Input price discrimination: The role of pass-through

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Abstract

We investigate input price discrimination under secret contracting between a manufacturer and competing retailers, whose activities exhibit retail effort spillovers. The effects of discriminatory pricing hinge upon the pass-through rate of input price to retail quantity. Such pass-through, defined according to the contractual structure (linear or two-part tariffs), varies with retail effort spillovers and product differentiation. Under each contractual structure, discriminatory pricing is welfare superior if and only if it magnifies the pass-through rate of production cost to input or retail price. Our results deliver novel insights into the role of pass-through in the antitrust assessment of input price discrimination.

Keywords: input price discrimination, pass-through, product differentiation, retail effort spillovers, secrect contracting.
JEL Classification: D43, L13, L42.

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1 Introduction

A common practice for a dominant manufacturer in vertically related markets is to discriminate across retailers by providing the input at different price conditions. Input price discrimination has long been investigated in the economic literature and scrutinized by antitrust authorities worldwide. A strand of literature has analyzed the economic consequences of input price discrimination across retailers with different technologies either under linear vertical contracts (e.g., DeGraba 1990; Gaudin and Lestage 2022; Katz 1987; Inderst and Valletti 2009; Valletti 2003; Yoshida 2000) or nonlinear vertical contracts (e.g., Herweg and Müller 2014; Inderst and Shaffer 2009). Other studies have considered secret contracting under different assumptions about the contractual structure (e.g., Bisceglia et al. 2021; O'Brien 2014; O'Brien and Shaffer 1994; Pinopoulos 2022; Rey and Tirole 2007). When retailers operate in multiple markets, further contributions have explored input price discrimination across buyers (Arya and Mittendorf 2010) or across resale markets (Miklós-Thal and Shaffer 2021).

Departing from the extant literature, we examine input price discrimination in a vertically related market where a manufacturer secretly deals with two competing retailers that exert effort into noncontractible activities in order to promote market demand, generating effort spillovers between retailers. In this framework, we unveil the role of pass-through in shaping the economic effects of input price discrimination. As it is widely recognized in the literature on vertical relationships (e.g., Gabrielsen and Johansen 2017; Kastl et al. 2011; Martimort and Piccolo 2010; Mathewson and Winter 1984), retailers often provide a variety of demand-enhancing services that are unobservable (or unverifiable) by the manufacturer and thus cannot be included in the terms of a contract. A retailer's promotional activities may exhibit positive retail effort spillovers and thus stimulate also the competitors' demand, such as general advertising, marketing and pre-sales services to potential customers. Alternatively, retail effort spillovers may be negative and thus depress the competitors' demand, as in the case of free delivery and after-sales services to customers, which can be interpreted as production of indivisible services bundled with the final product. Furthermore, in line with the long-standing bulk of literature on vertical contracting (e.g., Hart and Tirole 1990; Katz 1991; McAfee and Schwartz 1994; O'Brien and Shaffer 1992, 1994; Rey and Tirole 2007; Rey and Vergé 2004), we consider secret contracts between the manufacturer and the retailers. This creates a classical opportunism problem for the manufacturer, which succumbs to the temptation to offer a retailer secret deals at the expense of the competing retailers and thus cannot fully exploit its market power.

In this framework, we compare two pricing regimes. Under input price discrimination, the manufacturer is allowed to propose a different contract to each retailer. As contracting is secret, each retailer observes only its own offer. Under a ban on input price discrimination, the manufacturer is obliged to propose the same contract to both retailers. This makes contracting de facto public. We address a range of challenging questions. What are the economic effects of input price discrimination? What is the role of pass-through? What are the driving forces behind the results? How relevant is the contractual structure?

We show that, when vertical contracts consist of linear tariffs, the effects of input price discrimination on market outcomes and welfare hinge upon the total responsiveness of the retail quantity to a change in the wholesale price, defined as the *aggregate pass-through rate of input* *price to retail quantity*. Specifically, we find that input price discrimination leads to a lower wholesale price than a ban on input price discrimination if and only if it increases the (absolute) magnitude of the aggregate pass-through rate of input price to retail quantity. Intuitively, the manufacturer is more inclined to cut the wholesale price in the pricing regime where the resulting demand rise is more pronounced. A lower wholesale price translates into a lower retail price and induces each retailer to provide higher levels of effort and quantity. This enhances consumer surplus and total welfare. The comparison between the aggregate pass-through rates of input price to retail quantity under the two pricing regimes nontrivially depends on retail effort spillovers and product differentiation. We identify two opposite effects, referred to as the *retail effort effect* and the *retail price effect*. These effects capture the difference in the pass-through rates of input price to retail quantity between nondiscriminatory and discriminatory pricing via the retail effort channel and the retail price channel, respectively. We show that, as a consequence of the trade-off between these two opposite effects, the aggregate pass-through rate of input price to retail quantity is higher (in absolute value) under a ban on input price discrimination when goods are differentiated enough and retail effort spillovers are below a certain threshold. Otherwise, the opposite occurs and input price discrimination magnifies the aggregate pass-through rate of input price to retail quantity.

The adoption of linear tariffs may emerge in some industries, such as in the relationships between book publishers and retailers, cable TV distributors and channels, hospitals and insurers as well as grocery suppliers and retailers (e.g., Crawford et al. 2018; Crawford and Yurukoglu 2012; Gilbert 2015; Ho and Lee 2017; Inderst and Valletti 2009; Pagnozzi et al. 2016). In other industries, including gasoline, magazine distribution and water, nonlinear tariffs may be employed (e.g., Bonnet and Dubois 2009; Ferrari and Verboven 2012; Pagnozzi et al. 2016; Slade 1998). We show that, under two-part tariffs (specifying a fixed fee and a unit wholesale price), the effects of input price discrimination depend on the sign of the variation in the retailer's quantity driven by the rival's response to a change in the wholesale price, defined as the *cross pass-through rate of input price to retail quantity*, under a ban on input price discrimination. In particular, discriminatory pricing reduces the wholesale price if and only if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive. To understand the rationale for this result, it is worth noting that under a ban on input price discrimination each retailer, knowing that the same contract applies to the competitor, anticipates the demand variation driven by the rival's response to a higher wholesale price, which affects its own profits and thus the fixed fee that it is willing to pay. When the demand variation is positive, the retailer anticipates higher profits under a ban on input price discrimination in response to a rise in the wholesale price and thus the manufacturer becomes more eager to inflate the wholesale price. In this case, input price discrimination reduces the wholesale price and the retail price, thereby stimulating retail effort and quantity, which is beneficial to consumers and society as a whole. We show that the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive if and only if retail effort spillovers are below a certain threshold.

The economic consequences of input price discrimination can also be related to the magnitude of the rate at which a change in the input cost of production translates into a change in the wholesale price or, alternatively, in the retail price, namely, the *pass-through rate of production cost to input price* or, alternatively, *to retail price*. We show that, irrespective of the contractual structure (linear or two-part tariffs), discriminatory pricing is welfare superior if and only if it generates a higher pass-through rate of production cost to input or retail price. Prima facie, this may seem counterintuitive because a higher cost pass-through could be perceived as detrimental to welfare. To grasp the rationale for this result, it is helpful to realize that a higher cost of production induces the manufacturer to curb the retail quantity by charging a higher wholesale price. The manufacturer prefers a higher cost pass-through in the pricing regime where a rise in the wholesale price is more profitable. With linear tariffs, this regime exhibits a more pronounced aggregate pass-through rate of input price to retail quantity, because a rise in the wholesale price triggers a larger reduction in the retail quantity, which allows the manufacturer to save production costs to a greater extent. In light of the afore discussed result that under linear tariffs the pricing regime with a more pronounced aggregate pass-through rate of input price to retail quantity enhances welfare, we find that the regime with a higher cost pass-through is welfare superior. Under two-part tariffs, the regime with a higher cost pass-through reflects discriminatory pricing if and only if the cross pass-through rate of input price to retail quantity is positive under a ban on input price discrimination. As previously mentioned, banning input price discrimination allows each retailer to anticipate the demand variation driven by the rival's response to a rise in the wholesale price. A positive demand variation, which corresponds to a positive cross pass-through rate of input price to retail quantity, leads each retailer to expect higher profits that can be captured by the manufacturer via the fixed fee and thus mitigates the manufacturer's incentives to pass through a higher cost of production into the wholesale price in order to curb the retail quantity. In light of the afore discussed result that under two-part tariffs input price discrimination enhances welfare if and only if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive, we find that the regime with a higher cost pass-through is welfare superior under two-part tariffs as well.

Our analysis is robust to different extensions. In the baseline model, retailers engage in price competition and sell differentiated products. As contracting is secret, under input price discrimination we impose the standard requirement that retailers hold 'passive beliefs' or 'market-by-market bargaining conjectures', according to which a retailer receiving an unexpected offer from the manufacturer still believes that the manufacturer offers the equilibrium contracts to the competing retailers (e.g., Hart and Tirole 1990; O'Brien and Shaffer 1992, 1994; McAfee and Schwartz 1994; Rey and Tirole 2007; Rey and Vergé 2004). In Section 7 we extend the analysis to 'wary beliefs' (e.g., Gaudin 2019; McAfee and Schwartz 1994; Rey and Vergé 2004) and consider quantity competition between retailers.

Our results shed new light on the role of pass-through in the antitrust assessment of input price discrimination. As documented by Luchs et al. (2010) in their empirical analysis of the Robinson-Patman Act of 1936 that disciplines input price discrimination in the United States, recent rulings of the US Supreme Court have determined a substantial reduction in the likelihood that a defendant is found guilty of violating the Robinson-Patman Act.[1] This reflects

[1] A recent relevant US Supreme Court opinion is 'Volvo Trucks North America, Inc. v. Reeder-Simco GMC, Inc.' (546, US 164, 2006). The car dealer Reeder-Simco alleged that the car manufacturer Volvo provided other dealers with deeper discounts that were not available to Reeder-Simco. Overruling the decision of a lower court,

a judicial movement toward a welfare standard, which requires that the existence of competitive harm must be judged according to whether supracompetitive prices resulted from the questioned price discrimination. Adopting a legal perspective, Blair and DePasquale (2014) and Kim (2021) emphasize that the US Supreme Court has recently supported a better alignment of the Robison-Patman Act with the procompetitive goals of antitrust policy. Our analysis can contribute to the identification of compelling criteria and protocols that assist antitrust authorities in evaluating input price discrimination practices.

Structure of the paper. The rest of the paper is organized as follows. Section 2 provides a review of the related literature. Section 3 sets out the formal model. Section 4 derives the equilibrium features of input price discrimination and ban on input price discrimination with linear tariffs and compares the two pricing regimes. Section 5 turns to the case of two-part tariffs. Section 6 explores cost pass-through. Section 7 discusses the robustness of the model. Section 8 concludes the analysis. The main formal proofs are collected in the Appendix. Additional results and associated proofs are available in the Supplementary Appendix.

2 Related literature

Acknowledging the relevance of input price discrimination, the economic literature has extensively inquired into the merits of this practice. Subsequent to Bork's (1978) argument in favor of price discrimination, different lines of research have been pursued, with conflicting views about the competitive and welfare effects. In a setting where an upstream producer charges linear tariffs to downstream firms that differ in their abilities to integrate backward into the input supply, Katz (1987) shows that input price discrimination reduces welfare unless it prevents inefficient backward integration. DeGraba (1990) finds that input price discrimination leads a more efficient firm to pay a higher wholesale price and stifles cost-reducing investment incentives. Extending the results of Katz (1987) and DeGraba (1990), Yoshida (2000) establishes that a rise in the final good output driven by discriminatory pricing is a sufficient condition for welfare deterioration. Through a decomposition of the upstream monopolist's profits, Valletti (2003) shows that input price discrimination is typically detrimental to welfare.

The critical stance on input price discrimination that emerges from the aforementioned contributions has been challenged on different grounds. O'Brien and Shaffer (1994) consider a setting where a manufacturer engages in bilateral secret negotiations over nonlinear supply contracts with two retailers that compete in prices by taking the rival's contract as given when bargaining with the manufacturer. Input price discrimination drives the wholesale price to the manufacturer's marginal cost and thus definitely improves welfare. The existence of an opportunism problem for the manufacturer under secret contracting is confirmed by Rey and Tirole (2007) for the case of downstream quantity competition. In a framework that allows for either linear or two-part tariffs, we include retail effort spillovers at the demand level and

the US Supreme Court established that Volvo was not guilty of a violation of the Robinson-Patman Act, by imposing heightened evidentiary requirements. Luchs et al. (2010) find that, after the Volvo ruling, the probability for a plaintiff to win a secondary-line case (where the plaintiff is a customer of the allegedly discriminating seller) has dropped from 27% to 5%. We refer to O'Donoghue and Padilla (2020) for an authoritative treatment of the legal and economic principles behind the Article 102 of the Treaty on the Functioning of the European Union (TFEU) that governs input price discrimination in the European Union.

characterize opposite effects of input price discrimination, identifying the role of pass-through. When a monopolistic supplier offers two-part tariffs to downstream firms with different degrees of efficiency, Inderst and Shaffer (2009) show that discriminatory pricing amplifies differences in downstream firms' competitiveness and thus improves allocative efficiency. Constructing on Katz (1987) and DeGraba (1990), Inderst and Valletti (2009) show that, if the upstream supplier faces the threat of demand-side substitution, input price discrimination provides the more efficient firm with a discount and strengthens investment incentives. When buyers operate in multiple markets, Arya and Mittendorf (2010) show that input price discrimination leads to lower prices for buyers in markets with lower demand, which improves welfare when lower demand is associated with softer competition. Endogenizing the downstream industry structure, Herweg and Müller (2012) find that input price discrimination fosters entry. With a focus on the airport industry, Haskel et al. (2013) show that, under simultaneous negotiations between each airport and airline, discriminatory landing fees are lower than uniform fees. Extending Katz's (1987) model to bargaining, O'Brien (2014) finds that, if the backward integration threat is not a binding outside option, discriminatory pricing can reduce the average wholesale price.

Other aspects of input price discrimination have been explored in the literature. With nonlinear wholesale tariffs, Herweg and Müller (2014) demonstrate that input price discrimination is often detrimental to welfare when downstream firms have private information about their own costs. In a subsequent work, Herweg and Müller (2016) examine input price discrimination when downstream firms incur a fixed cost. Kim and Sim (2015) find that input price discrimination is welfare improving when the supplier sequentially contracts with two asymmetric retailers. Under downstream vertical differentiation, Chen (2017) shows that the welfare implications of input price discrimination depend on downstream cost and quality differences, whereas Brito et al. (2019) find a welfare increase if and only if the quality gap is sufficiently high. In a setting where a dominant supplier faces a competitive fringe, Akgün and Chioveanu (2019) show that input price discrimination strengthens the retailers' incentives to reduce the cost of acquiring the competitively supplied variety, which can improve market efficiency. When an upstream firm engage in cost-reducing investment activities, Pinopoulos (2020) identifies the impact of input price discrimination on investment levels and welfare according to whether nonlinear tariffs are observable or not. Pinopoulos (2022) finds that, in a market where an upstream supplier bargains over secret two-part tariffs with two cost-asymmetric downstream firms, the welfare effects of input price discrimination depend on the identity of the downstream firm. In a setting where a retailer may invest in an alternative source of supply, Evensen et al. (2021) show that the dominant supplier can gain from committing to nondiscriminatory pricing. When a downstream firm undertakes cost-reducing investment and the upstream monopolist can commit to a pricing policy, Lestage and Li (2022) find that input price discrimination may stimulate downstream investment. With increasing downstream marginal costs, Chen (2022) characterizes the conditions under which input price discrimination improves welfare. Under vertical shareholding, Lestage (2021) identifies the short-term and long-term social benefits of input price discrimination. Li and Shuai (2022) find that input price discrimination mitigates the anticompetitive effects of horizontal shareholding and discourages its formation. In a market where a monopolistic seller distributes its products both directly, through its own distribution channel, and indirectly, through some intermediaries, Bisceglia et al. (2021) show that wholesale price-parity agreements may benefit the intermediaries and consumers. Li (2014) derives the condition for a more efficient firm to receive a higher input price according to the shape of the demand function. In a similar setting, Gaudin and Lestage (2022) show that the effects of input price discrimination depend on the sum of the curvature of inverse demand and the quantity-elasticity of the pass-through rate. In a framework where a supplier offers nonlinear tariffs to competing firms that operate in multiple downstream markets, Miklós-Thal and Shaffer (2021) investigate input price discrimination across resale markets and establish conditions about output and welfare that involve the pass-through rates and demand curvatures in the downstream markets. Adopting a different perspective, we also unveil the role of pass-through, which makes our work complementary to previous studies highlighting the link between pass-through and input price discrimination.

3 The model

Environment. We consider a vertically related market where a monopolistic manufacturer M supplies two retailers, R_1 and R_2, which engage in price competition by selling differentiated products. In Section 7 we explore the case of quantity competition. Let $p_i(e_i, e_{-i}, q_i, q_{-i})$ be the inverse demand function faced by retailer R_i, $i \in \{1, 2\}$, where p_i is the retail price charged by R_i and q_i is the associated quantity, with $\partial p_i(\cdot)/\partial q_i < 0$. The retail effort $e_i \in \mathbb{R}_+$ is exerted by R_i for the provision of noncontractible activities, such as advertising, marketing, pre-sales services as well as free delivery and after-sales services. Such activities stimulate the consumers' willingness to pay for the product sold by R_i and thus a raise in e_i translates into a higher $p_i(\cdot)$, i.e., $\partial p_i(\cdot)/\partial e_i > 0$. As discussed in the introduction, retailers can impose either positive or negative spillovers on each other through the provision of services. When retail activities consist of advertising, marketing or pre-sales services, each retailer can benefit from the rival's effort, which creates a classical free-riding problem. In this case, the retail effort spillovers are positive and thus a raise in e_{-i} translates into a higher $p_i(\cdot)$, i.e., $\partial p_i(\cdot)/\partial e_{-i} > 0$. Conversely, when retail effort is devoted to the provision of indivisible services bundled with the final product, as in the case of free delivery and after-sales services, retail effort spillovers are negative and thus a raise in e_{-i} translates into a lower $p_i(\cdot)$, i.e., $\partial p_i(\cdot)/\partial e_{-i} < 0$. In the spirit of Che and Hausch (1999), effort can be interpreted as 'cooperative' if $\partial p_i(\cdot)/\partial e_{-i} > 0$ and as 'selfish' if $\partial p_i(\cdot)/\partial e_{-i} < 0$. We impose the standard assumption that own-effort effects are larger than cross-effort effects, i.e., $\partial p_i(\cdot)/\partial e_i > |\partial p_{-i}(\cdot)/\partial e_i|$. Goods are (imperfect) substitutes and own-price effects outweigh cross-price effects in the direct demand system, i.e., $|\partial q_i(\cdot)/\partial p_i| > \partial q_i(\cdot)/\partial p_{-i} \geq 0$. Exerting effort is costly for the retailer. Let $\psi(e_i)$ be the cost incurred by R_i to exert effort e_i, where $\partial \psi(e_i)/\partial e_i > 0$ and $\partial^2 \psi(e_i)/\partial e_i^2 > 0$ (for $e_i > 0$). The manufacturer faces a constant production cost $c \geq 0$ per unit of input. Each retailer converts the manufacturer's input into a final product with a one-to-one technology at no cost.

To gain further insights, in line with some relevant contributions (e.g., Kastl et al. 2011; Martimort and Piccolo 2010), we also consider the following inverse demand specification

$$p_i(e_i, e_{-i}, q_i, q_{-i}) = \alpha + e_i + \sigma e_{-i} - q_i - \gamma q_{-i}, \tag{1}$$

where the term $\alpha > 0$ denotes a (common) demand parameter.[2] Furthermore, $\sigma \in (-1, 1)$ identifies retail effort spillovers arising from retailers' promotional activities. Retail effort spillovers are positive for $\sigma > 0$ and negative for $\sigma < 0$. The parameter $\gamma \in [0, 1)$ captures the degree of product differentiation. A higher γ indicates that products are less differentiated. Inverting (1) yields the direct demand function

$$q_i\left(e_i, e_{-i}, p_i, p_{-i}\right) = \frac{\alpha\left(1-\gamma\right) + \left(1-\gamma\sigma\right)e_i + \left(\sigma-\gamma\right)e_{-i} - p_i + \gamma p_{-i}}{1-\gamma^2}. \tag{2}$$

For later purposes, we also introduce the standard quadratic formulation $\psi\left(e_i\right) = e_i^2$ for retailer R_i's cost of effort.

Vertical contracting. The manufacturer secretly makes a contractual offer to each retailer. Two alternative pricing regimes are considered. Under input price discrimination, the manufacturer is allowed to propose a different contract to each retailer, which observes only its own offer. When input price discrimination is banned, the manufacturer is obliged to propose the same contract to both retailers. Thus, contracting becomes de facto public. We disentangle the analysis according to whether vertical contracts consist of linear tariffs or two-part tariffs. With linear tariffs, a contract assumes the form $\mathcal{C}^{dl} \triangleq \{w_i\}_{i\in\{1,2\}}$ under input price discrimination, specifying a wholesale price w_i per unit of input sold to retailer R_i, and the form $\mathcal{C}^{bl} \triangleq \{w\}$ under a ban on input price discrimination, where the same wholesale price w is charged to both retailers. In the same vein, with two-part tariffs, $\mathcal{C}^{dt} \triangleq \{w_i, f_i\}_{i\in\{1,2\}}$ denotes a contract under input price discrimination, specifying a wholesale price w_i and a fixed fee f_i for retailer R_i, and $\mathcal{C}^{bt} \triangleq \{w, f\}$ is a contract under a ban on input price discrimination, where the same wholesale price w and the same fixed fee f are paid by both retailers.

Timing and equilibrium concept. The sequence of events unfolds as follows.

1. The social planner determines the pricing regime, namely, input price discrimination or ban on input price discrimination.

2. The manufacturer makes a contractual offer to each retailer, which decides whether to accept it or not. If the offer is rejected, the manufacturer and the retailer obtain an outside option (normalized to zero).

3. Each retailer that has accepted an offer exerts effort and competes in the downstream market, and contracts are executed.

The solution concept that we adopt is Perfect Bayesian Equilibrium. As each retailer cannot observe the contract offered to its rival under input price discrimination, we need to specify how a retailer revises its beliefs about the rival's contract when receiving an 'unexpected' (i.e., out-of-equilibrium) offer. In the baseline model, we adopt the standard equilibrium refinement of 'passive beliefs' or 'market-by-market bargaining conjectures', according to which a retailer that receives an unexpected offer from the manufacturer still believes that the manufacturer offers

[2] As shown in the Appendix, the inverse demand function in (1) follows from the utility maximization problem faced by a continuum of consumers whose preferences are characterized by the quasi-linear utility function in (A17). We refer to Vives (1999) for further details on this standard approach. Bonazzi et al. (2021) consider a demand specification similar to (1) for the case $\sigma = 0$.

the equilibrium contract to the competing retailers (e.g., Hart and Tirole 1990; McAfee and Schwartz 1994; O'Brien and Shaffer 1992, 1994; Rey and Tirole 2007; Rey and Vergé 2004). A defining property of passive beliefs is the focus on ensuring that the equilibrium survives unilateral deviations, which occur when a manufacturer revises its offer and deviates with only one retailer.[3] In Section 7 we extend the analysis to 'wary beliefs' (e.g., Gaudin 2019; McAfee and Schwartz 1994; Rey and Vergé 2004). We look for symmetric pure-strategy equilibria.

Throughout the paper, we impose the following assumptions on manufacturer M's profits π_M and on retailer R_i's profits π_{R_i}, $i \in \{1, 2\}$.

Assumption 1 (upstream second-order conditions). Under input price discrimination, it holds (i) $\partial^2 \pi_M / \partial w_i^2 < 0$, and (ii) $\left(\partial^2 \pi_M / \partial w_i^2\right)\left(\partial^2 \pi_M / \partial w_{-i}^2\right) - \left(\partial^2 \pi_M / \partial w_i \partial w_{-i}\right)^2 > 0$, $i, -i \in \{1, 2\}$, $i \neq -i$. Under a ban on input price discrimination, it holds $\partial^2 \pi_M / \partial w^2 < 0$.

Assumption 2 (downstream second-order conditions). It holds (i) $\partial^2 \pi_{R_i} / \partial p_i^2 < 0$, (ii) $\partial^2 \pi_{R_i} / \partial e_i^2 < 0$, and (iii) $\left(\partial^2 \pi_{R_i} / \partial p_i^2\right)\left(\partial^2 \pi_{R_i} / \partial e_i^2\right) - \left(\partial^2 \pi_{R_i} / \partial p_i \partial e_i\right)^2 > 0$, $i \in \{1, 2\}$.

Assumption 1 states that the Hessian matrix associated with manufacturer M's profit maximization problem is negative definite, which ensures the upstream second-order conditions. According to Assumption 2, the Hessian matrix associated with retailer R_i's profit maximization problem is negative definite, which guarantees that the downstream second-order conditions hold as well.[4]

4 Linear tariffs

As described in Section 3, with linear tariffs, manufacturer M sets a wholesale price w_i per unit of input sold to retailer R_i under input price discrimination, whereas the same wholesale price w is charged to both retailers under a ban on input price discrimination. We start our analysis with the case where discriminatory pricing is allowed.

4.1 Input price discrimination

Proceeding backward, under input price discrimination, in the product market competition stage retailer R_i facing the wholesale price w_i selects the retail price p_i and the retail effort e_i in order to maximize its profits $\Pi_{R_i} \triangleq (p_i - w_i)\, q_i - \psi(e_i)$, anticipating the equilibrium retail price p_{-i}^{dl} and retail effort e_{-i}^{dl} chosen by the competitor R_{-i}. Thus, R_i's profit maximization problem writes as

$$\max_{\{p_i, e_i\}} \; (p_i - w_i)\, q_i \left(e_i, e_{-i}^{dl}, p_i, p_{-i}^{dl}\right) - \psi(e_i) \,.$$

Taking the first-order conditions for p_i and e_i yields respectively

$$q_i \left(e_i, e_{-i}^{dl}, p_i, p_{-i}^{dl}\right) + (p_i - w_i) \frac{\partial q_i \left(e_i, e_{-i}^{dl}, p_i, p_{-i}^{dl}\right)}{\partial p_i} = 0 \qquad (3)$$

[3] The idea of passive beliefs shares the same spirit as the contract equilibrium à la Crémer and Riordan (1987) and O'Brien and Shaffer (1992) as well as the bargaining equilibrium à la O'Brien and Shaffer (1994). A ban on input price discrimination, which makes each retailer aware that the same contract applies to the competitor, is equivalent to 'symmetric beliefs' (e.g., McAfee and Schwartz 1994; Pagnozzi and Piccolo 2011).

[4] The standard Inada conditions for an interior solution also apply.

and

$$(p_i - w_i) \frac{\partial q_i \left(e_i, e_{-i}^{dl}, p_i, p_{-i}^{dl}\right)}{\partial e_i} - \frac{\partial \psi (e_i)}{\partial e_i} = 0. \tag{4}$$

Each retailer selects its price according to condition (3) that reflects the standard trade-off between the profit margin effect and the sales volume effect. Intuitively, a higher price enhances the retailer's profits stemming from the inframarginal consumers but discourages the marginal consumers from buying and thus reduces the retailer's sales volume. As condition (4) reveals, the level of effort provided by each retailer equalizes the marginal benefit of demand expansion and the marginal cost of effort. Conditions (3) and (4) identify the retail price $p_i^d(w_i)$ and the retail effort $e_i^d(w_i)$ chosen by retailer R_i conditionally upon the wholesale price w_i.

Anticipating the outcome of the product market competition stage, as identified by (3) and (4), manufacturer M sets the wholesale price w_i for retailer R_i in order to maximize its profits $\Pi_M \triangleq (w_i - c) q_i + (w_{-i} - c) q_{-i}$ as follows

$$\begin{aligned} &\max_{w_i} (w_i - c) q_i \left(e_i^d(w_i), e_{-i}^d(w_{-i}), p_i^d(w_i), p_{-i}^d(w_{-i})\right) \\ &+ (w_{-i} - c) q_{-i} \left(e_i^d(w_i), e_{-i}^d(w_{-i}), p_i^d(w_i), p_{-i}^d(w_{-i})\right). \end{aligned}$$

The first-order condition for w_i is given by

$$q_i + (w_i - c)\left(\frac{\partial q_i}{\partial e_i}\frac{de_i^d}{dw_i} + \frac{\partial q_i}{\partial p_i}\frac{dp_i^d}{dw_i}\right) + (w_{-i} - c)\left(\frac{\partial q_{-i}}{\partial e_i}\frac{de_i^d}{dw_i} + \frac{\partial q_{-i}}{\partial p_i}\frac{dp_i^d}{dw_i}\right) = 0, \tag{5}$$

which determines the equilibrium wholesale price under input price discrimination with linear tariffs.

4.2 Ban on input price discrimination

Proceeding backward, when input price discrimination is banned, in the product market competition stage retailer R_i facing the wholesale price w selects the retail price p_i and the retail effort e_i in order to maximize its profits $\Pi_{R_i} \triangleq (p_i - w) q_i - \psi(e_i)$, anticipating the retail price $p_{-i}^b(w)$ and the retail effort $e_{-i}^b(w)$ chosen by the competitor R_{-i} for the same w. Thus, R_i's profit maximization problem writes as

$$\max_{\{p_i, e_i\}} (p_i - w) q_i \left(e_i, e_{-i}^b(w), p_i, p_{-i}^b(w)\right) - \psi(e_i).$$

Taking the first-order conditions for p_i and e_i yields respectively

$$q_i \left(e_i, e_{-i}^b(w), p_i, p_{-i}^b(w)\right) + (p_i - w) \frac{\partial q_i \left(e_i, e_{-i}^b(w), p_i, p_{-i}^b(w)\right)}{\partial p_i} = 0 \tag{6}$$

and

$$(p_i - w) \frac{\partial q_i \left(e_i, e_{-i}^b(w), p_i, p_{-i}^b(w)\right)}{\partial e_i} - \frac{\partial \psi (e_i)}{\partial e_i} = 0. \tag{7}$$

Under nondiscriminatory pricing, each retailer knows that it faces the same wholesale price as the competitor and thus anticipates the retail price and the retail effort determined by the competitor according to the common wholesale price. Conditions (6) and (7) identify the retail price $p_i^b(w)$ and the retail effort $e_i^b(w)$ chosen by retailer R_i conditionally upon the wholesale price w under a ban on input price discrimination.

Anticipating the outcome of the product market competition stage, as identified by (6) and (7), manufacturer M sets the wholesale price w for both retailers in order to maximize its profits $\Pi_M \triangleq (w-c)(q_i + q_{-i})$ as follows

$$\max_{w} (w-c)\left[q_i\left(e_i^b(w), e_{-i}^b(w), p_i^b(w), p_{-i}^b(w)\right) + q_{-i}\left(e_i^b(w), e_{-i}^b(w), p_i^b(w), p_{-i}^b(w)\right)\right].$$

The first-order condition for w is given by

$$\sum\nolimits_{i=1}^{2}\left[q_i + (w-c)\left(\frac{\partial q_i}{\partial e_i}\frac{de_i^b}{dw} + \frac{\partial q_i}{\partial e_{-i}}\frac{de_{-i}^b}{dw} + \frac{\partial q_i}{\partial p_i}\frac{dp_i^b}{dw} + \frac{\partial q_i}{\partial p_{-i}}\frac{dp_{-i}^b}{dw}\right)\right] = 0, \tag{8}$$

which determines the equilibrium wholesale price under a ban on input price discrimination with linear tariffs.

4.3 Comparison between regimes

Equipped with the results in Sections 4.1 and 4.2, we can now proceed with our analysis by comparing the regimes of input price discrimination and ban on input price discrimination. Our findings are driven by the impact of each regime on the rate at which the retail quantity varies in response to a change in the wholesale price. Given the pricing regime $r \in \{b, d\}$, where b represents a ban on input price discrimination and d denotes input price discrimination, differentiating the retail quantity $q_i^r(w) \triangleq q_i\left(e_i^r(w), e_{-i}^r(w), p_i^r(w), p_{-i}^r(w)\right)$ with respect to the wholesale price w yields

$$\frac{dq_i^r}{dw} = \frac{\partial q_i}{\partial e_i}\frac{de_i^r}{dw} + \frac{\partial q_i}{\partial e_{-i}}\frac{de_{-i}^r}{dw} + \frac{\partial q_i}{\partial p_i}\frac{dp_i^r}{dw} + \frac{\partial q_i}{\partial p_{-i}}\frac{dp_{-i}^r}{dw}. \tag{9}$$

The expression in (9) captures, under each pricing regime r, the total responsiveness of the retail quantity to a change in the wholesale price, defined as the *aggregate pass-through rate of input price to retail quantity.* A higher wholesale price clearly translates into a lower retail quantity under both pricing regimes, i.e., $dq_i^r/dw < 0$, for $r \in \{b, d\}$.[5] Thus, it is helpful for our purposes to refer to the absolute value of dq_i^r/dw. In the following proposition we characterize a full comparison between the two pricing regimes.

Proposition 1 *Suppose that vertical contracts consist of linear tariffs. Then,*

(i) input price discrimination yields (a) a lower wholesale price, (b) a lower retail price, (c) a higher retail effort, (d) a higher retail quantity, if it generates a higher aggregate pass-through rate of input price to retail quantity (in absolute value) — i.e., (a) $w^{dl} < w^{bl}$, *(b)* $p^{dl} < p^{bl}$, *(c)* $e^{dl} > e^{bl}$, *(d)* $q^{dl} > q^{bl}$, *if* $\left|dq_i^d/dw\right| > \left|dq_i^b/dw\right|$;

(ii) a ban on input price discrimination yields (a) a lower wholesale price, (b) a lower retail price, (c) a higher retail effort, (d) a higher retail quantity, if it generates a higher aggregate pass-through rate of input price to retail quantity (in absolute value) — i.e., (a) $w^{bl} < w^{dl}$, *(b)* $p^{bl} < p^{dl}$, *(c)* $e^{bl} > e^{dl}$, *(d)* $q^{bl} > q^{dl}$, *if* $\left|dq_i^b/dw\right| > \left|dq_i^d/dw\right|$.

[5] Technical details are available in the proof of Proposition 1.

Proposition 1 shows that input price discrimination reduces the wholesale price if and only if it magnifies the pass-through rate of input price to retail quantity. Intuitively, under linear tariffs the manufacturer only cares about the profits stemming from the quantity sold through the retailers. Thus, the manufacturer is more eager to set a lower wholesale price under the pricing regime where the resulting demand rise is more pronounced. A lower wholesale price induces each retailer to charge a lower retail price and to provide a higher retail effort, which translates into a higher retail quantity.

Conducting a welfare analysis yields the following results.

Proposition 2 *Suppose that vertical contracts consist of linear tariffs. Then,*

(i) input price discrimination enhances consumer surplus and total welfare if it generates a higher pass-through rate of input price to retail quantity (in absolute value) — i.e., $CS^{dl} > CS^{bl}$ *and* $TW^{dl} > TW^{bl}$ *if* $\left|dq_i^d/dw\right| > \left|dq_i^b/dw\right|$*;*

(ii) a ban on input price discrimination enhances consumer surplus and total welfare if it generates a higher pass-through rate of input price to retail quantity (in absolute value) — i.e., $CS^{bl} > CS^{dl}$ *and* $TW^{bl} > TW^{dl}$ *if* $\left|dq_i^b/dw\right| > \left|dq_i^d/dw\right|$*.*

In light of the results in Proposition 1, we find from Proposition 2 that consumers are better off under the pricing regime that exhibits a higher pass-through rate of input price to retail quantity. Banning input price discrimination raises the manufacturer's profits by removing the opportunism problem associated with secret contracting. As the retailers' profits decline with the wholesale price, the retailers' preferences are fully aligned with those of consumers. The pricing regime that generates higher consumer surplus improves allocative efficiency and thus enhances total welfare as well.

To identify the forces behind the results in Propositions 1 and 2, we now compare the pass-through rates of input price to retail quantity in (9) under the two pricing regimes. To this aim, we resort to the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. Our results are driven by the trade-off between two opposite effects in a nontrivial manner.

To begin with, we consider the pass-through rate of input price to retail price dp_i^r/dw and the pass-through rate of input price to retail effort de_i^r/dw under each pricing regime $r \in \{b, d\}$. In the following lemma, we describe the main features of these pass-through rates under input price discrimination. The threshold $\widetilde{\gamma} > 0$ is derived in the proof of Lemma 1.

Lemma 1 *Under input price discrimination,*

(i) the pass-through rate of input price to retail price is positive if and only if goods are differentiated enough — i.e., $dp_i^d/dw > 0$ *if and only if* $\gamma < \widetilde{\gamma}$*;*

(ii) the pass-through rate of input price to retail effort is negative — i.e., $de_i^d/dw < 0$*.*

Point (i) of Lemma 1 shows that a higher wholesale price stimulates the retail price when goods are differentiated enough, i.e., $\gamma < \widetilde{\gamma}$. Conversely, the retail price decreases with the wholesale price for sufficiently substitutable goods, i.e., $\gamma > \widetilde{\gamma}$. To understand why, it is helpful to examine the impact of the wholesale price upon the retail effort. A rise in the wholesale price discourages the retailer from engaging in promotional activities, which entails a negative pass-through rate of input price to retail effort, as established in point (ii) of Lemma 1. The reason is that a higher wholesale price squeezes the retailer's profit margin and mitigates the benefit of effort associated with demand expansion. When goods are substitutes enough, a change in effort yields a significant impact on the retailer's demand. Thus, a lower effort stemming from a higher wholesale price triggers a substantial drop in demand, which induces the retailer to cut its price and generates a negative pass-through rate of input price to retail price.

In the following lemma, we describe the main features of the pass-through rates of input price to retail price and to retail effort when input price discrimination is prohibited.

Lemma 2 *Under a ban on input price discrimination,*

(i) the pass-through rate of input price to retail price is positive — i.e., $dp_i^b/dw > 0$*;*

(ii) the pass-through rate of input price to retail effort is negative — i.e., $de_i^b/dw < 0$*.*

Point (i) of Lemma 2 shows that under a ban on input price discrimination a higher wholesale price definitely translates into a higher retail price. This differs from input price discrimination, where the pass-through rate of input price to retail price is negative for sufficiently substitutable goods, as established in point (i) of Lemma 1. To understand why, it is worth noting that, when input price discrimination is banned, a retailer facing a higher wholesale price knows that the same price surge applies to the competitor, which induces both retailers to raise their prices for a given effort level. Such price increases reinforce each other in the presence of strategic complementarity in pricing decisions. Furthermore, in line with discriminatory pricing, a rise in the wholesale price leads each retailer to curb the amount of effort, which yields a negative pass-through rate of input price to retail effort, as established in point (ii) of Lemma 2. Under a ban on input price discrimination, each retailer anticipates the demand change stemming from a reduction in the competitor's effort in response to a higher wholesale price. Specifically, it follows from the demand function in (2) that a lower effort provided by the competitor stimulates ceteris paribus the retailer's demand when retail effort spillovers are lower than the degree of product differentiation (i.e., $\sigma < \gamma$), which magnifies the retailer's incentives to increase its price. Conversely, when retail effort spillovers exceed the degree of product differentiation and thus goods are sufficiently differentiated (i.e., $\sigma > \gamma$), the retailer's demand declines due to a lower effort provided by the competitor in response to a higher wholesale price. The resulting negative effect of a higher wholesale price on the retail price is, however, outweighed by the positive effect of a higher retail cost (due to a higher wholesale price), which is particularly significant for sufficiently differentiated goods.[6] Thus, differently from discriminatory pricing, the pass-through rate of input price to retail price is unambiguously positive.

We now compare the pass-through rates of input price to retail price and to retail effort under the two pricing regimes. The threshold $\widehat{\sigma} > 0$ is derived in the proof of Lemma 3.

Lemma 3 *There exists a threshold* $\widehat{\sigma} > 0$ *for retail effort spillovers* σ *such that*

(i) if $\sigma < \widehat{\sigma}$*, the pass-through rates of input price to retail price and to retail effort are higher under a ban on input price discrimination — i.e.,* $dp_i^b/dw > dp_i^d/dw$ *and* $de_i^b/dw > de_i^d/dw$*;*

(ii) if $\sigma > \widehat{\sigma}$*, the pass-through rates of input price to retail price and to retail effort are higher under input price discrimination — i.e.,* $dp_i^d/dw > dp_i^b/dw$ *and* $de_i^d/dw > de_i^b/dw$*.*

[6] This is in line with input price discrimination, where a positive pass-through rate of input price to retail price emerges for sufficiently differentiated goods, as shown in point (i) of Lemma 1.

It follows from the discussion after Lemmas 1 and 2 that, under a ban on input price discrimination, where each retailer knows that the same wholesale price is charged to the competitor, the retail price is more responsive to a change in the wholesale price for a given effort with respect to input price discrimination in the presence of strategic complementarity in the pricing decisions. Furthermore, as implied by the demand function in (2), a reduction in the competitor's effort arising from a higher wholesale price stimulates ceteris paribus the retailer's demand as long as retail effort spillovers are positive but small enough or, a fortiori, negative (i.e., $\sigma < \gamma$). This magnifies the retailer's incentives to increase its price in response to a higher wholesale price compared to input price discrimination. Consequently, there exists a threshold $\widehat{\sigma} > 0$ for retail effort spillovers σ such that, for $\sigma < \widehat{\sigma}$, banning input price discrimination generates a higher pass-through rate of input price to retail price, as established in point (i) of Lemma 3. This increases the retailer's benefit of effort associated with demand expansion and leads to a higher (namely, less negative) pass-through rate of input price to retail effort as well. Conversely, if retail effort spillovers are large enough, i.e., $\sigma > \widehat{\sigma}$, the demand reduction anticipated by a retailer under a ban on input price discrimination as a result of lower effort of the rival in response to a higher wholesale price mitigates the retailer's incentives to raise its price to such an extent that the pass-through rate of input price to retail price becomes higher under discriminatory pricing, as shown in point (ii) of Lemma 3. This implies that discriminatory pricing increases the retailer's benefit of effort associated with demand expansion and generates a higher pass-through rate of input price to retail effort as well.

Given the results in Lemma 3, we can now compare the aggregate pass-through rates of input price to retail quantity in (9) under the two pricing regimes. To this aim, we define by

$$\Delta_e \triangleq \underbrace{\underbrace{\left(\frac{\partial q_i}{\partial e_i} + \frac{\partial q_i}{\partial e_{-i}}\right)}_{>0} \underbrace{\left[\left(\frac{de_i^b}{dw} + \frac{de_{-i}^b}{dw}\right) - \left(\frac{de_i^d}{dw} + \frac{de_{-i}^d}{dw}\right)\right]}_{>0 \text{ if and only if } \sigma<\widehat{\sigma}}}_{\textit{retail effort effect}} \tag{10}$$

the difference in the pass-through rates of input price to retail quantity via the retail effort channel between nondiscriminatory and discriminatory pricing. The term Δ_e in (10) identifies the *retail effort effect*, which can be split into two components. Intuitively, the quantity impact of aggregate effort changes in the first round brackets in (10) is positive, as implied by the demand function in (2). As shown in Lemma 3, the difference in the pass-through rates of input price to retail effort between nondiscriminatory and discriminatory pricing, captured by the expression in square brackets in (10), is positive if and only if retail effort spillovers are below a certain threshold, i.e., $\sigma < \widehat{\sigma}$.

Furthermore, we define by

$$\Delta_p \triangleq \underbrace{\underbrace{\left(\frac{\partial q_i}{\partial p_i} + \frac{\partial q_i}{\partial p_{-i}}\right)}_{<0} \underbrace{\left[\left(\frac{dp_i^b}{dw} + \frac{dp_{-i}^b}{dw}\right) - \left(\frac{dp_i^d}{dw} + \frac{dp_{-i}^d}{dw}\right)\right]}_{>0 \text{ if and only if } \sigma<\widehat{\sigma}}}_{\textit{retail price effect}} \tag{11}$$

the difference in the pass-through rates of input price to retail quantity via the retail price channel between nondiscriminatory and discriminatory pricing. The term Δ_p in (11) represents the *retail price effect*, which can be decomposed into two parts, similarly to Δ_e in (10). The quantity impact of aggregate price changes in the first round brackets in (11) is negative, as implied by the demand function in (2). As established in Lemma 3, the difference in the pass-through rates of input price to retail price between nondiscriminatory and discriminatory pricing, captured by the expression in square brackets in (11), is positive if and only if retail effort spillovers are below a certain threshold, i.e., $\sigma < \widehat{\sigma}$.

Given the expression for the pass-through rate of input price to retail quantity dq_i^r/dw in (9), where $dq_i^r/dw < 0$ for $r \in \{b, d\}$, we find from (10) and (11) that

$$\left|\frac{dq_i^d}{dw}\right| > \left|\frac{dq_i^b}{dw}\right| \iff \underbrace{\Delta_e}_{\textit{retail effort effect}:\ >0 \text{ if and only if } \sigma<\widehat{\sigma}} + \underbrace{\Delta_p}_{\textit{retail price effect}:\ <0 \text{ if and only if } \sigma<\widehat{\sigma}} > 0. \tag{12}$$

As the retail effort effect and the retail price effect move in opposite directions, the comparison between the aggregate pass-through rates of input price to retail quantity (in absolute value) under the two pricing regimes — captured by the expression in (12) — crucially hinges upon the trade-off between these two effects. We first consider the retail effort effect. It follows from Δ_e in (10) that, for $\sigma < \widehat{\sigma}$, the retail effort effect is positive. As (12) indicates, this makes ceteris paribus the aggregate pass-through rate of input price to retail quantity higher (in absolute value) under discriminatory pricing. To understand why, it is worth noting from Lemma 3 that, for $\sigma < \widehat{\sigma}$, discriminatory pricing increases the (absolute) magnitude of the pass-through rate of input price to retail effort. Thus, it also inflates the pass-through rate of input price to retail quantity (in absolute value) via the retail effort channel. Adopting the same rationale, the opposite occurs for $\sigma > \widehat{\sigma}$. Now, we turn to the retail price effect. It follows from Δ_p in (11) that, for $\sigma < \widehat{\sigma}$, the retail price effect is negative. As (12) reveals, this makes ceteris paribus the aggregate pass-through rate of input price to retail quantity lower (in absolute value) under discriminatory pricing. We know from Lemma 3 that, for $\sigma < \widehat{\sigma}$, discriminatory pricing reduces the pass-through rate of input price to retail price. Thus, it also curbs the pass-through rate of input price to retail quantity (in absolute value) via the retail price channel. Following the same logic, the opposite occurs for $\sigma > \widehat{\sigma}$.

Combining (10) and (11), we can compute the ratio between the retail effort effect and the retail price effect (in absolute value), which writes as

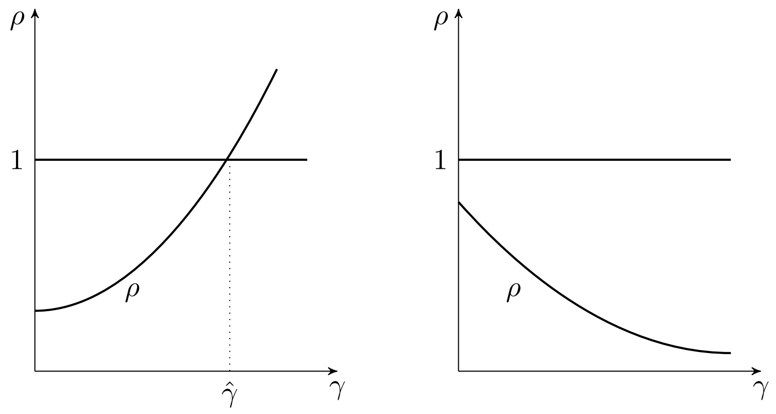
$$\rho \triangleq \underbrace{\frac{|\Delta_e|}{|\Delta_p|}}_{\textit{retail effort–price effect ratio}}. \tag{13}$$

Using the retail effort–price effect ratio in (13), we find from (12) that

$$\left|\frac{dq_i^d}{dw}\right| > \left|\frac{dq_i^b}{dw}\right| \iff \rho > 1 \text{ for } \sigma < \widehat{\sigma} \tag{14}$$

and

$$\left|\frac{dq_i^d}{dw}\right| > \left|\frac{dq_i^b}{dw}\right| \iff \rho < 1 \text{ for } \sigma > \widehat{\sigma}. \tag{15}$$



(a) $\sigma < \hat{\sigma}$ (b) $\sigma > \hat{\sigma}$

Figure 1: The retail effort–price effect ratio

The condition in (14) indicates that, for $\sigma < \widehat{\sigma}$, the aggregate pass-through rate of input price to retail quantity is higher (in absolute value) under input price discrimination if and only if the retail effort–price effect ratio ρ in (13) is higher than unity. As (12) reveals, in this case the positive retail effort effect dominates the negative retail price effect. However, the condition in (15) shows that, for $\sigma > \widehat{\sigma}$, the aggregate pass-through rate of input price to retail quantity is higher (in absolute value) under input price discrimination if and only if the retail effort–price effect ratio ρ in (13) is lower than unity. As (12) indicates, in this case the negative retail effort effect is more than compensated by the positive retail price effect.

We are now in a position to characterize the conditions for the comparison between the aggregate pass-through rates of input price to retail quantity under the two pricing regimes. The novel threshold $\widehat{\gamma} > 0$ is derived in the proof of Proposition 3.

Proposition 3 *There exist a threshold $\widehat{\gamma} > 0$ for the degree of product differentiation γ and a threshold $\widehat{\sigma} > 0$ for retail effort spillovers σ such that*

(i) if $\gamma < \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$, the aggregate pass-through rate of input price to retail quantity is higher (in absolute value) under a ban on input price discrimination — i.e., $\left|dq_i^b/dw\right| > \left|dq_i^d/dw\right|$;

(ii) otherwise, i.e., either if $\gamma > \widehat{\gamma}$ or $\sigma > \widehat{\sigma}$, the aggregate pass-through rate of input price to retail quantity is higher (in absolute value) under input price discrimination — i.e., $\left|dq_i^d/dw\right| > \left|dq_i^b/dw\right|$.

To grasp the intuition behind the results in Proposition 3, it is helpful to refer to Figure 1, where the retail effort–price effect ratio ρ in (13) is represented as a function of the degree of product differentiation γ. For γ small enough, the impact of the effort provided by each retailer on its own demand in (2) is relatively moderate. As effort is costly, this implies that the retail effort effect in (10) is weaker than the retail price effect in (11) and thus $\rho < 1$. For $\sigma < \widehat{\sigma}$, a higher γ magnifies the retailer's demand rise stemming from higher effort because more severe competition (as implied by a higher γ) makes each retailer's effort more effective in attracting additional consumers. This strengthens the retail effort effect compared to the retail price effect, i.e., ρ rises with γ.[7] Hence, for $\sigma < \widehat{\sigma}$, there exists a threshold $\widehat{\gamma} > 0$ below which it holds $\rho < 1$, as shown in panel (a) of Figure 1. It follows from the condition in (14) that, for $\gamma < \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$, the aggregate pass-through rate of input price to retail quantity is higher (in absolute value) under a ban on input price discrimination, which is established in point (i) of Proposition 3. As panel (a) of Figure 1 illustrates, it holds $\rho > 1$ for $\gamma > \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$. In this case, we find from the condition in (14) that input price discrimination generates a higher aggregate pass-through rate of input price to retail quantity, as point (ii) of Proposition 3 indicates. For $\sigma > \widehat{\sigma}$, a higher γ mitigates the retailer's demand rise stemming from higher effort because tougher competition aggravates the free-riding problem associated with positive retail effort spillovers. This implies that the retail effort effect declines compared to the retail price effect and thus ρ monotonically decreases with γ, as shown in panel (b) of Figure 1. Given that $\rho < 1$, it follows from the condition in (15) that, for $\sigma > \widehat{\sigma}$, input price discrimination generates a higher aggregate pass-through rate of input price to retail quantity (in absolute value), which is formalized in point (ii) of Proposition 3. Combining the results in Propositions 1 through 3, we find that, as a consequence of the trade-off between the retail effort effect and the retail price effect, if goods are differentiated enough and retail effort spillovers are below a certain threshold, i.e., $\gamma < \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$, the results in point (ii) of Propositions 1 and 2 apply. Otherwise, the results in point (i) of Propositions 1 and 2 emerge.

5 Two-part tariffs

We now turn to the case of two-part tariffs. As described in Section 3, manufacturer M sets a wholesale price w_i and a fixed fee f_i for retailer R_i under input price discrimination, whereas the same wholesale price w and the same fixed fee f are charged to both retailers under a ban on input price discrimination. As for the case of linear tariffs, we commence our analysis with the regime of input price discrimination.

5.1 Input price discrimination

As the fixed fee does not affect the retailer's choices, the retail price and the retail effort determined by retailer R_i conditionally upon the wholesale price w_i are the same as those with linear tariffs, i.e., $p_i^d(w_i)$ and $e_i^d(w_i)$ identified by (3) and (4), with the only difference that the equilibrium retail price p_{-i}^{dl} and retail effort e_{-i}^{dl} are replaced by p_{-i}^{dt} and e_{-i}^{dt}, respectively. The fixed fee f_i is charged by manufacturer M to fully extract the profits that retailer R_i expects to

[7] The positive impact of γ on ρ holds at least for γ large enough. Specifically, when retail effort spillovers are (weakly) negative (i.e., $\sigma \leq 0$), ρ monotonically increases with γ. When retail effort spillovers are positive but relatively small (i.e., $0 < \sigma < \widehat{\sigma}$), ρ initially decreases with γ. Starting from relatively small values of γ, a higher γ mitigates the retailer's demand rise stemming from higher effort because tougher competition exacerbates the free-riding problem associated with positive retail effort spillovers, which curbs the retailer's benefit of effort associated with demand expansion. This implies that the retail effort effect declines compared to the retail price effect and thus a higher γ reduces ρ. The opposite occurs for relatively large values of γ. The reason is that, in a relatively competitive market, an even higher level of competition leads to a rise in the retailer's ability to attract additional consumers through promotional activities, which outweighs the aforementioned exacerbation of the free-riding problem, provided that positive retail effort spillovers are relatively small. This magnifies the retail effort effect compared to the retail price effect and thus ρ increases with γ for γ large enough. We refer to the proof of Proposition 3 for technical details.

obtain, i.e., $f_i = \left[p_i^d(w_i) - w_i\right] q_i\left(e_i^d(w_i), e_{-i}^{dt}, p_i^d(w_i), p_{-i}^{dt}\right) - \psi\left(e_i^d(w_i)\right)$. Hence, manufacturer M sets the wholesale price w_i and the fixed fee f_i for retailer R_i in order to maximize its profits $\Pi_M \triangleq (w_i - c) q_i + f_i + (w_{-i} - c) q_{-i} + f_{-i}$ as follows

$$\max_{w_i} (w_i - c) q_i\left(e_i^d(w_i), e_{-i}^d(w_{-i}), p_i^d(w_i), p_{-i}^d(w_{-i})\right) + \left[p_i^d(w_i) - w_i\right] q_i\left(e_i^d(w_i), e_{-i}^{dt}, p_i^d(w_i), p_{-i}^{dt}\right)$$
$$- \psi\left(e_i^d(w_i)\right) + (w_{-i} - c) q_{-i}\left(e_i^d(w_i), e_{-i}^d(w_{-i}), p_i^d(w_i), p_{-i}^d(w_{-i})\right)$$
$$+ \left[p_{-i}^d(w_{-i}) - w_{-i}\right] q_{-i}\left(e_i^{dt}, e_{-i}^d(w_{-i}), p_i^{dt}, p_{-i}^d(w_{-i})\right) - \psi\left(e_{-i}^d(w_{-i})\right).$$

Noting that $e_i^d(w_i) = e_i^{dt}$ and $p_i^d(w_i) = p_i^{dt}$ in equilibrium and from (3) and (4) that $p_i^d(w_i) - w_i = -q_i/\left(\partial q_i/\partial p_i\right)$ and $\partial\psi(e_i)/\partial e_i = -q_i\left(\partial q_i/\partial e_i\right)/\left(\partial q_i/\partial p_i\right)$, the first-order condition for w_i can be written after some manipulation as

$$(w_i - c)\left(\frac{\partial q_i}{\partial e_i}\frac{de_i^d}{dw_i} + \frac{\partial q_i}{\partial p_i}\frac{dp_i^d}{dw_i}\right) + (w_{-i} - c)\left(\frac{\partial q_{-i}}{\partial e_i}\frac{de_i^d}{dw_i} + \frac{\partial q_{-i}}{\partial p_i}\frac{dp_i^d}{dw_i}\right) = 0. \tag{16}$$

As it is well established in the literature (e.g., Hart and Tirole 1990; McAfee and Schwartz 1994; O'Brien and Shaffer 1992, 1994; Rey and Tirole 2007; Rey and Vergé 2004), the opportunism problem under secret two-part tariffs (and passive beliefs) leads the manufacturer to set the wholesale price at the marginal cost of production in order to maximize the joint profits with each retailer, which can be extracted via the fixed fee.

5.2 Ban on input price discrimination

The retail price and the retail effort arising in the product market competition stage are still the same as those with linear tariffs, i.e., $p_i^b(w)$ and $e_i^b(w)$ identified by (6) and (7). The fixed fee fully extracts the retailers' profits, i.e., $f = \left[p_i^b(w) - w\right] q_i\left(e_i^b(w), e_{-i}^b(w), p_i^b(w), p_{-i}^b(w)\right) - \psi\left(e_i^b(w)\right)$ (which holds for $i \in \{1, 2\}$ as retailers are symmetric). Thus, manufacturer M sets the wholesale price w and the fixed fee f for each retailer R_i in order to maximize its profits $\Pi_M \triangleq (w - c)(q_i + q_{-i}) + 2f$ as follows

$$\max_{w} (w - c)\left[q_i\left(e_i^b(w), e_{-i}^b(w), p_i^b(w), p_{-i}^b(w)\right) + q_{-i}\left(e_i^b(w), e_{-i}^b(w), p_i^b(w), p_{-i}^b(w)\right)\right]$$
$$+ \left[p_i^b(w) - w\right] q_i\left(e_i^b(w), e_{-i}^b(w), p_i^b(w), p_{-i}^b(w)\right) - \psi\left(e_i^b(w)\right)$$
$$+ \left[p_{-i}^b(w) - w\right] q_i\left(e_i^b(w), e_{-i}^b(w), p_i^b(w), p_{-i}^b(w)\right) - \psi\left(e_{-i}^b(w)\right).$$

As (6) and (7) imply $p_i^b(w) - w = -q_i/\left(\partial q_i/\partial p_i\right)$ and $\partial\psi(e_i)/\partial e_i = -q_i\left(\partial q_i/\partial e_i\right)/\left(\partial q_i/\partial p_i\right)$, the first-order condition for w can be written after some manipulation as

$$(w - c)\sum_{i=1}^{2}\left(\frac{\partial q_i}{\partial e_i}\frac{de_i^b}{dw} + \frac{\partial q_i}{\partial e_{-i}}\frac{de_{-i}^b}{dw} + \frac{\partial q_i}{\partial p_i}\frac{dp_i^b}{dw} + \frac{\partial q_i}{\partial p_{-i}}\frac{dp_{-i}^b}{dw}\right)$$
$$-\sum_{i=1}^{2}\left[\frac{q_i}{\partial q_i/\partial p_i}\left(\frac{\partial q_i}{\partial e_{-i}}\frac{de_{-i}^b}{dw} + \frac{\partial q_i}{\partial p_{-i}}\frac{dp_{-i}^b}{dw}\right)\right] = 0, \tag{17}$$

which determines the equilibrium wholesale price under a ban on input price discrimination with two-part tariffs.

5.3 Comparison between regimes

In light of the results in Sections 5.1 and 5.2, we can now compare the regimes of input price discrimination and ban on input price discrimination. Differently from the case of linear tariffs, the comparison between the two pricing regimes relies upon the sign of the rate at which the retailer's quantity varies as a result of the rival's response to a change in the wholesale price under a ban on input price discrimination. Differentiating the retail quantity $q_i^b(w) \triangleq q_i\left(\cdot, e_{-i}^b(w), \cdot, p_{-i}^b(w)\right)$ with respect to the wholesale price w yields

$$\frac{\partial q_i^b}{\partial w} = \frac{\partial q_i}{\partial e_{-i}} \frac{de_{-i}^b}{dw} + \frac{\partial q_i}{\partial p_{-i}} \frac{dp_{-i}^b}{dw}. \tag{18}$$

The expression in (18) captures the variation in the retailer's quantity driven by the rival's response to a change in the wholesale price, defined as the *cross pass-through rate of input price to retail quantity*, under a ban on input price discrimination. This corresponds to the components of the aggregate pass-through rate of input price to retail quantity in (9) stemming from the rival's effort and price adjustments under a ban on input price discrimination. Comparing the two pricing regimes, we find the following results.

Proposition 4 *Suppose that vertical contracts consist of two-part tariffs. Then,*

(*i*) *input price discrimination yields (a) a lower wholesale price, (b) a lower retail price, (c) a higher retail effort, (d) a higher retail quantity, if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive — i.e., (a)* $w^{dt} < w^{bt}$, *(b)* $p^{dt} < p^{bt}$, *(c)* $e^{dt} > e^{bt}$, *(d)* $q^{dt} > q^{bt}$, *if* $\partial q_i^b / \partial w > 0$;

(*ii*) *a ban on input price discrimination yields (a) a lower wholesale price, (b) a lower retail price, (c) a higher retail effort, (d) a higher retail quantity, if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is negative — i.e., (a)* $w^{bt} < w^{dt}$, *(b)* $p^{bt} < p^{dt}$, *(c)* $e^{bt} > e^{dt}$, *(d)* $q^{bt} > q^{dt}$, *if* $\partial q_i^b / \partial w < 0$.

Under two-part tariffs, the comparison between the two pricing regimes hinges no longer upon the magnitude of the aggregate pass-through rates of input price to retail quantity under the two regimes, i.e., dq_i^r/dw for $r \in \{b, d\}$ in (9), but only upon the sign of the pass-through components associated with the rival's effort and price under a ban on input price discrimination, i.e., $\partial q_i^b / \partial w$ in (18). To substantiate the rationale behind this result, it is helpful to realize that, under two-part tariffs, the manufacturer internalizes through the fixed fee the retailer's effort and price adjustments to a change in the wholesale price, irrespective of the pricing regime. Under a ban on input price discrimination, each retailer anticipates the demand variation driven by the rival's response to a higher wholesale price, which affects its own profits and thus the fixed fee that it is willing to pay. When the demand variation is positive, i.e., $\partial q_i^b / \partial w > 0$, the retailer expects higher profits under a ban on input price discrimination in response to a rise in the wholesale price with respect to input price discrimination. This allows the manufacturer to charge a higher fixed fee and exacerbates the manufacturer's incentives to inflate the wholesale price. Consequently, the manufacturer sets a lower wholesale price under input price discrimination, which leads to a lower retail price and higher levels of retail effort and quantity, as established in point (i) of Proposition 4. By the same token, we find from point

(ii) of Proposition 4 that the opposite occurs when the demand variation driven by the rival's response to a higher wholesale price is negative, i.e., $\partial q_i^b/\partial w < 0$. In this case, banning input price discrimination pushes the wholesale price below the marginal cost of production, which is the level of the wholesale price under input price discrimination.

We obtain the following welfare findings.

Proposition 5 *Suppose that vertical contracts consist of two-part tariffs. Then,*

(i) input price discrimination enhances consumer surplus and total welfare if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive — i.e., $CS^{dt} > CS^{bt}$ *and* $TW^{dt} > TW^{bt}$ *if* $\partial q_i^b/\partial w > 0$*;*

(ii) a ban on input price discrimination enhances consumer surplus and total welfare if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is negative — i.e., $CS^{bt} > CS^{dt}$ *and* $TW^{bt} > TW^{dt}$ *if* $\partial q_i^b/\partial w < 0$.

The results in Proposition 5 share the same rationale as those in Proposition 2 for the case of linear tariffs, with the main difference that, under two-part tariffs, the welfare comparison between the two pricing regimes depends on the sign of the cross pass-through rate of input price to retail quantity under a ban on input price discrimination in (18). In light of the results in Proposition 4, we find from Proposition 5 that consumers benefit from discriminatory pricing if and only if $\partial q_i^b/\partial w > 0$. The manufacturer gains from banning input price discrimination that removes the opportunism problem. The retailers are clearly indifferent between the two pricing regimes because their profits are fully extracted through the fixed fee. The pricing regime with higher consumer surplus improves allocative efficiency and thus makes society as a whole better off as well.

As for the case of linear tariffs, we now identify the forces behind the results in Propositions 4 and 5 by exploring the sign of the cross pass-through rate of input price to retail quantity under a ban on input price discrimination in (18). To this aim, we consider the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. This yields the following results.

Proposition 6 *There exists a threshold* $\widehat{\sigma} > 0$ *for retail effort spillovers* σ *such that*

(i) if $\sigma < \widehat{\sigma}$*, the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive — i.e.,* $\partial q_i^b/\partial w > 0$*;*

(ii) if $\sigma > \widehat{\sigma}$*, the cross pass-through rate of input price to retail quantity under a ban input price discrimination is negative — i.e.,* $\partial q_i^b/\partial w < 0$.

We find from the demand function in (2) and the results in Lemma 2 that the impact of a change in the wholesale price on the retailer's quantity through the rival's effort, captured by the first term in (18), is positive if and only if retail effort spillovers are lower than the degree of product differentiation (i.e., $\sigma < \gamma$). In this case, a lower effort provided by the rival in response to a higher wholesale price stimulates the retailer's demand in (2). Under product substitutability (i.e., $\gamma > 0$), the impact of a change in the wholesale price on the retailer's quantity through the rival's price, measured by the second term in (18), is unambiguously positive. This implies that there exists a threshold $\widehat{\sigma} > 0$ for retail effort spillovers σ such that, for $\sigma < \widehat{\sigma}$, the cross pass-through rate of input price to retail quantity under a ban on input price discrimination in (18) is positive, i.e., $\partial q_i^b/\partial w > 0$, as established in point (i) of Proposition 6. The opposite occurs when retail effort spillovers are sufficiently pronounced, i.e., $\sigma > \widehat{\sigma}$, which is formalized in point (ii) of Proposition 6. It is worth noting from Lemma 3 and Proposition 6 that the pass-through rate of input price to retail price is higher under a ban on input price discrimination, i.e., $dp_i^b/dw > dp_i^d/dw$, if and only if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive, i.e., $\partial q_i^b/\partial w > 0$. Anticipating the demand variation driven by the rival's response to a higher wholesale price, each retailer prefers to pass through a higher wholesale price into the retail price more extensively than under discriminatory pricing, i.e., $dp_i^b/dw > dp_i^d/dw$, if and only if the demand variation is positive, i.e., $\partial q_i^b/\partial w > 0$, because this mitigates the fall in demand due to a higher wholesale price. Combining the results in Propositions 4 through 6, we find that, if retail effort spillovers are lower than a certain threshold, i.e., $\sigma < \widehat{\sigma}$, the results in point (i) of Propositions 4 and 5 apply. Otherwise, the results in point (ii) of Propositions 4 and 5 emerge. It is interesting to note that the contractual structure significantly affects the impact of demand interdependence on the comparison between the two pricing regimes. In particular, combining the results in Propositions 1 through 6, we find that, if retail effort spillovers are above a certain threshold, i.e., $\sigma > \widehat{\sigma}$, input price discrimination is more desirable under linear tariffs but the opposite occurs under two-part tariffs.

6 Cost pass-through

In light of the results in Sections 4 and 5, we now show that the welfare superiority of a pricing regime relates to on the rate at which a change in the cost of production is passed through into the wholesale price or, alternatively, into the retail price, regardless of whether linear tariffs or two-part tariffs are adopted. Given the pricing regime $r \in \{b, d\}$ and the contractual structure $s \in \{l, t\}$, we denote by dw^{rs}/dc the *pass-through rate of production cost to input price* and by dp^{rs}/dc *the pass-through rate of production cost to retail price.* We obtain the following results.

Proposition 7 *Irrespective of whether vertical contracts consist of linear tariffs or two-part tariffs,*

(i) input price discrimination enhances consumer surplus and total welfare if it generates a higher pass-through rate of production cost to input price or, alternatively, to retail price — i.e., $CS^{ds} > CS^{bs}$ *and* $TW^{ds} > TW^{bs}$ *if* $dw^{ds}/dc > dw^{bs}/dc$ *or, alternatively, if* $dp^{ds}/dc > dp^{bs}/dc$*, for* $s \in \{l, t\}$*;*

(ii) a ban on input price discrimination enhances consumer surplus and total welfare if it generates a higher pass-through rate of production cost to input price or, alternatively, to retail price — i.e., $CS^{bs} > CS^{ds}$ *and* $TW^{bs} > TW^{ds}$ *if* $dw^{bs}/dc > dw^{ds}/dc$ *or, alternatively, if* $dp^{bs}/dc > dp^{ds}/dc$*, for* $s \in \{l, t\}$*.*

Proposition 7 shows that input price discrimination is welfare superior if and only if a change in the cost of production has a larger impact on the wholesale price or, alternatively, on the retail price with respect to a ban on input price discrimination. To understand the rationale for this apparently counterintuitive result, it is worth noting that, when facing a higher cost of production, the manufacturer prefers to reduce the retail quantity through a rise in the wholesale price. With linear tariffs, the manufacturer chooses a higher pass-through rate of production cost to input price under the pricing regime r that exhibits a more pronounced aggregate pass-through rate of input price to retail quantity in (9), i.e., $|dq_i^r/dw| > |dq_i^{-r}/dw|$, for $r, -r \in \{b, d\}$ and $r \neq -r$. A higher sensitivity of the retail quantity to the wholesale price under the pricing regime r leads to a more significant reduction in the retail quantity in response to a rise in the wholesale price, which engenders larger savings in production costs and thus makes the manufacturer better off. Intuitively, each retailer's reaction implies a higher pass-through rate of production cost to retail price under the same pricing regime r. Recall from Proposition 2 that the pricing regime r improves consumer surplus and total welfare if and only $|dq_i^r/dw| > |dq_i^{-r}/dw|$, for $r, -r \in \{b, d\}$ and $r \neq -r$. Consequently, discriminatory pricing is welfare superior if and only if it leads to a higher cost pass-through. With two-part tariffs, as discussed in Section 5.3, the manufacturer internalizes through the fixed fee the retailer's effort and price adjustments to a change in the wholesale price, irrespective of the pricing regime. Under a ban on input price discrimination, the retailer anticipates the demand variation driven by the rival's response to a higher wholesale price. This alleviates the manufacturer's incentives to pass through a higher cost of production into the wholesale price if and only if the demand variation is positive or, equivalently, the cross pass-through rate of input price to retail quantity under a ban on input price discrimination in (18) is positive, i.e., $\partial q_i^b/\partial w > 0$. A positive demand variation leads each retailer to anticipate higher profits that can be extracted by the manufacturer through the fixed fee and thus makes less attractive for the manufacturer to inflate the wholesale price in order to reduce the retail quantity. In this case, the pass-through rates of production cost to input price and to retail price are higher under discriminatory pricing. We know from Proposition 5 that discriminatory pricing improves consumer surplus and total welfare if and only if $\partial q_i^b/\partial w > 0$. Thus, discriminatory pricing is welfare superior if and only it leads to a higher cost pass-through, as in the case of linear tariffs.

7 Robustness and extensions

Our results can be extended in different directions. The formal proofs of our descriptive claims are collected in the Supplementary Appendix.

Wary beliefs. As discussed in Section 3, under input price discrimination we adopt the standard equilibrium refinement of passive beliefs, whereby a retailer expects the manufacturer to stick to the equilibrium offers to the competing retailers upon receiving an out-of-equilibrium offer. In addition to the analytical tractability, a common justification for passive beliefs is that the manufacturer resorts to partner-specific agents that simultaneously and independently negotiate with each retailer on the manufacturer's behalf (e.g., Bisceglia et al. 2021; Gabrielsen and Johansen 2017; Rey and Vergé 2020). Unfortunately, as shown by Rey and Vergé (2004) for the case of two-part tariffs, a perfect equilibrium with passive beliefs may fail to exist for some parameter constellations because the interdependence between the contracts offered to the retailers may render the candidate equilibrium vulnerable to multilateral deviations, where the manufacturer revises its offers and simultaneously deviates with the retailers. Furthermore, passive beliefs prevent the retailers from anticipating such contractual interdependence. Gaudin (2019) finds that the equilibrium existence issue is less severe with linear tariffs.[8]

To show the robustness of our results, we extend the analysis to the case where retailers hold 'wary beliefs' under input price discrimination, according to which a retailer facing an unexpected offer believes that the manufacturer would adjust its offers to the competing retailers in order to maximize its own profits (e.g., Gaudin 2019; McAfee and Schwartz 1994; Rey and Vergé 2004). This makes wary beliefs more suitable than passive beliefs to accommodate for the manufacturer's incentives for multilateral deviations. Irrespective of the contractual structure, our results qualitatively carry over to the case of wary beliefs. In particular, with linear tariffs, input price discrimination leads to a lower wholesale price and thus enhances welfare if and only it increases the (absolute) magnitude of the pass-through rate of input price to retail quantity. Interestingly, with two-part tariffs, we show that wary beliefs give rise to a cross pass-through rate of input price to retail quantity also under input price discrimination. This captures the variation in the retailer's quantity driven by the rival's response to a change in the wholesale price that the retailer believes to be offered to the rival as a result of a change in its own wholesale price.[9] Following the intuition provided in the main analysis, input price discrimination leads to a lower wholesale price and thus improves welfare if and only if it generates a lower cross pass-through rate of input price to retail quantity. In this case the retailer expects lower profits from an increase in the wholesale price with respect to a ban on input price discrimination, which can be extracted by the manufacturer through the fixed fee, thereby alleviating the manufacturer's incentives to raise the wholesale price. As in the baseline model, we also find that the pricing regime with a higher cost pass-through is welfare superior, irrespective of the contractual structure. Our results in terms of retail effort spillovers and product differentiation are robust to wary beliefs. Notably, in line with the insights of Gaudin (2019) for linear tariffs and Rey and Vergé (2004) for two-part tariffs, the departure from a ban on input price discrimination is smaller under wary beliefs than under passive beliefs if and only if under wary beliefs the retailer believes that a change in its own wholesale price will affect positively the wholesale price of the competitor. Thus, wary beliefs mitigate the manufacturer's opportunism problem if and only if this condition holds.

Quantity competition. Our analysis can be also generalized to the case where retailers engage in quantity competition.[10] Under linear tariffs, discriminatory pricing still reduces the wholesale price and thus enhances welfare if and only if it magnifies the pass-through rate of input price to retail quantity. Under two-part tariffs, the comparison between the pricing regimes relies upon the retail price impact that a retailer anticipates from the rival's response to a change in the wholesale price, referred to as the cross pass-through rate of input price to retail price, under a ban on input price discrimination. Specifically, discriminatory pricing is preferable if and only if the cross pass-through rate of input price to retail price under a ban on input price discrimination is positive. Following the intuition provided in the main analysis, in

[8]Notably, point (ii) of Assumption 1 ensures that the equilibrium resists multilateral deviations (e.g., Gaudin 2019; Rey and Vergé 2004).

[9]Note that this vanishes under passive beliefs because a retailer does not revise its beliefs about the equilibrium offer to the rival upon receiving an out-of-equilibrium offer.

[10]As it is well established in the literature (e.g., Gaudin 2019; Hart and Tirole 1990; Rey and Vergé 2004), passive beliefs are equivalent to wary beliefs in our framework with quantity competition.

this case the retailer anticipates higher profits from a rise in the wholesale price under a ban on input price discrimination, which can be captured by the manufacturer via the fixed fee. This makes the manufacturer more eager to inflate the wholesale price under a ban on input price discrimination. Interestingly, the condition for the comparison between the pricing regimes under linear tariffs coincides with the one under two-part tariffs. When retailers compete in a Cournot fashion, the contracts offered to the retailers under input price discrimination affect the manufacturer's profits in a separable manner. Thus, irrespective of the contractual structure, the manufacturer is more reluctant to increase the wholesale price with respect to a ban on input price discrimination exactly when the retailer's quantity reduction in response to a rise in the wholesale price is larger. A positive cross pass-through rate of input price to retail price under a ban on input price discrimination mitigates the retailer's incentives to curb its quantity vis-à-vis a higher wholesale price with respect to input price discrimination. This occurs when retail effort spillovers are positive but relatively small or, a fortiori, negative. The idea is that a higher wholesale price discourages the rival's effort and thus inflates the retailer's price as long as retail effort spillovers are negative. Furthermore, a higher wholesale price depresses the rival's quantity and thus stimulates the retailer's price with substitutable goods. Hence, input price discrimination is more desirable if and only if retail effort spillovers are below a certain threshold. Our results about the role of cost pass-through also apply to quantity competition between retailers.

8 Concluding remarks

In light of the common adoption of price discrimination practices in vertically related markets, we investigate their economic effects in a framework where a manufacturer engages in secret contracting with two retailers that sell differentiated products and conduct noncontractible, demand-enhancing activities with retail effort spillovers. We identify the role of pass-through as a key driver for the impact of discriminatory pricing on market outcomes and welfare under different contractual structures. Specifically, we show that, with linear tariffs, input price discrimination leads to a lower wholesale price than a ban on input price discrimination if and only if it amplifies the pass-through rate of input price to retail quantity, which captures the total responsiveness of the retail quantity to a change in the wholesale price. In this case, each retailer charges a lower price and provides higher levels of effort and quantity, thereby benefiting consumers and society as a whole. The comparison between the pass-through rates of input price to retail quantity under the two pricing regimes crucially depends on the trade-off between two opposite effects — referred to as the retail effort effect and the retail price effect — involving retail effort spillovers and the degree of production differentiation. With two-part tariffs, we find that input price discrimination is preferable if and only if the cross pass-through rate of input price to retail quantity under a ban on input price discrimination is positive, which represents the variation in the retailer's quantity driven by the rival's response to a change in the wholesale price. Irrespective of the contractual structure, we establish the welfare superiority of the pricing regime under which the input cost of production is passed through into the wholesale price or, alternatively, into the retail price more extensively.

Our results exhibit some potentially significant implications for antitrust policy. Specifically, our analysis delivers novel insights into the role of pass-through for the antitrust treatment of input price discrimination, which can help antitrust authorities with the design of empirically testable instruments in order to comprehensively assess the economic consequences of discriminatory pricing. This seems particularly relevant in light of the current US antitrust approach to input price discrimination that reflects a judicial movement toward a welfare standard, as discussed in the introduction. Remarkably, in our model retailers compete to a different extent depending on the degree of product differentiation and engage in promotional activities that generate externalities with different sign and magnitude. This makes our framework flexible enough to capture some relevant features of the US antitrust treatment of input price discrimination, which requires the proof of actual competition between retailers and substantial competitive injury, according to a recent opinion of the US Supreme Court that overruled the decision of a lower court.[11] As banning input price discrimination makes contracting de facto public, our results can also substantiate the antitrust authorities' stance on information exchange between firms in vertically related markets.

Appendix

Proof of Proposition 1. Substituting the first-order condition (5) into the left-hand side of the first-order condition (8), we find after some manipulations that $w^{dl} < w^{bl}$ if and only if $\left|dq_i^d/dw\right| > \left|dq_i^b/dw\right|$, where dq_i^r/dw for $r \in \{b, d\}$ is given by (9) and $dq_i^r/dw < 0$ by Assumption 1 (upstream second-order conditions). It follows from $dq_i^r/dw < 0$ that $q^{dl} > q^{bl}$ if and only if $w^{dl} < w^{bl}$. Using $\partial p_i(\cdot)/\partial q_i < 0$, we have $p^{dl} < p^{bl}$ if and only if $w^{dl} < w^{bl}$.[12] Furthermore, we find from $de_i^r/dw < 0$ (otherwise $dq_i^r/de_i > 0$ would imply $dq_i^r/dw \geq 0$, which contradicts $dq_i^r/dw < 0$) that $e^{dl} > e^{bl}$ if and only if $w^{dl} < w^{bl}$.

We now derive the equilibrium values for the wholesale price, the retail price, the retail effort and the retail quantity under each pricing regime for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. We first consider input price discrimination. Using (3) and (4), we obtain

$$p_i^d(w_i) = \frac{2\left(1-\gamma^2\right)\left[\alpha(1-\gamma) + (\sigma-\gamma)e_{-i}^{dl} + \gamma p_{-i}^{dl}\right] + \left[1 + 2\gamma\sigma - \gamma^2\left(2+\sigma^2\right)\right]w_i}{3 + 2\gamma\sigma - \gamma^2\left(4+\sigma^2\right)} \tag{A1}$$

and

$$e_i^d(w_i) = \frac{(1-\gamma\sigma)\left[\alpha(1-\gamma) + (\sigma-\gamma)e_{-i}^{dl} + \gamma p_{-i}^{dl} - w_i\right]}{3 + 2\gamma\sigma - \gamma^2\left(4+\sigma^2\right)}. \tag{A2}$$

Noting that $e_{-i}^d(w_{-i}) = e_{-i}^{dl}$ and $p_{-i}^d(w_{-i}) = p_{-i}^{dl}$ in equilibrium and substituting (A1) and

[11] The US Supreme Court opinion is 'Volvo Trucks North America, Inc. v. Reeder-Simco GMC, Inc.' (546, US 164, 2006). We refer to the introduction for further details about this case.

[12] Given that $p_i(\cdot)$ is also affected by the retail effort, $\partial p_i(\cdot)/\partial q_i < 0$ might not ensure that $p^{dl} < p^{bl}$ if and only if $w^{dl} < w^{bl}$ for some formulations of the retail cost of effort. As shown below, we find that $p^{dl} < p^{bl}$ if and only if $w^{dl} < w^{bl}$ for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. Notably, as consumer surplus and total welfare depend ultimately on the retail quantity only, our welfare findings are unchanged.

(A2) into (2) yields

$$q_i\left(\cdot, e^d_{-i}(w_{-i}), \cdot, p^d_{-i}(w_{-i})\right) = \frac{2\left[\alpha(1-\gamma) + (\sigma-\gamma)e^d_{-i}(w_{-i}) + \gamma p^d_{-i}(w_{-i}) - w_i\right]}{3 + 2\gamma\sigma - \gamma^2(4+\sigma^2)} \tag{A3}$$

and

$$\begin{aligned} q_{-i}\left(\cdot, e^d_{-i}(w_{-i}), \cdot, p^d_{-i}(w_{-i})\right) &= \frac{\alpha\left[3+\sigma-\gamma\left(2+2\gamma-\sigma+\sigma^2\right)\right] + \left(2\gamma-\sigma+\gamma\sigma^2\right)w_i}{3+2\gamma\sigma-\gamma^2(4+\sigma^2)} \\ &+ \frac{\left[3+\sigma^2-2\gamma^2-\gamma\sigma\left(1+\sigma^2\right)\right]e^d_{-i}(w_{-i}) - \left(3-2\gamma^2+\gamma\sigma\right)p^d_{-i}(w_{-i})}{3+2\gamma\sigma-\gamma^2(4+\sigma^2)}. \end{aligned} \tag{A4}$$

The first-order condition for w_i in (5) for manufacturer M's profit maximization problem becomes

$$\frac{2\alpha(1-\gamma) + c\left[2+\sigma-\gamma\left(2+\sigma^2\right)\right] + 2(\sigma-\gamma)e^d_{-i}(w_{-i}) + 2\gamma p^d_{-i}(w_{-i}) - 4w_i + \left(2\gamma-\sigma+\gamma\sigma^2\right)w_{-i}}{3+2\gamma\sigma-\gamma^2(4+\sigma^2)} = 0. \tag{A5}$$

Solving the system of (A1), (A2) and (A5) yields the wholesale price, the retail price and the retail effort in equilibrium under input price discrimination with linear tariffs. The equilibrium wholesale price is given by

$$w^{dl} = \frac{\alpha\left[6+4\gamma\sigma-2\gamma^2\left(4+\sigma^2\right)\right] + \left[2+\sigma-\gamma\left(2+\sigma^2\right)\right]\left[3-\sigma+\gamma\left(2-2\gamma+\sigma+\sigma^2\right)\right]c}{(4-\sigma)(3+\sigma)+2\gamma^3(2+\sigma^2)-2\gamma(1-5\sigma-\sigma^3)-\gamma^2[16+\sigma(4+6\sigma+\sigma^2+\sigma^3)]}. \tag{A6}$$

The equilibrium retail price is

$$\begin{aligned} p^{dl} &= \frac{2\alpha\left[5+\sigma-\gamma\left(2-2\sigma+\sigma^2-2\gamma^2-\gamma^2\sigma^2+6\gamma+\gamma\sigma+\gamma\sigma^2\right)\right]}{(4-\sigma)(3+\sigma)+2\gamma^3(2+\sigma^2)-2\gamma(1-5\sigma-\sigma^3)-\gamma^2[16+\sigma(4+6\sigma+\sigma^2+\sigma^3)]} \\ &+ \frac{\left[2+\sigma-\gamma\left(2+\sigma^2\right)\right]\left[1-\sigma+\gamma\left(2+\sigma+\sigma^2\right)\right]c}{(4-\sigma)(3+\sigma)+2\gamma^3(2+\sigma^2)-2\gamma(1-5\sigma-\sigma^3)-\gamma^2[16+\sigma(4+6\sigma+\sigma^2+\sigma^3)]}. \end{aligned} \tag{A7}$$

The equilibrium retail effort is

$$e^{dl} = \frac{(\alpha-c)(1-\gamma\sigma)\left[2+\sigma-\gamma\left(2+\sigma^2\right)\right]}{(4-\sigma)(3+\sigma)+2\gamma^3(2+\sigma^2)-2\gamma(1-5\sigma-\sigma^3)-\gamma^2[16+\sigma(4+6\sigma+\sigma^2+\sigma^3)]}. \tag{A8}$$

Substituting (A7) and (A8) into (2), the equilibrium retail quantity is

$$q^{dl} = \frac{2(\alpha-c)\left[2+\sigma-\gamma\left(2+\sigma^2\right)\right]}{(4-\sigma)(3+\sigma)+2\gamma^3(2+\sigma^2)-2\gamma(1-5\sigma-\sigma^3)-\gamma^2[16+\sigma(4+6\sigma+\sigma^2+\sigma^3)]}. \tag{A9}$$

Now, we turn to a ban on input price discrimination. Using (6) and (7), we obtain

$$p^b_i(w) = \frac{2\alpha\left(1-\gamma^2\right) + \left[1-\sigma+\gamma\left(2+\sigma+\sigma^2\right)\right]w}{3-2\gamma^2-\sigma+\gamma(2+\sigma+\sigma^2)} \tag{A10}$$

and

$$e^b_i(w) = \frac{(1-\gamma\sigma)(\alpha-w)}{3-2\gamma^2-\sigma+\gamma(2+\sigma+\sigma^2)}. \tag{A11}$$

Substituting (A10) and (A11) into (2) yields

$$q_i(w) = \frac{2(\alpha - w)}{3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)}. \tag{A12}$$

The first-order condition for w in (8) for manufacturer M's profit maximization problem becomes

$$\frac{4(\alpha + c - 2w)}{3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)} = 0.$$

Then, the equilibrium wholesale price under a ban on input price discrimination with linear tariffs is given by

$$w^{bl} = \frac{\alpha + c}{2}. \tag{A13}$$

Substituting (A13) into (A10), the equilibrium retail price is

$$p^{bl} = \frac{\alpha\left[5 - 4\gamma^2 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)\right] + \left[1 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)\right]c}{2\left[3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)\right]}. \tag{A14}$$

Substituting (A13) into (A11), the equilibrium retail effort is

$$e^{bl} = \frac{(\alpha - c)(1 - \gamma\sigma)}{2\left[3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)\right]}. \tag{A15}$$

Substituting (A13) into (A12), the equilibrium retail quantity is

$$q^{bl} = \frac{\alpha - c}{3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)}. \quad \blacksquare \tag{A16}$$

Proof of Proposition 2. As consumer surplus (net of consumer expenditure) increases with the retail quantity, it holds $CS^{dl} > CS^{bl}$ if and only if $q^{dl} > q^{bl}$. Furthermore, as total welfare (defined as the sum of consumer surplus and total profits) also increases with the retail quantity (up to the socially optimal quantity), it holds $TW^{dl} > TW^{bl}$ if and only if $q^{dl} > q^{bl}$. The results in the proposition follow from Proposition 1.

We now derive the equilibrium values for consumer surplus and total welfare under each pricing regime for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. To compute the expression for consumer surplus, consider a continuum of consumers characterized by a quasi-linear utility function of the form

$$\Psi(q_1, q_2, y) = V(q_1, q_2) + y, \tag{A17}$$

where y denotes the composite good. The consumer maximization problem is

$$\max_{\{q_1, q_2, y\}} V(q_1, q_2) + y$$

subject to the budget constraint $\sum_{i=1}^{2} p_i q_i + p_y y \leq I$, where I is the income level and p_y is the price for the composite good. Constructing the Lagrangian function yields

$$\max_{\{q_1, q_2, y\}} V(q_1, q_2) + y - \lambda\left(\sum_{i=1}^{2} p_i q_i + p_y y - I\right),$$

where $\lambda \geq 0$ is the Lagrange multiplier. Taking the first-order conditions for q_i and y and treating y as the numéraire ($p_y = 1$) yields $\frac{\partial V}{\partial q_i} = p_i$, for $i \in \{1, 2\}$. Consumer surplus is equal to the consumer utility $\Psi(\cdot)$ in (A17) net of consumer expenditure $\sum_{i=1}^{2} p_i q_i$ (ignoring y without any loss of generality). Using (1) and integrating $\frac{\partial V}{\partial q_i} = p_i$ (where the constant of integration is ignored without any loss of generality), we find that consumer surplus is defined as

$$CS \triangleq \alpha \sum_{i=1}^{2} q_i + \sum_{i=1}^{2} q_i (e_i + \sigma e_{-i}) - \frac{1}{2} \sum_{i=1}^{2} q_i^2 - \gamma q_i q_{-i} - \sum_{i=1}^{2} p_i q_i. \tag{A18}$$

Substituting (A7), (A8) and (A9) into (A18), we obtain that the equilibrium consumer surplus under input price discrimination with linear tariffs amounts to

$$CS^{dl} = \frac{4(\alpha - c)^2 (1 + \gamma) \left[2 + \sigma - \gamma \left(2 + \sigma^2\right)\right]^2}{\{(4 - \sigma)(3 + \sigma) + 2\gamma^3 (2 + \sigma^2) - 2\gamma (1 - 5\sigma - \sigma^3) - \gamma^2 [16 + \sigma (4 + 6\sigma + \sigma^2 + \sigma^3)]\}^2}. \tag{A19}$$

Substituting (A6) and (A9) into $\Pi_M \triangleq (w_i - c) q_i + (w_{-i} - c) q_{-i}$, the equilibrium manufacturer M's profits are

$$\Pi_M^{dl} = \frac{8(\alpha - c)^2 \left[2 + \sigma - \gamma \left(2 + \sigma^2\right)\right] \left[3 + 2\gamma\sigma - \gamma^2 \left(4 + \sigma^2\right)\right]}{\{(4 - \sigma)(3 + \sigma) + 2\gamma^3 (2 + \sigma^2) - 2\gamma (1 - 5\sigma - \sigma^3) - \gamma^2 [16 + \sigma (4 + 6\sigma + \sigma^2 + \sigma^3)]\}^2}.$$

Substituting (A6), (A7), (A8) and (A9) into $\Pi_{R_i} \triangleq (p_i - w_i) q_i - \psi(e_i)$, the equilibrium retailer R_i's profits are

$$\Pi_R^{dl} = \frac{(\alpha - c)^2 \left[2 + \sigma - \gamma \left(2 + \sigma^2\right)\right]^2 \left[3 + 2\gamma\sigma - \gamma^2 \left(4 + \sigma^2\right)\right]}{\{(4 - \sigma)(3 + \sigma) + 2\gamma^3 (2 + \sigma^2) - 2\gamma (1 - 5\sigma - \sigma^3) - \gamma^2 [16 + \sigma (4 + 6\sigma + \sigma^2 + \sigma^3)]\}^2}.$$

Given $TW \triangleq CS + \Pi_M + \sum_{i=1}^{2} \Pi_{R_i}$, the equilibrium total welfare amounts to

$$\begin{aligned} TW^{dl} = &\frac{2(\alpha - c)^2 \left[2 + \sigma - \gamma \left(2 + \sigma^2\right)\right]}{\{(4 - \sigma)(3 + \sigma) + 2\gamma^3 (2 + \sigma^2) - 2\gamma (1 - 5\sigma - \sigma^3) - \gamma^2 [16 + \sigma (4 + 6\sigma + \sigma^2 + \sigma^3)]\}^2} \\ &\times \left\{22 + 5\sigma - \gamma \left[6 - 14\sigma + 3\sigma^2 - \gamma^2 \left(8 + 6\sigma^2 + \sigma^4\right) + \gamma \left(28 + 8\sigma + 8\sigma^2 + 3\sigma^3\right)\right]\right\}. \end{aligned} \tag{A20}$$

Substituting (A14), (A15) and (A16) into (A18), we find that the equilibrium consumer surplus under a ban on input price discrimination with linear tariffs amounts to

$$CS^{bl} = \frac{(\alpha - c)^2 (1 + \gamma)}{[3 - 2\gamma^2 - \sigma + \gamma (2 + \sigma + \sigma^2)]^2}. \tag{A21}$$

Substituting (A13) and (A16) into $\Pi_M \triangleq (w - c)(q_i + q_{-i})$, the equilibrium manufacturer M's profits are

$$\Pi_M^{bl} = \frac{(\alpha - c)^2}{3 - 2\gamma^2 - \sigma + \gamma (2 + \sigma + \sigma^2)}.$$

Substituting (A13), (A14), (A15) and (A16) into $\Pi_{R_i} \triangleq (p_i - w) q_i - \psi(e_i)$, the equilibrium retailer R_i's profits are

$$\Pi_R^{bl} = \frac{(\alpha - c)^2 \left[3 + 2\gamma\sigma - \gamma^2 \left(4 + \sigma^2\right)\right]}{4 [3 - 2\gamma^2 - \sigma + \gamma (2 + \sigma + \sigma^2)]^2}.$$

Given $TW \triangleq CS + \Pi_M + \sum_{i=1}^{2} \Pi_{R_i}$, the equilibrium total welfare amounts to

$$TW^{bl} = \frac{(\alpha - c)^2 \left[11 - 2\sigma + \gamma \left(6 + 4\sigma + 2\sigma^2 - 8\gamma - \gamma\sigma^2\right)\right]}{2\left[3 - 2\gamma^2 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)\right]^2}. \quad \blacksquare \tag{A22}$$

Proof of Lemma 1. Taking the derivative of $p_i^b(w_i)$ in (A1) and of $e_i^b(w_i)$ in (A2) with respect to w_i (and imposing $w_i = w$ without any loss of generality) yields respectively

$$\frac{dp_i^d}{dw} = \frac{1 + 2\gamma\sigma - \gamma^2\left(2 + \sigma^2\right)}{3 + 2\gamma\sigma - \gamma^2\left(4 + \sigma^2\right)} \tag{A23}$$

and

$$\frac{de_i^d}{dw} = -\frac{1 - \gamma\sigma}{3 + 2\gamma\sigma - \gamma^2\left(4 + \sigma^2\right)}. \tag{A24}$$

It follows from Assumption 2 (downstream second-order conditions) that $\frac{dp_i^d}{dw} > 0$ if and only if $\gamma < \widetilde{\gamma}$, where $\widetilde{\gamma} \triangleq \frac{\sigma + \sqrt{2(1+\sigma^2)}}{2+\sigma^2} > 0$, and that $\frac{de_i^d}{dw} < 0$. $\blacksquare$

Proof of Lemma 2. Taking the derivative of $p_i^b(w)$ in (A10) and of $e_i^b(w)$ in (A11) with respect to w yields respectively

$$\frac{dp_i^b}{dw} = \frac{1 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)}{3 - 2\gamma^2 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)} \tag{A25}$$

and

$$\frac{de_i^b}{dw} = -\frac{1 - \gamma\sigma}{3 - 2\gamma^2 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)}. \tag{A26}$$

We find from Assumption 2 (downstream second-order conditions) that $\frac{dp_i^b}{dw} > 0$ and $\frac{de_i^b}{dw} < 0$. $\blacksquare$

Proof of Lemma 3. Using (A23), (A24), (A25) and (A26), we find that there exists a threshold $\widehat{\sigma} \triangleq \frac{1-\sqrt{1-8\gamma^2}}{2\gamma} > 0$ such that, if $\sigma < \widehat{\sigma}$, it holds $\frac{dp_i^b}{dw} > \frac{dp_i^d}{dw}$ and $\frac{de_i^b}{dw} > \frac{de_i^d}{dw}$. If $\sigma > \widehat{\sigma}$, it holds $\frac{dp_i^d}{dw} > \frac{dp_i^b}{dw}$ and $\frac{de_i^d}{dw} > \frac{de_i^b}{dw}$, where the inequalities follow from Assumption 2 (downstream second-order conditions). $\blacksquare$

Proof of Proposition 3. Using (2) and substituting (A23) and (A24) into (9) under input price discrimination yields

$$\frac{dq_i^d}{dw} = -\frac{2 + \sigma - \gamma\left(2 + \sigma^2\right)}{3 + 2\gamma\sigma - \gamma^2\left(4 + \sigma^2\right)} < 0, \tag{A27}$$

where the inequality follows from Assumption 1 (upstream second-order conditions). Using (2) and substituting (A25) and (A26) into (9) under a ban on input price discrimination yields

$$\frac{dq_i^b}{dw} = -\frac{2}{3 - 2\gamma^2 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)} < 0, \tag{A28}$$

where the inequality follows from Assumption 1 (upstream second-order conditions). We find from (A27) and (A28) that there exist a threshold $\widehat{\gamma} \triangleq \frac{1+\sigma}{4}\sigma + \frac{1}{4}\sqrt{8 - 8\sigma + \sigma^2 + 2\sigma^3 + \sigma^4} > 0$

and a threshold $\widehat{\sigma} > 0$ (defined in the proof of Lemma 3) such that, if $\gamma < \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$, it holds $\left|\frac{dq_i^b}{dw}\right| > \left|\frac{dq_i^d}{dw}\right|$. Otherwise, i.e., either if $\gamma > \widehat{\gamma}$ or if $\sigma > \widehat{\sigma}$, it holds $\left|\frac{dq_i^d}{dw}\right| > \left|\frac{dq_i^b}{dw}\right|$.

Using (A6), (A7), (A8), (A9), (A13), (A14), (A15) and (A16), we obtain that, if $\gamma < \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$ (where $\widehat{\gamma} > 0$ is defined above and $\widehat{\sigma} > 0$ is defined in the proof of Lemma 3), it holds (a) $w^{bl} < w^{dl}$, (b) $p^{bl} < p^{dl}$, (c) $e^{bl} > e^{dl}$, (d) $q^{bl} > q^{dl}$. Otherwise, i.e., either if $\gamma > \widehat{\gamma}$ or if $\sigma > \widehat{\sigma}$, it holds (a) $w^{dl} < w^{bl}$, (b) $p^{dl} < p^{bl}$, (c) $e^{dl} > e^{bl}$, (d) $q^{dl} > q^{bl}$. Combining these results with those in Proposition 3, we find that the results in Proposition 1 are corroborated for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. Furthermore, using (A19), (A20), (A21) and (A22), we obtain that, if $\gamma < \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$, it holds $CS^{bl} > CS^{dl}$ and $TW^{bl} > TW^{dl}$. Otherwise, i.e., either if $\gamma > \widehat{\gamma}$ or if $\sigma > \widehat{\sigma}$, it holds $CS^{dl} > CS^{bl}$ and $TW^{dl} > TW^{bl}$. Combining these results with those in Proposition 3, we find that the results in Proposition 2 are corroborated for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$.

Substituting (A24) and (A26) into (10) and substituting (A23) and (A25) into (11), we obtain from (2) and (13) that $\rho = \frac{(1+\sigma)(1-\gamma\sigma)}{2(1-\gamma^2)}$, which yields $\frac{\partial\rho}{\partial\gamma} = \frac{(1+\sigma)[\gamma(2-\gamma\sigma)-\sigma]}{2(1-\gamma^2)^2}$. If $\sigma < \widehat{\sigma}$ it holds $\frac{\partial\rho}{\partial\gamma} > 0$ for $\sigma \leq 0$ and it holds $\frac{\partial\rho}{\partial\gamma} > 0$ if and only if $\gamma > \frac{1-\sqrt{1-\sigma^2}}{\sigma}$ for $\sigma \in (0, \widehat{\sigma})$, whereas if $\sigma \geq \widehat{\sigma}$ it holds $\frac{\partial\rho}{\partial\gamma} < 0$. ■

Proof of Proposition 4. Substituting the first-order condition (16) into the left-hand side of the first-order condition (17), we find after some manipulations that $w^{dt} < w^{bt}$ if and only if $\partial q_i^b/\partial w > 0$, where $\partial q_i^b/\partial w$ is given by (18). Any other result in the proposition follows from the same approach adopted in the proof of Proposition 1.

We now derive the equilibrium values for the wholesale price, the retail price, the retail effort and the retail quantity under each pricing regime for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. We first consider input price discrimination. Using (A1), (A2), (A3) and (A4), where e_{-i}^{dl} and p_{-i}^{dl} are replaced by e_{-i}^{dt} and p_{-i}^{dt}, with $e_{-i}^{d}(w_{-i}) = e_{-i}^{dt}$ and $p_{-i}^{d}(w_{-i}) = p_{-i}^{dt}$ in equilibrium, the first-order condition for w_i in (16) for manufacturer M's profit maximization problem becomes

$$\frac{\left[2+\sigma-\gamma\left(2+\sigma^2\right)\right]c - 2w_i - \left[\sigma-\gamma\left(2+\sigma^2\right)\right]w_{-i}}{3+2\gamma\sigma-\gamma^2\left(4+\sigma^2\right)} = 0. \tag{A29}$$

Solving the system of (A1), (A2) and (A29), where e_{-i}^{dl} and p_{-i}^{dl} are replaced by e_{-i}^{dt} and p_{-i}^{dt}, with $e_{-i}^{d}(w_{-i}) = e_{-i}^{dt}$ and $p_{-i}^{d}(w_{-i}) = p_{-i}^{dt}$ in equilibrium, we obtain the wholesale price, the retail price and the retail effort in equilibrium under input price discrimination with two-part tariffs. The equilibrium wholesale price is given by

$$w^{dt} = c. \tag{A30}$$

The equilibrium retail price is

$$p^{dt} = c + \frac{2(\alpha-c)\left(1-\gamma^2\right)}{3-2\gamma^2-\sigma+\gamma\left(2+\sigma+\sigma^2\right)}. \tag{A31}$$

The equilibrium retail effort is

$$e^{dt} = \frac{(\alpha - c)(1 - \gamma\sigma)}{3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)}. \tag{A32}$$

Substituting (A31) and (A32) into (2), the equilibrium retail quantity is

$$q^{dt} = \frac{2(\alpha - c)}{3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)}. \tag{A33}$$

Now, we turn to a ban on input price discrimination. Using (A10), (A11) and (A12), the first-order condition for w in (17) for manufacturer M's profit maximization problem becomes

$$4\frac{4\alpha(1+\gamma)\left[\gamma\left(2+\sigma^2\right)-\sigma\right] + \left[3 - \sigma + \gamma\left(2 - 2\gamma + \sigma + \sigma^2\right)\right]c - \left[3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2\right]w}{\left[3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)\right]^2} = 0.$$

Then, the equilibrium wholesale price under a ban on input price discrimination with two-part tariffs is given by

$$w^{bt} = \frac{\alpha(1+\gamma)\left[\gamma\left(2+\sigma^2\right)-\sigma\right] + \left[3 - \sigma + \gamma\left(2 - 2\gamma + \sigma + \sigma^2\right)\right]c}{3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2}. \tag{A34}$$

Substituting (A34) into (A10), the equilibrium retail price is

$$p^{bt} = \frac{\alpha(1+\gamma)\left[2 - \sigma(1 - \gamma\sigma)\right] + \left[1 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)\right]c}{3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2}. \tag{A35}$$

Substituting (A34) into (A11), the equilibrium retail effort is

$$e^{bt} = \frac{(\alpha - c)(1 - \gamma\sigma)}{3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2}. \tag{A36}$$

Substituting (A34) into (A12), the equilibrium retail quantity is

$$q^{bt} = \frac{2(\alpha - c)}{3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2}. \quad \blacksquare \tag{A37}$$

Proof of Proposition 5. The results in the proposition follow from the same approach adopted in the proof of Proposition 2.

We now derive the equilibrium values for consumer surplus and total welfare under each pricing regime for the demand function in (1) and retail cost of effort $\psi(e_i) = e_i^2$. We first consider input price discrimination. Substituting (A31), (A32) and (A33) into (A18), we find that the equilibrium consumer surplus under input price discrimination with two-part tariffs amounts to

$$CS^{dt} = \frac{4(\alpha - c)^2(1+\gamma)}{\left[3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)\right]^2}. \tag{A38}$$

Substituting (A30) and (A33) into $\Pi_M \triangleq (w_i - c)\,q_i + f_i + (w_{-i} - c)\,q_{-i} + f_{-i}$ (where f_i is given in Section 5.1), the equilibrium manufacturer M's profits are

$$\Pi_M^{dt} = \frac{2(\alpha - c)^2\left[3 + 2\gamma\sigma - \gamma^2\left(4 + \sigma^2\right)\right]}{\left[3 - 2\gamma^2 - \sigma + \gamma(2 + \sigma + \sigma^2)\right]^2}.$$

Given $\Pi_{R_i} \triangleq (p_i - w_i)\, q_i - \psi(e_i) - f_i$, the equilibrium retailer R_i's profits are

$$\Pi_R^{dt} = 0.$$

Given $TW \triangleq CS + \Pi_M + \sum_{i=1}^{2} \Pi_{R_i}$, the equilibrium total welfare amounts to

$$TW^{dt} = \frac{2(\alpha - c)^2 \left[5 + 2\gamma(1+\sigma) - \gamma^2\left(4 + \sigma^2\right)\right]}{\left[3 - 2\gamma^2 - \sigma + \gamma\left(2 + \sigma + \sigma^2\right)\right]^2}. \tag{A39}$$

Substituting (A35), (A36) and (A37) into (A18), we find that the equilibrium consumer surplus under a ban on input price discrimination with two-part tariffs amounts to

$$CS^{bt} = \frac{4(\alpha - c)^2 (1+\gamma)}{\left[3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2\right]^2}. \tag{A40}$$

Substituting (A34) and (A37) into $\Pi_M \triangleq (w - c)(q_i + q_{-i}) + 2f$ (where f is given in Section 5.2), the equilibrium manufacturer M's profits are

$$\Pi_M^{bt} = \frac{2(\alpha - c)^2}{3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2}.$$

Substituting (A34), (A35) and (A37) into $\Pi_{R_i} \triangleq (p_i - w)\, q_i - \psi(e_i) - f$, the equilibrium retailer R_i's profits are

$$\Pi_R^{bt} = 0.$$

Given $TW \triangleq CS + \Pi_M + \sum_{i=1}^{2} \Pi_{R_i}$, the equilibrium total welfare amounts to

$$TW^{bt} = \frac{2(\alpha - c)^2 \left[5 + 6\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2\right]}{\left[3 + 4\gamma - 2\sigma + \gamma(2+\gamma)\sigma^2\right]^2}. \quad \blacksquare \tag{A41}$$

Proof of Proposition 6. Using (2) and substituting (6) and (7) into (18), we find that, if $\sigma < \widehat{\sigma}$ (where $\widehat{\sigma} > 0$ is defined in the proof of Lemma 3), it holds $\frac{\partial q_i^b}{\partial w} > 0$. If $\sigma > \widehat{\sigma}$, it holds $\frac{\partial q_i^b}{\partial w} < 0$.

Using (A30), (A31), (A32), (A33), (A34), (A35), (A36) and (A37), we obtain that, if $\sigma < \widehat{\sigma}$ (where $\widehat{\sigma} > 0$ is defined in the proof of Lemma 3), it holds (a) $w^{dt} < w^{bt}$, (b) $p^{dt} < p^{bt}$, (c) $e^{dt} > e^{bt}$, (d) $q^{dt} > q^{bt}$. If $\sigma > \widehat{\sigma}$, it holds (a) $w^{bt} < w^{dt}$, (b) $p^{bt} < p^{dt}$, (c) $e^{bt} > e^{dt}$, (d) $q^{bt} > q^{dt}$. Combining these results with those in Proposition 6, we find that the results in Proposition 4 are corroborated for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. Using (A38), (A39), (A40) and (A41), we obtain that, if $\sigma < \widehat{\sigma}$, it holds $CS^{dt} > CS^{bt}$ and $TW^{dt} > TW^{bt}$. If $\sigma > \widehat{\sigma}$, it holds $CS^{bt} > CS^{dt}$ and $TW^{bt} > TW^{dt}$. Combining these results with those in Proposition 6, we find that the results in Proposition 5 are corroborated for the demand function in (1) and the retail cost of effort $\psi(e_i) = e_i^2$. $\blacksquare$

Proof of Proposition 7. First, we consider linear tariffs. Taking the derivative of w^{dl} in (A6) and of w^{bl} in (A13) with respect to c yields

$$\frac{dw^{dl}}{dc} = \frac{\left[2 + \sigma - \gamma\left(2 + \sigma^2\right)\right]\left[3 - \sigma + \gamma\left(2 - 2\gamma + \sigma + \sigma^2\right)\right]}{(4-\sigma)(3+\sigma) + 2\gamma^3\left(2+\sigma^2\right) - 2\gamma\left(1 - 5\sigma - \sigma^3\right) - \gamma^2\left[16 + \sigma\left(4 + 6\sigma + \sigma^2 + \sigma^3\right)\right]}$$

and

$$\frac{dw^{bl}}{dc} = \frac{1}{2}.$$

Furthermore, taking the derivative of p^{dl} in (A7) and of p^{bl} in (A14) with respect to c yields

$$\frac{dp^{dl}}{dc} = \frac{\left[2+\sigma-\gamma\left(2+\sigma^2\right)\right]\left[1-\sigma+\gamma\left(2+\sigma+\sigma^2\right)\right]}{(4-\sigma)(3+\sigma)+2\gamma^3\left(2+\sigma^2\right)-2\gamma\left(1-5\sigma-\sigma^3\right)-\gamma^2\left[16+\sigma\left(4+6\sigma+\sigma^2+\sigma^3\right)\right]}$$

and

$$\frac{dp^{bl}}{dc} = \frac{1}{2} - \frac{1-\gamma^2}{3-2\gamma^2-\sigma+\gamma\left(2+\sigma+\sigma^2\right)}.$$

We find that, if $\gamma < \widehat{\gamma}$ and $\sigma < \widehat{\sigma}$ (where $\widehat{\gamma} > 0$ is defined in the proof of Proposition 3 and $\widehat{\sigma} > 0$ is defined in the proof of Lemma 3), it holds $\frac{dw^{bl}}{dc} > \frac{dw^{dl}}{dc}$ and $\frac{dp^{bl}}{dc} > \frac{dp^{dl}}{dc}$. Otherwise, i.e., either if $\gamma > \widehat{\gamma}$ or if $\sigma > \widehat{\sigma}$, it holds $\frac{dw^{dl}}{dc} > \frac{dw^{bl}}{dc}$ and $\frac{dp^{dl}}{dc} > \frac{dp^{bl}}{dc}$. Then, the results in the proposition for linear tariffs follow from Propositions 2 and 3.

Now, we turn to the case of two-part tariffs. Taking the derivative of w^{dt} in (A30) and of w^{bt} in (A34) with respect to c yields

$$\frac{dw^{dt}}{dc} = 1$$

and

$$\frac{dw^{bt}}{dc} = \frac{3-\sigma+\gamma\left(2-2\gamma+\sigma+\sigma^2\right)}{3+4\gamma-2\sigma+\gamma(2+\gamma)\sigma^2}.$$

Furthermore, taking the derivative of p^{dt} in (A32) and of p^{bt} in (A35) with respect to c yields

$$\frac{dp^{dt}}{dc} = 1 - \frac{2\left(1-\gamma^2\right)}{3-2\gamma^2-\sigma+\gamma\left(2+\sigma+\sigma^2\right)}$$

and

$$\frac{dp^{bt}}{dc} = \frac{1-\sigma+\gamma\left(2+\sigma+\sigma^2\right)}{3+4\gamma-2\sigma+\gamma(2+\gamma)\sigma^2}.$$

We find that, if $\sigma < \widehat{\sigma}$, it holds $\frac{dw^{dt}}{dc} > \frac{dw^{bt}}{dc}$ and $\frac{dp^{dt}}{dc} > \frac{dp^{bt}}{dc}$. If $\sigma > \widehat{\sigma}$, it holds $\frac{dw^{bt}}{dc} > \frac{dw^{dt}}{dc}$ and $\frac{dp^{bt}}{dc} > \frac{dp^{dt}}{dc}$. Then, the results in the proposition for two-part tariffs follow from Propositions 5 and 6. ■

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