alpha_2; \phi) := \alpha^U(\phi) - \alpha_2$, we have to distinguish four cases similar to the four cases depicted in Figure 1. For $\alpha_2 > \alpha^D(\phi)$ the quantities offered by M are identical under both pricing regimes such that $\Delta W = 0$. The welfare implications for the remaining cases parallel those drawn in the standard model without an alternative source of input supply.

(i) Follows from the proof of Proposition 4.

(ii) For $\alpha_2 < \alpha^D(\phi) \leq \alpha_1^U(\alpha_2; \phi) \leq \alpha_1$, we have $q_{H1}^D = q_H^U = \phi < q_{H2}^D = \hat{q}^D(\alpha_2)$. According to (10), the difference in expected welfare amounts to

$$\Delta W = (1-\alpha_2)\left\{\int_{\phi}^{\hat{q}^D(\alpha_2)} P(z)dz - (c_H + K)\left[\hat{q}^D(\alpha_2) - \phi\right]\right\} \tag{B.13}$$

Thus, $\Delta W > 0$ if and only if

$$\int_0^{\hat{q}^D(\alpha_2)} P(z)dz - (c_H + K)\hat{q}^D(\alpha_2) > \int_0^{\phi} P(z)dz - (c_H + K)\phi. \tag{B.14}$$

To see that this inequality indeed is satisfied, note that the function $\int_0^q P(z)dz - (c_H + K)q$ attains its maximum at q^w which is implicitly characterized by $P(q^w) = c_H + K$. Comparing this last expression with the first-order condition (5) immediately implies $\hat{q}^D(\alpha_2) < q^w$. Since the function $\int_0^q P(z)dz - (c_H + K)q$ is strictly concave in q whenever $P > 0$, the result follows from $\phi < \hat{q}^D(\alpha_2)$. □

Now, we prove the statement made in footnote # 24 that for $\alpha_2 < \alpha^D(\phi) < \alpha_1 < \alpha_1^U(\alpha_2; \phi)$ ΔW is strictly increasing in α_1. Notice that in this case we have $q_{H1}^D = \phi < q_H^U = \hat{q}^U(\alpha_\Sigma) < q_{H2}^D = \hat{q}^D(\alpha_2)$. The difference in expected welfare then is

$$\begin{aligned}\Delta W = (1-\alpha_1)&\left\{\int_{\hat{q}^U(\alpha_\Sigma)}^{\phi} P(z)dz - (c_H + K)\left[\phi - \hat{q}^U(\alpha_\Sigma)\right]\right\}\\ &+ (1-\alpha_2)\left\{\int_{\hat{q}^U(\alpha_\Sigma)}^{\hat{q}^D(\alpha_2)} P(z)dz - (c_H + K)\left[\hat{q}^D(\alpha_2) - \hat{q}^U(\alpha_\Sigma)\right]\right\}.\end{aligned} \tag{B.15}$$

Differentiation with respect to α_1 yields

$$\begin{aligned}\frac{d\Delta W}{d\alpha_1} = -&\left\{\int_{\hat{q}^U(\alpha_\Sigma)}^{\phi} P(z)dz - (c_H + K)\left[\phi - \hat{q}^U(\alpha_\Sigma)\right]\right\}\\ &- (2-(\alpha_1+\alpha_2))\frac{\hat{q}^U(\alpha_\Sigma)}{d\alpha_1}\left[P(\hat{q}^U(\alpha_\Sigma)) - (c_H + K)\right].\end{aligned} \tag{B.16}$$

Note that $\phi < \hat{q}^U(\alpha_\Sigma) < q^w$, where q^w is defined in the proof of Proposition of 9(ii) and the second inequality follows from (8). The same reasoning as in the proof of Proposition of 9(ii) implies that $-\left\{\int_{\hat{q}^U(\alpha_\Sigma)}^{\phi} P(z)dz - (c_H + K)\left[\phi - \hat{q}^U(\alpha_\Sigma)\right]\right\} > 0$. By (8) $P(\hat{q}^U(\alpha_\Sigma)) - (c_H + K) = P'(\hat{q}^U(\alpha_\Sigma))\hat{q}^U(\alpha_\Sigma) + \frac{\alpha_\Sigma}{2-\alpha_\Sigma}(c_H - c_L) > 0$, and the desired result follows from $d\hat{q}^U(\alpha_\Sigma)/d\alpha_1 < 0$.

Proof of Corollary 2. Follows from Proposition 9 in combination with Proposition 5. □

To close the analysis, we now give a detailed account for under what circumstances M prefers to serve only one type of downstream firm. Unless stated otherwise, the following observations apply to both pricing regimes.

Clearly, when serving only one type of downstream firm with cost c, the highest possible profit M could hope for would be achieved by offering the joint-surplus-maximizing quantity $q^{JS}(c)$ and charging a transfer that just ensures participation by that type, $t = \pi(q^{JS}(c), c) - \pi^A(c)$. This observation has two immediate implication. First, for $\phi \in [q^{JS}(c_H), q^{JS}(c_L)]$ it never pays off for M to serve only one type of downstream firm because, according to Proposition 10 (iii), under the optimal contract that serves both cost types each type is offered the respective joint-surplus-maximizing quantity and—with both participation constraints binding—M extracts all the extra surplus generated from these bilateral relationships. A second implication is that even for $\phi < q^{JS}(c_H)$ it can never be optimal for M to exclude the low-cost type because this type does not reject the bundle $(q^{JS}(c_H), \pi(q^{JS}(c_H), c_H) - \pi_H^A)$, which makes the high-cost type just break even. Thus, for $\phi < q^{JS}(c_H)$ the upstream supplier will always benefit from serving both types of downstream firms instead of designing a contract that excludes the low-cost type.

The remaining question is whether M might benefit from excluding the high-cost type when $\phi \leq q^{JS}(c_H)$. Given Assumption 5, a high-cost firm always rejects the bundle $(q^{JS}(c_L), \pi(q^{JS}(c_L), c_L) - \pi_L^A)$. Hence, M's profits under pricing regime $r \in \{D, U\}$ from serving only type L are given by

$$\Pi_L^r = \alpha^r \left[\pi(q^{JS}(c_L), c_L) - \pi_L^A - Kq^{JS}(c_L)\right] \ . \tag{B.17}$$

If, on the other hand, M serves both types of downstream firms, we know that both (IC$_L$) and (IR$_H$) are binding under both pricing regimes for $\phi \leq q^{JS}(c_H)$. With transfers being pinned down by these constraints, the quantities offered correspond to $q_L^r(\alpha^r) = q^{JS}(c_L)$ and $q_H^r(\alpha^r)$ as identified in Proposition 10. Thus, M's profits from serving both types of downstream firms under pricing regime r are

$$\begin{aligned}\Pi_{LH}^r = \alpha^r &\left\{\pi(q^{JS}(c_L), c_L) - (c_H - c_L)q_H^r(\alpha^r) - \pi_H^A - Kq^{JS}(c_L)\right\} \\ &+ \delta^r \left\{\pi(q_H^r(\alpha^r), c_H) - \pi_H^A - Kq_H^r(\alpha^r)\right\} . \end{aligned} \tag{B.18}$$

Comparison of (B.17) and (B.18) reveals that M prefers to serve only the low-cost type if

$$\alpha^r(c_H - c_L)(q_H^r(\alpha^r) - \phi) > \delta^r \left[\pi(q_H^r(\alpha^r), c_H) - \pi_H^A - Kq_H^r(\alpha^r)\right] . \tag{B.19}$$

Since $\pi(q_H, c_H) - Kq_H$ is strictly increasing in q_H on $[0, q^{JS}(c_H))$, under Assumption 4 there exists a unique quantity between 0 and $q^{JS}(c_H)$ at which the right-hand side (RHS) of (B.19) equals zero. Let this quantity-threshold be denoted by $\tilde{\phi}$. Formally, $\tilde{\phi}$ is implicitly defined by

$$\pi(\tilde{\phi}, c_H) - \pi_H^A - K\tilde{\phi} \equiv 0. \tag{B.20}$$

As we will prove below, for $\phi \in [\tilde{\phi}, q^{JS}(c_H)]$ it never pays off for M to exclude the high-cost downstream firm. With ϕ being relatively large, a low-cost downstream firm benefits by far more from procuring the input from the alternative source of supply than a high-cost downstream firm. Thus, the rents the manufacturer can extract when contracting with a low-cost type are relatively low. This in turn implies that cutting back on information rents paid to a low-cost type is less important but contracting with a high-cost type is not that unimportant. Hence, it is optimal always to contract with a high-cost downstream firm. For $\phi \in [0, \tilde{\phi})$, on the other hand, we are closer to the standard case without an alternative supply. While M serves both types of downstream firms when the probability of facing a high-cost type is high, once α^r exceeds a certain threshold, M considers it profitable to serve only the low-cost type. To characterize this threshold formally, fix some $\phi \in [0, \tilde{\phi})$ and consider values of $\alpha^r \in (0, \tilde{\alpha}^r]$, where $\tilde{\alpha}^r$ is implicitly defined by $\hat{q}^r(\tilde{\alpha}^r) = \tilde{\phi}$. Application of the envelope theorem yields

$$\frac{d(\Pi_L^r - \Pi_{LH}^r)}{d\alpha^r} = (c_H - c_L)(q_H^r(\alpha^r) - \phi) + \left[\pi(q_H^r(\alpha^r), c_H) - \pi_H^A - Kq_H^r(\alpha^r)\right] > 0, \quad \text{(B.21)}$$

where the inequality follows from the definition of $\tilde{\phi}$ in (B.20) and $\hat{q}^r(\alpha^r) \geq \tilde{\phi}$ for $\alpha^r \in (0, \tilde{\alpha}^r]$. Since $\Pi_L - \Pi_{LH}^r|_{\alpha^r=0} < 0$ and $\Pi_L - \Pi_{LH}^r|_{\alpha^r=\tilde{\alpha}^r} > 0$, by the intermediate value theorem we know that for any $\phi \in [0, \tilde{\phi})$ there exists a unique value $\tilde{\alpha}^r(\phi) \in (0, \tilde{\alpha}^r)$ such that

$$\Pi_L^r - \Pi_{LH}^r|_{\alpha^r=\alpha^r(\phi)} \equiv 0, \quad \text{(B.22)}$$

which yields the desired characterization of the threshold.

We summarize these observations in the following lemma, which is illustrated for a discriminatory pricing regime in Figure 4. In the light-gray shaded area both types of downstream firms are served, whereas in the dark-gray shaded area the high-cost type is excluded.[26] In consequence, all the statements in the main text refer to the light-gray shaded area and $\phi \geq \tilde{\phi}$ is a sufficient condition for both types of downstream firms to be always served.

Lemma 4. *Suppose Assumptions 4 holds and that $\phi \leq q^{JS}(c_H)$. Under either pricing regime, the low-cost type is never excluded. Under pricing regime $r \in \{D, U\}$, M does not exclude the high-cost type if (i) $\phi \in [\tilde{\phi}, q^{JS}(c_H)]$, or (ii) $\phi \in [0, \tilde{\phi})$ and $\alpha^r \leq \tilde{\alpha}^r(\phi)$.*

Proof. We first prove part (i). First, consider the case $\phi \in [\tilde{\phi}, q^{JS}(c_H)]$. Under pricing regime $r \in \{D, U\}$, according to Proposition 10 (ii), for $\alpha^r \geq \alpha^r(\phi)$ the optimal quantity to offer when serving the high-cost type is $q_H^r(\alpha^r) = \phi$. In consequence, the left-hand side (LHS) of (B.19) equals zero, whereas the RHS is (at least weakly) positive, i.e., M does not exclude the high-cost type. If $\alpha^r < \alpha^r(\phi)$, then—according to Proposition 10 (i)—the optimal quantity to offer when serving a high-cost downstream firm is $q_H^r(\alpha^r) = \hat{q}^r(\alpha^r) \geq \phi$. To see that M prefers to serve both types of downstream firms in this case as well, suppose that—while leaving the quantity to a low-cost firm unchanged—M could offer $q_H = \phi$ to a high-cost downstream firm (instead of $\hat{q}^r(\alpha^r)$) together with tariffs chosen such that (IR$_H^A$) and (IC$_L$) bind. Since $q_H = \phi$,

[26] As becomes obvious from (B.19), the threshold $\tilde{\alpha}^r(\phi)$ depends on both π_L^A and π_H^A. In order to depict the locus of this threshold in the (α^r, ϕ)-space, in Figure 4 it is implicitly assumed that variations in ϕ are due to changes of either π_L^A or π_H^A.

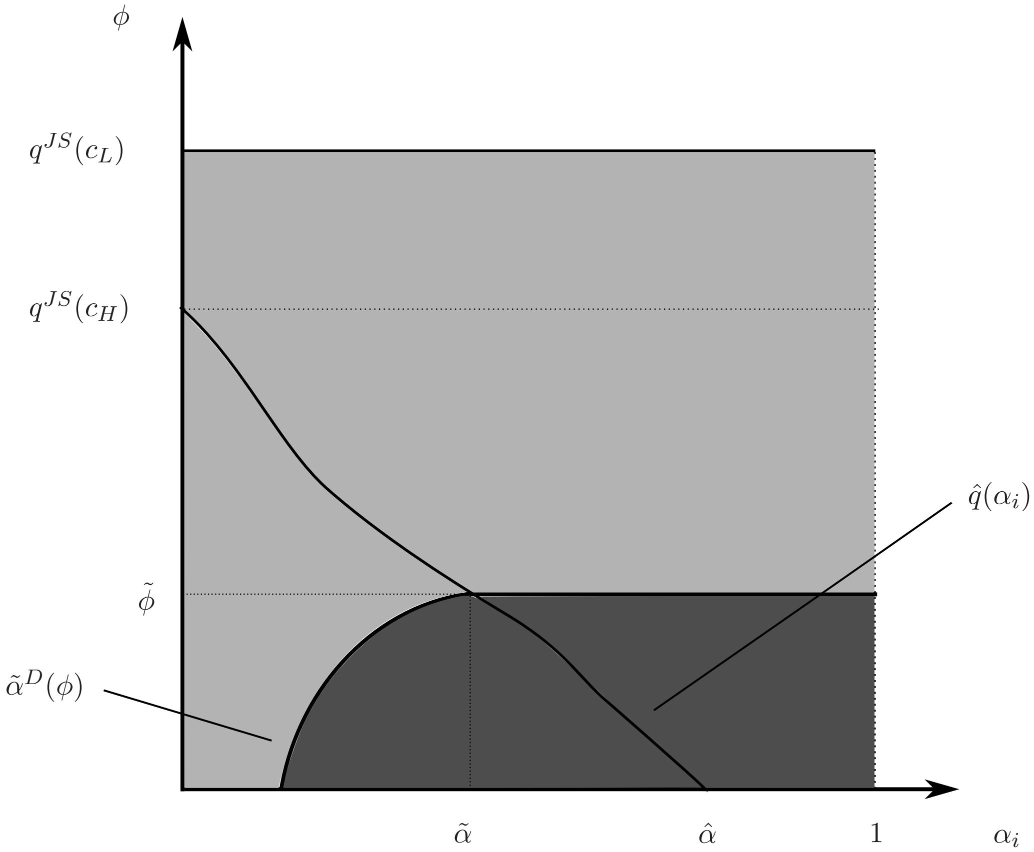

Figure 4: M's decision which types to serve

(IR$_L^A$) is satisfied with equality. With this contractual menu, the LHS of (B.19) obviously equals zero, whereas the RHS is (at least weakly) positive since $\phi \geq \tilde{\phi}$, i.e., M prefers serving both types of downstream firms with this alternative allocation over serving only the low-cost type. Clearly, M's profits under the optimal contractual menu for serving both typs of downstream firms as identified in Proposition 10 (i) cannot be lower than profits under this altered allocation. In summary, under pricing regime $r \in \{D, U\}$, for $\phi \in [\tilde{\phi}, q^{JS}(c_H)]$ we have $\Pi_L^r \geq \Pi_{LH}^r$ irrespective of α^r, i.e., M will always serve both types of downstream firms.

Regarding part (ii) it remains to show that M prefers to serve only the low-cost type for $\phi < \tilde{\phi}$ and $\alpha^r > \tilde{\alpha}^r$. If $\alpha^r \in (\tilde{\alpha}^r, \alpha^r(\phi))$, then $\phi < \hat{q}^r(\alpha^r) < \tilde{\phi}$, which implies that the LHS of (B.19) is strictly positive whereas the RHS of (B.19) is strictly negative, i.e., M prefers to serve only the low-cost type of downstream firm. If $\alpha^r \geq \alpha^r(\phi)$, then $q_H^r(\alpha^r) = \phi$. Since $\phi < \tilde{\phi}$, the left-hand side (LHS) of (B.19) equals zero, whereas the RHS is strictly negative. Thus, M prefers to exclude the high-cost type in this case as well, which establishes the desired result. □

Note that M's motive for not serving the high-cost type changes as α^r increases: For α^r only slightly above the threshold $\alpha^r(\phi)$ the (IR$_L^A$) constraint is slack under the optimal contract when serving both firms, so M's incentive for excluding the high-cost type is rooted in the desire to cut back on the information rent paid to the low-cost type. For relatively high values of α^r, on the other hand, (IR_L^A) is binding under the optimal contract when serving both firms; here, exclusion of the high-cost type is rooted in M's desire to avoid making losses from serving this type.

B.2. Three-Part Wholesale Tariffs

Suppose M cannot offer menu contracts to downstream firms and is restricted to offer three-part wholesale tariffs. The tariff offered to downstream firm $i \in \{1, 2\}$ is

$$\Gamma_i(q) = \begin{cases} L_i + \hat{w}_i q & \text{for } q \leq \bar{q}_i \\ L_i + \hat{w}_i \bar{q}_i + \tilde{w}_i(\bar{q}_i - q) & \text{for } q > \bar{q}_i \end{cases}. \tag{B.23}$$

The tariff is designed such that one cost type operates at the marginal wholesale price $\hat{w}$ and the other cost type at the marginal wholesale price $\tilde{w}$. Under price discrimination Γ_1 can be different from Γ_2 whereas under uniform pricing $\Gamma_1 = \Gamma_2 = \Gamma^U$. Put differently, M chooses $\{(L_i, \hat{w}_i, \tilde{w}_i, \bar{q}_i)\}_{i=1,2}$ under price discrimination and $(L, \tilde{w}, \hat{w}, \bar{q})$ under uniform pricing.

Instead of solving for the parameters of the optimal three-part wholesale tariff directly, it is convenient to rewrite M's problem. Note that offering a three-part tariff is equivalent to offering two two-part tariffs. The three-part tariff is the lower envelope of the two two-part tariffs. The parts of the two two-part tariffs that do not belong to the three-part tariff are dominated from a downstream firm's perspective and therefore are irrelevant. Let the two two-part tariffs be (T_j, w_j) with $j = L, H$, where T_j denotes the lump-sum fee and w_j the wholesale price per unit.

As before, $\pi(q, c) = [P(q) - c]q$. Let the net profit of a downstream firm be

$$\begin{aligned} v(w + c) &\equiv \max_q \{\pi(q, c) - wq\} \\ &= \hat{q}(w + c)[P(\hat{q}(w + c)) - (w + c)], \end{aligned} \tag{B.24}$$

with $\hat{q}(w + c)$ being implicitly defined by the first-order condition

$$P(\hat{q}(w + c)) + \hat{q}(w + c)P'(\hat{q}(w + c)) \equiv w + c. \tag{B.25}$$

Price Discrimination.—If price discrimination is permitted, the manufacturer solves two independent maximization problems. When contracting with a downstream firm that produces at low cost with probability α, the optimal discriminatory three-part tariff solves the following program:

$$\max_{T_L, w_L, T_H, w_H} \alpha[T_L + (w_L - k)\hat{q}(w_L + c_L)] + (1 - \alpha)[T_H + (w_H - K)\hat{q}(w_H + c_H)] \tag{B.26}$$

subject to:

$$v(w_L + c_L) - T_L \geq 0 \tag{IR_L}$$

$$v(w_H + c_H) - T_H \geq 0 \tag{IR_H}$$

$$v(w_L + c_L) - T_L \geq v(w_H + c_L) - T_H \tag{IC_L}$$

$$v(w_H + c_H) - T_H \geq v(w_L + c_H) - T_L \tag{IC_H}$$

In optimum the binding constraints are (IR_H) and (IC_L) which implies that the fixed fees are given by

$$T_H = v(w_H + c_H), \tag{B.27}$$

$$T_L = v(w_L + c_L) - v(w_H + c_L) + v(w_H + c_H). \tag{B.28}$$

The manufacturer's problem can be rewritten as the following unconstraint maximization problem:

$$\max_{w_L, w_H} \alpha\big[v(w_L + c_L) - v(w_H + c_L) + v(w_H + c_H) + (w_L - K)\hat{q}(w_L + c_L)\big] + (1-\alpha)\big[v(w_H + c_H) + (w_H - K)\hat{q}(w_H + c_H)\big], \tag{B.29}$$

with $\hat{q}(w+c)$ being defined by (B.25). By the implicit function theorem, from (B.25) we obtain:

$$\hat{q}'(w + c) = \frac{1}{2P'(\hat{q}(w + c) + \hat{q}(w + c)P''(\hat{q}(w + c))} < 0. \tag{B.30}$$

Moreover, note that

$$v'(w + c) = -\hat{q}(w + c). \tag{B.31}$$

From the first-order condition of profit maximization with respect to w_L we obtain

$$w_L^D(\alpha) = K, \quad \text{which implies that} \quad \hat{q}(w_L^D(\alpha) + c_L) = q^{JS}(c_L). \tag{B.32}$$

Thus, also under the optimal three-part wholesale tariff a low-cost firm obtains the joint surplus maximizing quantity.

From the first-order condition with respect to w_H it follows that

$$w_H^D(\alpha) = K + \frac{\alpha}{1-\alpha} \cdot \frac{\hat{q}(w_H^D(\alpha) + c_L) - \hat{q}(w_H^D(\alpha) + c_H)}{-\hat{q}'(w_H^D(\alpha) + c_H)} > K, \tag{B.33}$$

which characterizes the quantity procured by a high-cost type, $\hat{q}(w_H^D + c_H)$, if it is optimal for the manufacturer to serve high-cost types. Note that the quantity procured by a high-cost type is distorted downwards compared to the joint surplus maximizing quantity and that this distortion is increasing in α—in particular, $\hat{q}(w_H^D + c_H) \to q^{JS}(c_H)$ for $\alpha \to 0$.[27]

[27] To be precise, by applying the implicit function theorem, from (B.33) we obtain that $dw_H^D/d\alpha > 0$ if Assumption 1 holds—i.e., marginal revenue downstream is concave.

Uniform Pricing.—Using the same approach as above it is readily obtained that $w_L^U(\alpha_\Sigma) = K$ and that

$$w_H^U(\alpha_\Sigma) = K + \frac{\alpha_\Sigma/2}{1-\alpha_\Sigma/2} \cdot \frac{\hat{q}(w_H^U(\alpha_\Sigma)+c_L) - \hat{q}(w_H^U(\alpha_\Sigma)+c_H)}{-\hat{q}'(w_H^U(\alpha_\Sigma)+c_H)} > K, \tag{B.34}$$

if it is optimal for the manufacturer to serve high-cost types.

Thus, independent of the pricing regime, low-cost types always procure the joint surplus maximizing quantity. Assuming that marginal downstream revenue is concave, i.e., $3P''(q) - qP'''(q) < 0$, it is readily verified that $w_H^D(\alpha_2) \leq w_H^U(\alpha_\Sigma) \leq w_H^D(\alpha_1)$. In consequence, the quantity procured by a high-cost firm under uniform pricing is bracketed by the quantities procured by high-cost types under price discrimination:

$$\hat{q}(w_H^D(\alpha_1)+c_H) \leq \hat{q}(w_H^U(\alpha_\Sigma)+c_H) \leq \hat{q}(w_H^D(\alpha_2)+c_H) < q^{JS}(c_H),$$

which is the equivalent to Lemma 2 from the main text.

Linear Demand.— Suppose that $P(q) = \max\{1-q, 0\}$ which implies that $\hat{q}(w+c) = \frac{1}{2}(1-w-c)$ and $v(w+c) = \frac{1}{4}(1-w-c)^2$. The optimal per-unit wholesale price for low-quantities, i.e., for the high-cost type, is

$$w_H^r(\alpha) = K + \frac{\alpha}{1-\alpha}(c_H - c_L),$$

with $\alpha \in \{\alpha_1, \alpha_2\}$ for $r = D$ and $\alpha = \alpha_\Sigma/2$ for $r = U$. Thus, the quantities procured by high-cost types are

$$\hat{q}(w_H^r(\alpha)+c_H) = q^{JS}(c_H) - \frac{\alpha}{1-\alpha}\frac{c_H - c_L}{2} \quad \text{if } \alpha \leq \frac{1-K-c_H}{1-K-c_L},$$

and zero otherwise.

Notice that the quantities procured by the downstream firms under the optimal three-part tariffs are exactly the same as the quantities optimally specified in the quantity-transfer lists we consider in the main text. Moreover, high-cost production takes place under a given pricing regime for exactly the same parameter values under the optimal three-part tariffs as under the optimal quantity-transfer lists. This implies that Proposition 5 also holds if the manufacturer is restricted to offer three-part tariffs.