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Input Price Discrimination (Bans), Entry and Welfare*

Markus Dertwinkel-Kalt† Justus Haucap‡ Christian Wey§

June 2013

Abstract

Katz (1987), DeGraba (1990), and Yoshida (2000) have formulated theories that price discrimination bans in intermediary goods markets tend to have positive effects on allocative, dynamic and productive efficiency, respectively. We show that none of these results is robust vis-à-vis endogenous changes in downstream market structure. An upstream monopolist's ability to price discriminate can intensify competition through entry (by a technically inefficient entrant), resulting in socially preferable market outcomes. In contrast, discrimination bans tend to blockade entry of relatively inefficient firms, thereby strengthening downstream market concentration.

JEL Classification: L13, D43, K31.

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1 Introduction

In order to prevent price discrimination, many countries have adopted legal price discrimination bans, which require dominant firms not to charge different buyers different prices for the same product.[1] Our focus is on intermediary goods markets,[2] for which Katz (1987), Yoshida (2000), and DeGraba (1990) have developed three important arguments in favor of non-discrimination rules based on allocative, productive and dynamic efficiency considerations, respectively.[3] To some extent, all these arguments build on the fact that a uniformity rule constrains the upstream monopolist's monopoly power. At a first glance, it then appears intuitive that constraining the monopolist's ability to extract rents from downstream firms should lead to a lower uniform wholesale price compared to the (average) wholesale price when discrimination is feasible.

In fact, Katz (1987) considers a powerful downstream firm (endowed with an outside option which constraints the upstream monopolist's wholesale price) and shows that a uniformity rule increases allocative efficiency because it reduces the input price downstream firms pay in equilibrium. If buyer power is absent and discrimination is feasible, the more efficient firm pays a higher input price than a less efficient rival firm. Banning discrimination by a uniformity rule then increases productive efficiency as it induces the efficient firm to produce more while inefficient firms reduce their output levels (Yoshida 2000). Finally, a uniformity rule is also likely to foster dynamic efficiency because it constraints the ability of the upstream monopolist to extract rents from innovations (DeGraba 1990).

Our point is that potential changes in the underlying market structure need to be considered when comparing different regulatory regimes, as market structures are not independent from changes in the regulatory environment, but endogenous. Hence, it does not suffice to evaluate the welfare effects of a uniform pricing rule by comparing

[1] For instance, in the US Section 2 of the Clayton Act, known as the Robinson-Patman Act due to a 1936 amendment, prohibits price discrimination that would lessen competititon. Thus a supplier that charges one firm more than another would violate Section 2 of the Clayton Act, unless they have good excuses. Acceptable excuses include that the price difference is attributable to cost differences, or that the price difference is a response to meeting competition (for an overview see Scherer and Ross 1990). In the EU discriminatory pricing is made illegal by Article 102(c) of the EC Treaty.

[2] Input market discrimination is also an issue in network industries such as telecommunications, gas and electricity, or rail transport, where pricing rules for access to essential facilities are typically set by regulatory bodies. These access regulations almost always prescribe that access prices to upstream facilities have to be non-discriminatory (see, e.g., Vickers, 1995).

[3] All those works assume an upstream monopolist setting linear wholesale prices, while the downstream firms are competing à la Cournot in the final good market. See O'Brien and Shaffer (1994) and Inderst and Shaffer (2009) for models which analyze an input price discrimination ban when two-part tariffs are feasible.

prices, sales and welfare measures for a *given* market structure. Instead, one should consider the potential effects that these rules may have on market entry, and hence, equilibrium market structure.[4]

Our main argument against a ban on price discrimination in input markets relies on the insight that price discrimination is generally more "entry-friendly" than uniform pricing. An upstream monopolist is less likely to set an "entry-inducing" uniform wholesale price which facilitates entry by an inefficient entrant, as this would mean lowering the (uniform) price to all downstream firms. Hence, an input price discrimination ban may blockade market entry for relatively inefficient entrants. In contrast, discriminatory pricing leads to more downstream competition, as input price discrimination allows the upstream monopolist to adapt a pricing structure which facilitates entry by even an inefficient entrant firm without lowering the price to more efficient incumbents (and foregoing these revenues). By facilitating entry of inefficient firms, input price discrimination can also benefit final consumers and increase social welfare. We show that this insight also remains valid if we account for buyer power in a static setting, where the incumbent firms form a buying group (with price-setting power). Finally, our argument also carries over when we consider innovation incentives.

The literature on input price discrimination and non-discrimination rules in vertically *separated* industries has so far neglected the effects on entry into the discriminated (downstream) market. Most important for this issue are three articles by Katz (1987), DeGraba (1990) and Yoshida (2000), which identify particular conditions under which a non-discrimination rule serves both consumer interests and social welfare.

Our objective is to show that none of these arguments in favor of a price-discrimination ban is robust vis-à-vis the introduction of a relatively inefficient entrant firm. We discuss the arguments in the order in which we will qualify them below.

Firstly, Yoshida (2000) presents a static Cournot model with linear demand, where an upstream monopolist sets input prices before downstream oligopolists compete in quantities. The comparison of third-degree price discrimination and uniform pricing yields that welfare is always lower with price discrimination (see Yoshida 2000, Proposi-

[4]Traditionally concerns against price discrimination have either circled around the anticompetitive effects on downstream rivals of a vertically integrated firm (see, e.g., Vickers, 1995) or on potential adverse effects on consumer surplus. While the first concern relates to vertically integrated firms which may leverage their upstream marlet power to foreclose the downstream market, the latter reasoning has been heavily criticized already long ago by many economists such as Bork (1978) according to whom price discrimination is efficiency enhancing, as it allows monopolists to expand their output beyond the output level set at a uniform price. As Bork (1978, p. 397) has pointed out, price discrimination has often been discussed "as though the seller were instituting discrimination between two classes of customers he already serves, but discrimination may be a way of adding an entire category of customers he would not otherwise approach because the lower price would have spoiled his existing market."

tion 2). Even though the overall output level remains unchanged, *productive efficiency* is lower under discriminatory pricing since the upstream monopolist charges less from a less efficient firm. Hence, the less efficient firm produces more under price discrimination than under a regime where price discrimination is not allowed.[5]

Yoshida's result does not remain generally valid anymore once the entry blockading effects of a non-discrimination rule are taken into account. Price discrimination induces entry for a larger set of parameter constellations. The resulting more intense competition in the downstream segment tends to benefit consumers and can lead to a higher overall welfare level as well.

Secondly, Katz (1987) analyzes price-discrimination bans in a vertical structure with an upstream monopolist and a downstream duopoly, where one downstream firm can credibly threaten to integrate backward.[6] If the outside option is binding, the uniform input price, which is charged to all downstream firms, is lower than the (average) input price under discrimination. Hence, a price discrimination ban can increase *allocative efficiency* in this setting.[7]

Our concern about the entry-blockading effects of price discrimination bans also proves to be critical when a powerful buyer constraints the upstream monopolist's price setting.[8] In stark contrast to Katz' finding, a powerful buyer may induce an *increase* of the uniform input price which blockades entry, while entry would be the outcome under discriminatory input prices. Similar to arguments put forward in the literature on the anticompetitive effects of industry-wide wage contracts, a high uniform input price can benefit powerful downstream firms through a raising rivals' costs mechanism (see Williamson, 1968, and Haucap, Pauly, and Wey, 2001). Hence, the presence of a powerful buyer adds to our argument that price discrimination bans can unfold entry blockading effects in a static setting, so that theories emphasizing the allocative and productive efficiency effects of such rules are reversed.

Thirdly, our paper also qualifies DeGraba's (1990) argument that a uniform pricing rule will spur innovative efforts by downstream firms, and thereby, increase *dynamic*

[5] This result only holds if it is possible to order firms according to their efficiencies. If firms have more than one efficiency characteristic they cannot always be ordered unambiguously so that the above result may not hold any longer. Related is Valletti (2003) who also examines how the curvature of the demand function affects Yoshida's results.

[6] We focus on the linear demand case in Katz' (1987) analysis which was was also used in DeGraba (1990) and Yoshida (2000).

[7] See Inderst and Valletti (2009) for a generalization of Katz' analysis.

[8] In contrast to Katz (1987) we model buyer power in the tradition of the classical monopsony model. Accordingly, a powerful downstream firm in our analysis is able to make a (binding) take-it or leave-it offer to the upstream monopolist.

efficiency.[9] A downstream firm's cost reduction tends to increase the monopolist's profit maximizing input price. However, the input price increase is considerably constrained under uniform pricing, as the input supplier can only increase the uniform price for all firms. Hence, the innovator can appropriate a higher rent from innovation under a price discrimination ban. Moreover, there is a second argument why innovation incentives are stimulated under a uniform pricing rule. This is because a productivity enhancing innovation does not only lower the innovator's own costs, but also raises rivals' costs via the increase in the (uniform) input price, which makes them, ceteris paribus, less competitive in the downstream market (see Haucap and Wey, 2004).

Our concerns over entry are also instructive in such a dynamic environment. As input price discrimination makes it easier for a potential entrant to actually enter a market, incumbent firms may also have larger incentives to innovate, given the "threat" of entry. This is because under uniform pricing efficient firms actually benefit to some degree from the existence of an inefficient competitor. The presence of an inefficient competitor puts a constraint on the input price charged by the monopolist. An innovation can now backfire under a discrimination ban as it may induce the upstream monopolist to raise the (uniform) input price to such a high level at which entry is blockaded. Hence, if an innovation induces entry blockading upstream prices under a uniform pricing rule, then there are reasonable constellations under which input price discrimination would spur investment efforts to the benefit of consumer surplus.

We proceed as follows. In Section 2 we describe the analytical framework which allows us to reverse the arguments made in the literature. In Section 3, we solve the static case which relates to Yoshida (2000). Section 4 examines the static case with buyer power which targets Katz (1987). In Section 5, we present the analysis of the dynamic case with investment effort to qualify DeGraba (1990). Finally, Section 6 offers concluding remarks.

2 The Analytical Framework

We consider a vertically separated two-tier industry with an upstream monopolist, M, and a downstream segment with two incumbent firms, $i = 1, 2$, and one potential entrant firm, $i = 3$. The upstream firm supplies an intermediate good to the downstream firms. Firm i's final output is denoted by q_i, and we suppose that the inverse demand for the final product is linear $p(Q) = a - Q$, with $Q := \sum_i q_i$. Let us also assume that the upstream monopolist has a constant marginal production cost, which we normalize to

[9] See also Banerjee and Lin (2003) who have shown that fixed price contracts can induce larger investments than floating price contracts.

zero.

Following Yoshida (1990), downstream firm i's marginal cost function is given by $k_i = \alpha_i w_i + \beta_i$ which depends (linearly) on the input price w_i (α-efficiency) and a firm-specific constant (β-efficiency). Accordingly, firms may differ with respect to their α-efficiency and/or β-efficiency. We consider different cost specifications depending on our argument.

- In the "static case" (which relates to Yoshida, 2000), we focus on differences in firms' β-efficiences while we abstract from differences in the α-component. Precisely, we set $\alpha_i = 1$, for all $i = 1, 2, 3$, and $\beta_1 = \beta_2 = c$, while firm 3 is assumed to be β-inefficient with $\beta_3 = c + \Delta$, and $c, \Delta > 0$.[10]

- In the "static case with buyer power" (which focusses on Katz, 1987) we assume that all firms have the same β-efficiency but differ with respect to their α-efficiency. We set $\beta_i = 0$, for all $i = 1, 2, 3$, and $\alpha_1 = \alpha_2 = 1$, while firm 3 is assumed to be α-inefficient with $\alpha_3 > 1$.

- The "dynamic case" (which aims at DeGraba, 1990) assumes away differences in the α-component (we set $\alpha_i = 1$, for all $i = 1, 2, 3$) but focuses on the β-efficiency level. With regard to the β-efficiency we assume $\beta_1 = c - \theta$, $\beta_2 = c$, and $\beta_3 = c + \Delta$, where $\theta > 1$ is the marginal cost reduction if firm 1 decides to invest in a cost-reducing innovation.

All those cases have in common that the entrant firm 3 is disadvantaged vis-à-vis the incumbent firms 1 and 2. In the "static case" and the "dynamic case" where we qualify Yoshida (2000) and DeGraba (1990), respectively, it suffices to focus on the analytically more tractable β-efficiency. In the "static case with buyer power" (which targets Katz, 1987) we must refer to the α-efficiency to obtain our result.

We compare two pricing regimes $R \in \{D, U\}$, namely, discriminatory pricing (regime D) and uniform pricing (regime U). The input price, w, is the same for all buyers under a uniformity rule, while the input price may vary between buyers if discriminatory pricing is allowed (in the latter case w_i is firm i's input price).

The basic game consists of two stages. In the first stage, the upstream monopolist sets the input price(s), and in the second stage the downstream firms compete in Cournot fashion. While this timing structure fully describes the "static case", the two remaining cases require some adjustments. In the "static case with buyer power" we assume that firms 1 and 2 (which form a buyer group) can make a take-it or leave-it offer to the upstream monopolist, while the remaining stages are the same as in the basic game.

[10] The exact parameter ranges are specified below.

The "dynamic case" augments our basic game by considering an initial stage in which firm 1 can undertake an investment project to lower its marginal costs by θ.

3 The Static Case

Solving the basic game by backward induction we derive the subgame perfect equilibrium outcomes. Firm i's profit function can be written as

$$\pi_i = (a - Q)q_i - k_i q_i, \text{ for } i = 1, 2, 3,$$

where $k_i := w_i + \beta_i$ for $i = 1, 2, 3$, with $\beta_1 = \beta_2 = c$ and $\beta_3 = c + \Delta$. Given the input prices w_1, w_2, and w_3, the downstream firms compete in Cournot fashion. Depending on the relative disadvantage of the entrant firm, Δ, we have to consider two possible market structures, $\psi \in \{NE, E\}$, where $\psi = NE$ stands for the duopoly structure where no entry occurs, and $\psi = E$ stands for the "entry"-case, where the entrant joins the incumbents to serve the market. Solving firms' maximization problems results in the following optimal output levels:

$$q_i = \max\left\{0, \begin{pmatrix} (a - 3k_i + k_j + k_3)/4, & \text{if } \psi = E \\ (a - 2k_i + k_j)/3, & \text{if } \psi = NE \end{pmatrix}\right\}, \text{ and} \tag{1}$$

$$q_3 = \max\left\{0, (a - 3k_3 + k_i + k_j)/4\right\}, \text{ for } i \neq j,\ i, j = 1, 2. \tag{2}$$

With uniform input prices $w_1 = w_2 = w_3$, the entry blockading input price is given by

$$\overline{w} = a - c - 3\Delta \tag{3}$$

such that for all $w \geq \overline{w}$ the less efficient firm 3 does not enter the market. We invoke the following assumption to ensure that, while the entrant is disadvantaged vis-à-vis the incumbent firms, it would still enter the downstream market and produce a positive quantity if the upstream segment were perfectly competitive.

Assumption 1 (A1). *Let $0 < \Delta < \widehat{\Delta}$, with $\widehat{\Delta} := (a - c)/3$, so that the entrant is strictly disadvantaged, but would produce a strictly positive quantity if the input were priced at marginal cost.*

Assumption 1 follows directly from (3). The less efficient firm produces a positive quantity, whenever the input is priced at marginal cost (which is normalized to zero). We proceed with the analysis of regime D and then turn to regime U.

Discriminatory Pricing. Given the input demands (1) and (2), the upstream monopolist maximizes its profits, $L^R_\psi = \sum_i w_i q_i$, by charging the monopoly input prices (superscripts indicate the pricing regime R)

$$w_i^D = (a - \beta_i)/2 \text{ for } i = 1, 2, 3. \tag{4}$$

Substituting the optimal input prices into the inverse demands for the input, we obtain the equilibrium output levels

$$q_i^D = (a - c + \Delta)/8, \text{ for } i = 1, 2, \text{ and } q_3^D = (a - c - 3\Delta)/8.$$

Accordingly, total output is given by $Q^D = [3(a-c) - \Delta]/8$. The input monopolist can either sell to all three downstream firms or restrict sales to the two efficient firms that are symmetric. If the monopolist sells to the latter two firms only (i.e., sets w_3 sufficiently large), then each incumbent duopolist produces $q_1 = q_2 = (a - c - w)/3$, and the upstream monopolist can realize maximum profits of $L_{NE}^D = (a-c)^2/6$. Selling at differentiated prices to all three downstream firms, however, secures a profit of $L_E^D = \left(3(a-c)^2 - \Delta[2(a-c) - 3\Delta]\right)/16$, which exceeds L_{NE}^D for all $\Delta < \widehat{\Delta}$. This gives our first result.

Lemma 1. *In the unique equilibrium market structure under the discriminatory regime D is the three-firm oligopoly, $\psi^D = E$, so that the entrant firm always produces a strictly positive quantity.*

Note that Assumption 1 ensures that the potential entrant does not stay out of the market, but produces always a strictly positive quantity under the discriminatory regime.

Uniform Pricing. With uniform pricing, regime U, we have to distinguish two cases depending on whether or not the less efficient firm enters the market. That means, the upstream monopolist can either set a comparatively high uniform input price which blockades entry for the less efficient firm so that only the two downstream incumbents buy the input, or the upstream monopolist can set a comparatively low uniform input price, which induces the disadvantaged firm to enter the market so that the upstream monopolist can sell to all three firms.

Let us first consider the case where the less efficient firm is at a disadvantage so large that the upstream monopolist rather sells to the two downstream incumbents only, as the less efficient firm does not enter the market at the upstream monopolist's profit maximizing uniform input price. This input price charged to the two downstream incumbents is the same as in Equation (4), with $w_{NE}^U = (a-c)/2$, so that we obtain for firms 1 and 2 the same equilibrium output levels

$$q_{NE}^U = (a - c)/6.$$

However, the input price w_{NE}^U only blockades entry for the less efficient firm if $\Delta \geq (a-c)/6$. For $\Delta < (a-c)/6$, the upstream monopolist would have to charge the entry blockading input price $\overline{w}$ (see Condition 3) in order to exclude the less efficient firm from the downstream market.

Now assume that the upstream monopolist's profit maximizing uniform input price is sufficiently small to induce the less efficient firm to enter the downstream market. Then the upstream monopolist sets the uniform input price

$$w_E^U = (a - c - \Delta/3)/2, \tag{5}$$

and the equilibrium output levels are

$$q_{i,E}^U = (a - c + 7\Delta/3)/8, \text{ for } i = 1, 2, \text{ and } q_{3,E}^U = (a - c - 17\Delta/3)/8, \tag{6}$$

so that the aggregate output level is given by

$$Q_E^U = [3(a - c) - \Delta]/8. \tag{7}$$

From Equation (6) we can see that the less efficient downstream firm only enters the market under uniform pricing for $\Delta < 3(a - c)/17$. To decide which price to set (i.e., whether to serve two or three downstream firms), the upstream monopolist will compare its profit under the two downstream market structures. Lemma 2 gives us the monopolist's optimal pricing policy and the associated equilibrium market structure when price discrimination is not allowed (the proof is presented in the Appendix).

Lemma 2. *For regime U, there exists a unique threshold value* $\widetilde{\Delta} = (3 - 2\sqrt{2})(a - c)$ *such that for all* $\Delta \geq \widetilde{\Delta}$ *the equilibrium market structure is* $\psi^U = NE$*, while for all* $\Delta < \widetilde{\Delta}$ *the equilibrium market structure is* $\psi^U = E$*. Moreover,* $\widetilde{\Delta} < \widehat{\Delta}$*.*

Lemma 2 shows that the less efficient firm is excluded under a uniform input pricing regulation, whenever the potential entrant is sufficiently disadvantaged; i.e., $\Delta \geq \widetilde{\Delta}$ holds. We therefore, conclude that the discriminatory regime D tends to be more "entry-friendly" than a uniform input pricing regime.

Comparison. Given our assumption that an entrant is disadvantaged vis-à-vis incumbent firms, banning price discrimination upstream weakens competition in the downstream market. Under a uniformity rule the less efficient firm will only enter the market if the monopolist sets a relatively low price for *all* firms in the industry. Quite obviously, lowering the input price, compared to the price at which only the two efficient incumbents are served, is the less attractive for the upstream monopolist the more disadvantaged the entrant is. Consequently, the upstream monopolist will rather serve the two efficient firms at a relatively high price than all three firms at a lower price, unless the entrant's productive efficiency is sufficiently high.

In contrast, a discriminatory pricing regime is more "entry-friendly", as any firm that would enter the downstream market if inputs were priced at marginal cost, also enters if input price discrimination is feasible. While this difference between uniform and discriminatory pricing straightforwardly follows from the upstream monopolist's optimization

problem, it also means that previous welfare assessments of non-discrimination rules are less clear-cut than has been suggested in parts of the literature. Most prominently, Yoshida (2000) has shown that in a Cournot-model with linear demands input price discrimination unambiguously causes productive inefficiencies and, thereby, a welfare loss when compared to uniform pricing.[11] However, this result does not unambiguously hold once the entry blockading effects of non-discrimination rules are taken into account, as the following proposition shows. We obtain the following result (see the Appendix for the proof).

Proposition 1. *Comparison of social welfare and consumer surplus under regimes D and U yields the following orderings:*
i) Social welfare: If entry is not blockaded under regime U (i.e., $\Delta < \widetilde{\Delta}$ *holds with* $\psi^U = E$ *emerging), then social welfare is larger under regime U than under regime D. If entry does not occur under regime U (i.e.,* $\Delta \geq \widetilde{\Delta}$ *holds with* $\psi^U = NE$ emerging), *then there exists a unique threshold value,* $\Delta^U > \widetilde{\Delta}$*, with* $\Delta^U := 31(a-c)/141$*, such that social welfare is larger under regime D than under U, whenever* $\Delta < \Delta^U$ *holds. The opposite is true for* $\Delta > \Delta^U$ *(with equality at* $\Delta = \Delta^U$*). Moreover,* $\widetilde{\Delta} < \Delta^U < \widehat{\Delta}$.
ii) Consumer Surplus: If entry is blockaded under regime U (i.e., $\Delta > \widetilde{\Delta}$*), then consumer surplus is strictly larger under regime D than under regime U. Otherwise, consumer surplus is the same under both regimes*

Yoshida's finding that social welfare should decrease with price discrimination is only valid if a price discrimination ban does not affect downstream market structure. If, however, a price discrimination ban adversely affects the donwstream business by blockading entry, then our results show that welfare *can* be higher with a price discriminating monopolist than under a price discrimination ban. This is the more likely to be the case the relatively more efficient the entrant produces. However, the incumbency advantage between the active incumbents and the potential entrant has to be sufficiently large, as otherwise the upstream monopolist would not exclude the entrant under a uniformity rule in the first place, but serve all three firms at a lower price.

4 The Static Case with Buyer Power

Katz (1987) has shown that buyer power can be a reason for banning price discrimination in input markets. Buyer power (which is based on a buyer's ability to integrate backward)

[11] See Yoshida (2000, Proposition 2), where it is shown that a sufficient condition for this result is that firms can be ordered along the lines of their productive efficiency (as is the case in our setting). However, as pointed out above, Yoshida's analysis takes the number of active firms as exogenously given.

makes a uniform pricing rule attractive because it tends to lower the input prices for *all* firms. If discrimination is feasible then the upstream firm's ability to extract rents increases which tends to raise the average mark-up on the upstream firm's product.

We qualify this favorable perspective on discrimination bans in the presence of buyer power. In fact, we show that the exact opposite can also occur, i.e., buyer power may also induce the input price for all firms to rise. The reason is a "raising rivals' costs" strategy where a powerful buyer wants to raise the uniform input price when this induces rival firms to lower their output levels more than its own (see Haucap et al., 2001). While under uniform pricing blockading entry can be an equilibrium outcome, entry is always accommodated under a discriminatory pricing regime.

Formally, we now augment our previous analysis by considering buyer power for the incumbent firms $i = 1, 2$ so as to re-examine Katz's (1987) argument. In Katz (1987) one downstream firm has buyer power in the sense that it has an opportunity to integrate backwards. We deviate from that approach slightly by assuming that firms 1 and 2 can form a buying group which can make a take-it or leave-it offer to the upstream monopolist. Given firm i's marginal cost function function $k_i = \alpha_i w_i + \beta_i$, all downstream firms have the same β-efficiency (which we normalize to zero), while they differ with respect to their α-efficiency. We invoke the following assumption concerning firms' α-efficiency levels.

Assumption 2 (A2). *Firms 1 and 2 are assumed to have an α-efficiency level of $\alpha_1 = \alpha_2 = 1$, while firm 3 is disadvantaged in this regard such that $\alpha_3 = \alpha \in (1, \bar{\alpha})$ with $\bar{\alpha} = (4 + \sqrt{6})/(8 - 3\sqrt{6}) \approx 9.9$.*

We augment our basic game by an initial stage 0, in which firms 1 and 2 make a (binding) take-it or leave-it offer w to the upstream monopolist.[12] The upstream monopolist can then accept or reject the offer made by firms 1 and 2 (in case of rejection, firms 1 and 2 exit the market). In the next stage (stage 1), the monopolist sets the input price to the entrant firm 3 which does not have any buyer power.[13] In the last stage, (stage 2), all active firms set their quantity levels.

In the non-discriminatory regime, firms 1 and 2 essentially set the binding input price for all downstream firms (including firm 3) if their offer is accepted by the upstream monopolist. If the proposal is rejected, then firms 1 and 2 must leave the market.[14]

[12] Firms 1 and 2 act as a single player which we can interpret as a "buying group."

[13] The entrant firm is not member of the buying group which can be a reason why it does not have buyer power.

[14] The ability of firms 1 and 2 to commit to exit the market if their offer is rejected is the only source of buyer power in our setting. If firms 1 and 2 cannot commit that way, then the upstream monopolist would simply reject the initial offer to make his own take-it or leave-it offer in the next stage.

Given that all firms are active, and given input prices w_1, w_2, and w_3, we obtain from (1) and (2) the derived demands

$$q_i(w_1, w_2, w_3) = \frac{a - 3w_i + w_j + \alpha w_3}{4} \text{ for } i, j = 1, 2, \text{ and} \quad (8)$$

$$q_3(w_1, w_2, w_3) = \frac{a - 3\alpha w_3 + w_1 + w_2}{4}. \quad (9)$$

Uniform Pricing. When firms 1 and 2 have (joint) buyer power, then they make a take-it or leave-it offer to the upstream monopolist to maximize their profit. Substituting the derived demands (8)-(9) into the joint profit function gives

$$\pi_1^U + \pi_2^U = 2(a - 2q - q_3)q_1 - 2wq = \frac{1}{4}aw\alpha + \frac{1}{8}a^2 + \frac{1}{8}w^2\alpha^2 + \frac{1}{2}w^2 - \frac{1}{2}aw - \frac{1}{2}w^2\alpha,$$

so that $\partial(\pi_1^U + \pi_2^U)/\partial w > 0$ if and only if $\alpha > 2$ (given that $q_3 > 0$). For $\alpha > 2$, the profit function $\pi_1^U + \pi_2^U = 2\pi_1^U$ is strictly increasing in w and firms 1 and 2 set at least the entry blockading price $w = a/(3\alpha - 2)$. If entry by firm 3 is blockaded (i.e., $q_3 = 0$), demands are $q_1 = q_2 = (a - w)/3$ and the joint profit of firms 1 and 2 is decreasing in w. Thus, optimally firms 1 and 2 propose $w = a/(3\alpha - 2)$, which is the minimal input price that prevents firm 3 from market entry. This proposal is accepted due to the following reasoning. If the upstream monopolist rejects $w = a/(3\alpha - 2)$, firms 1 and 2 leave the market and firm 3 is a downstream monopolist. The upstream monopolist's profit in that case is $a^2/(8\alpha)$ compared to $2a^2(\alpha - 1)/(3\alpha - 2)^2$ in case of accepting a proposal of $w = a/(3\alpha - 2)$. The second term is larger for all $\alpha > 2$.

For $1 < \alpha < 2$, firms 1 and 2 propose the minimal price w that will be accepted by the monopolist. This w is given by making the monopolist indifferent between rejecting and accepting, i.e., $a^2/(8\alpha) = w(q_1+q_2+q_3)$. This gives $w = (3a\alpha - a\sqrt{7\alpha^2 - 4\alpha})/(2\alpha(\alpha+2))$. All firms are active in this case.

Thus, the profits of firms 1 and 2 are either decreasing in the input price (namely, if $\alpha < 2$), or increasing in the input price (namely, if $\alpha > 2$). The former relationship was the focus in Katz (1987) which has been supporting a favorable view of a non-discrimination rule in the presence of buyer power. Our analysis reveals that for $\alpha > 2$ the joint profit of firms 1 and 2 is an increasing function of a uniform input price.[15] In those instances "powerful" retailers want to increase a non-discriminatory input price to blockade market entry by rival retailers.

Price Discrimination. We consider a regime according to which price discrimination is possible. Due to buyer power, firms 1 and 2 can make a take-it or leave-it offer to the monopolist concerning their own price $w = w_1 = w_2$. The monopolist, however, can price discriminate and may set a different input price to entrant firm 3. If the

[15] Below we show that this also implies ambiguous welfare conclusions.

monopolist rejects the offer by firms 1 and 2, he sells only to firm 3 and makes a profit of $a^2/(8\alpha)$. Since the joint profit of firms 1 and 2 is decreasing in w, they set the lowest price which is accepted by the upstream monopolist. We derive the proposal w by solving the monopolist's indifference condition between accepting and rejecting proposal w. Equalizing the profit in case of rejection, $a^2/(8\alpha)$, with the profit in case of acceptance for an optimally set w_3, $wq_1 + wq_2 + w_3q_3$, yields the equilibrium input prices[16]

$$w^D = (a/2)(1 + 7\alpha + \sqrt{6} - 3\sqrt{6}\alpha)/(10\alpha - \alpha^2 - 1) \tag{10}$$

and

$$w_3^D = a(18\alpha + 6\alpha^2 - 2\sqrt{6}\alpha - 3\sqrt{6}\alpha^2 + \sqrt{6})/(6\alpha(10\alpha - \alpha^2 - 1)). \tag{11}$$

For the optimal quantities, entry of firm 3 is never blockaded for $\alpha \in (1, \bar{\alpha})$; i.e., whenever A2 holds.

Comparison of Pricing Regimes. The following Proposition summarizes the comparison of social welfare and consumer surplus under the discriminatory and the uniform regimes (see the Appendix for the proof).

Proposition 2. *Comparison of social welfare under discriminatory and uniform pricing gives the following orderings when firms 1 and 2 have buyer power.*

i) If $\alpha < 2$, then $W^U > W^D$ and $CS^U > CS^D$.

If $\alpha > 2$, then there exists a critical value $\widehat{\alpha} < \bar{\alpha}$ such that

ii) $W^U < W^D$ and $CS^U < CS^D$, for $2 < \alpha < \widehat{\alpha}$, and

iii) $W^U > W^D$ and $CS^U < CS^D$, for $\widehat{\alpha} < \alpha < \bar{\alpha}$.

Moreover, $W^U = W^D$ holds for $\alpha = \widehat{\alpha}$.

Comparing consumer surplus under both regimes shows that it is higher under a discriminatory regime for $\alpha > 2$. The same holds for social welfare with the qualification that it is only higher under a discriminatory regime if $2 < \alpha < \widehat{\alpha}$ with $\widehat{\alpha} \approx 6.311$. The intuition is the following: for reasonably efficient entrants, i.e., $1 < \alpha < 2$, uniform pricing is optimal from a consumer surplus and a welfare point of view, since buyer power leads to a low input price for all downstream firms, which benefits consumers. For inefficient entrants, i.e., $\alpha > 2$, firms 1 and 2 set the input price sufficiently high to prevent firm 3's entry. These relatively high input prices are passed on to consumers, which result in a lower consumer surplus compared to the discriminatory regime. However, due to the inefficiency of the entrant, welfare is lower under a discriminatory regime when the entrant is very inefficient, i.e., $\alpha > \widehat{\alpha}$.

Having analyzed the merits of input price discrimination (bans) in a static framework, let us now turn to the analysis of uniform input pricing rules in a dynamic setting, as the

[16] The subgame perfect input price charged from firm 3 is $w_3(w) = (2w\alpha + a + 2w)/(6\alpha)$.

(negative) effects of price discrimination on innovation incentives have been put forward as an important reason for prohibiting input price discrimination (DeGraba, 1990).

5 The Dynamic Case

We augment the basic game by an initial stage, in which one of the two incumbents, say firm 1, can undertake an innovation project, $I(\theta)$, which carries a fixed cost of I and lowers the innovator's marginal costs by $\theta > 0$. If the innovation is realized, then firm 1's marginal cost is $k_1 = w_1 + c - \theta$. Subsequent to firm 1's investment decision, the upstream monopolist sets the input price(s) before downstream firms finally compete in Cournot fashion.

In the following we analyze firm 1's innovation incentives under regimes D and U. The different innovation incentives under the different regimes can be measured by the gross gain, $\Psi^R(\theta) \equiv \pi_1^R(\theta) - \pi_1^R(0)$, where the argument θ (0) indicates that the innovation has (not) been undertaken.[17] We impose the following assumption on the marginal-cost reduction associated with the implementation of an innovation project.

Assumption 3 (A3). *Let $0 < \theta < \widehat{\theta}$ with $\widehat{\theta} := (\sqrt{3} - 1)(a - c)/2$, so that the non-innovating incumbent firm remains active under both regimes D and U when the innovation project is undertaken.*

Assumption 3 is derived in the Appendix. It guarantees that firm 1's marginal cost reduction is non-drastic, i.e., the downstream market will not be monopolized after the innovation. Hence, firm 1's innovation is such that the non-innovating incumbent firm 2 remains active in the market under any regime.[18] The following lemma characterizes the equilibrium market structures under the two regimes for the parameter space under consideration.

Lemma 3. *The following equilibrium market structures emerge when firm 1 decides to innovate:*
i) Regime U: If $\Delta < \Delta'$, with $\Delta' := \widetilde{\Delta} - \theta(\sqrt{2} - 1)$, then $\psi^U = E$, while for $\Delta \geq \Delta'$ entry does not occur with $\psi^U = NE$ resulting.

[17] Our approach follows Bester and Petrakis (1993) and Haucap and Wey (2004). By focussing on a firm's unilateral innovation incentives we can abstract from coordination issues which arise when entry deterrence is possible (see Bernheim, 1984).

[18] The possibility of monopolization under both regimes gives an obvious argument in favor of the hypothesis that innovation incentives can be larger under regime D than under U. This follows directly from inspecting our measure for innovation incentives, Ψ. A monopolizing innovation project would yield the same profit level for the innovator under both regimes. As, however, the profit level in the absence of innovation is typically lower under discriminatory pricing, it immediately follows that innovation incentives are larger under regime D than under regime U in cases of such drastic innovations.

ii) Regime D: If $\Delta < \Delta''$*, with* $\Delta'' := \widehat{\Delta} - \theta/3$*, then* $\psi^D = E$*, while for* $\Delta \geq \Delta''$ *entry does not occur and* $\psi^D = NE$ *holds.*

Part i) of Lemma 3 shows that the parameter range for blockaded entry under regime U increases when firm 1 innovates (the threshold value Δ' decreases in θ). We can, therefore, distinguish two cases under regime U for parameter values $\Delta \geq \Delta'$: If $\Delta \in (\Delta', \widetilde{\Delta})$, then firm 1's innovation actually affects market structure, as the disadvantaged entrant only refrains from entry if firm 1 innovates. If, however, $\Delta > \widetilde{\Delta}$ holds, then the innovation does not affect market structure, as the entrant firm would not enter the market even without firm 1 innovating (see Lemma 2).

Part ii) of Lemma 3 shows that firm 1's innovation also tends to increase the range for entry blockading prices under regime D. Using Lemmas 1-3 we can summarize the effects that firm 1's innovation has on market structure as follows.

Lemma 4. *The decision to innovate affects market structure in the following way:*
i) Regime U: For $\Delta \in [\Delta', \widetilde{\Delta})$*, an innovation affects market structure, as it blockades entry for firm 3. For all remaining constellations the innovation does not affect market structure.*
ii) Regime D: For $\Delta \geq \Delta''$*, an innovation affects market structure, as it blockades entry for firm 3. For* $\Delta < \Delta''$ *the innovation does not affect market structure.*

Lemma 4 shows that innovations can induce the upstream monopolist to set entry-blockading input prices for firm 3, if firm 3's disadvantage is sufficiently large. Note, in this context, that $\Delta'' > \widetilde{\Delta} > \Delta'$ for all $\widehat{\theta} > \theta > 0$. That means that the scope for entry-blockading innovations is smaller under regime D (as $\Delta' < \Delta''$ holds). Only for $\Delta > \Delta''$ the innovation would also lead to a more concentrated market structure under regime D. The analysis of the innovation incentives is now summarized in the next proposition (the proof is relegated to the Appendix).

Proposition 3. *Innovation incentives can be ordered under regimes U and D as follows:*
i) If the innovation does not affect the equilibrium market structure under regime U, then regime U carries larger innovation incentives than regime D: i.e., $\Psi^U(\theta) > \Psi^D(\theta)$ *if* $\Delta \notin [\Delta', \widetilde{\Delta})$*.*
ii) If the innovation affects the equilibrium market structure under regime U (i.e. $\Delta \in [\Delta', \widetilde{\Delta})$ *holds), then there exists a critical value* $\Delta^* \in [\Delta', \widetilde{\Delta})$ *such that for all* $\Delta \in [\Delta^*, \widetilde{\Delta})$ *the innovation incentives are larger under regime D than under regime U; i.e.,* $\Psi^D(\theta) > \Psi^U(\theta)$ *if and only if* $\Delta \in [\Delta', \widetilde{\Delta})$ *and* $\Delta > \Delta^*$ *holds. In contrast, innovation incentives are larger under regime U than under regime D for* $\Delta \in [\Delta', \Delta^*]$*.*

Proposition 3 reveals that DeGraba's result that innovation incentives are largest under a uniformity rule critically depends on the market entry consideration. More pre-

cisely, by part i) of Proposition 3 DeGraba's result remains valid whenever an innovation does not affect market structure under regime U. Part ii) of Proposition 2, however, shows that this conclusion does not hold any longer when an innovation induces the upstream monopolist to increase its uniform price by so much that the potential entrant refrains from market participation. To understand the underlying logic, note that under a price discrimination ban the innovating downstream firm typically also benefits from the existence of less efficient firms in the market, as the existence of less efficient firms leads to a reduction in the uniform input price.[19]

As long as the upstream monopolist finds it optimal to serve them at a comparatively low uniform price, the innovating firm benefits from the associated mild input price increases which result from the innovation.[20] If, however, the innovation induces the input monopolist to forego the revenue stream obtained from selling to the inefficient entrant and rather to raise its uniform input price so as to increase the revenues from the two remaining firms, the price increase for the innovating firm becomes significantly larger than under a constant market structure. Moreover, the larger the potential entrant's initial exogenous disadvantage, Δ, the more downward pressure is exerted by the entrant on input prices. Hence, Δ has to be sufficiently large to result in lower investment incentives under uniform prices than under input price discrimination.

The next proposition proves that under those circumstances welfare also rises (see the Appendix for the proof).

Proposition 4 *For all $\Delta \in [\Delta^*, \widetilde{\Delta})$, consumer surplus increases if an innovation takes place under regime D but not under regime U.*

As Proposition 4 reveals, consumer surplus may be increased by input price discrimination, as both market competition and innovation incentives can increase compared to a uniform pricing regime. The positive consumer surplus effect results when an innovation takes place under regime D, but the innovation would not be implemented under regime U.

6 Conclusion

We have used a fairly simple model to demonstrate that the results obtained by Katz (1987), DeGraba (1990) and Yoshida (2000) have to be qualified once market structure

[19] The equilibrium output of firm 1 under regime U is given $q_{E,1}^U = (3(a-c) + 7\Delta + 17\theta)/24$, which is increasing in Δ.

[20] For regime U, the input price increases by $\theta/6$ under a triopoly and by $\theta/4$ under a duopoly where entry is blockaded.

is not exogenously given and entry is an issue. The entry blockading effects of input price discrimination bans, as provided for by the Robinson-Patman Act in the US and Article 82 of the European Treaty, may have damaging effects on consumer surplus and overall welfare. More generally, additional entry under price discrimination can drive down prices, which benefits consumers and possibly overall social welfare.

Whenever regulations are imposed on businesses, the economy is shifted from one equilibrium to another. While this clearly involves adjustments of prices and sales, it can also have substantial effects on industry structure. We have accounted for this by considering a potential entrant, and have shown that entry is less likely when price discrimination is forbidden. The entry blockading effect of uniformity regulations tend to reduce the competitive intensity, so that recent arguments in favor of input price discrimination bans developed by Katz (1987), Yoshida (2000), and DeGraba (1990) have to be qualified. An upstream monopolist is more likely to sell its product to a relatively inefficient firm if price discrimination is feasible. The result is stronger competition among downstream firms, so that consumer surplus and even social welfare can be larger than under uniform pricing.

While our model has straightforward applications for vertically separated industries such as airports and ports, the model is also applicable to unionized oligopolies. As has been recently argued collective wage-setting by an industry (or even nation-wide union) may have some benefits because of the positive effects that egalitarian (i.e., non-discriminatory) wage-setting may have on firms' incentives to innovate (see Haucap and Wey, 2004). If we, however, account for the entry blockading effects of those labor market regimes, then our insights may also qualify these results. More specifically, recent trends towards more flexible wage setting at the firm-level (which we interpret as some form of wage-discrimination) may unfold "entry-friendly" effects, not only in a static setting but also in a more dynamic world where cost reduction is an important aspect of industry performance.

Appendix

In this Appendix we present the omitted proofs and we derive Assumptions 2 and 3.

Proof of Lemma 2. We have to compare the upstream monopolist's profit depending on whether or not the less efficient entrant firm is served. With the monopoly input price given by (5) the entrant remains active for all $\Delta < 3(a-c)/17$, in which case the upstream monopoly profit becomes $L_E^U = [3(a-c)-\Delta]^2/48$. Note that the upstream monopolist's profit is strictly decreasing in Δ.

If, however, the monopolist prefers to serve only the two efficient downstream firms,

then its profit maximizing input price is $w^U_{NE} = (a-c)/2$, for all $\Delta \geq (a-c)/6$. However, for all $\Delta < (a-c)/6$ the inefficient firm would purchase inputs at a price of w^U_{NE}. In those cases, therefore, the input monopolist has to charge the entry-blockading input price $\overline{w}$ if he wants to ensure that only two firms are served. Clearly, the monopoly profit at $\overline{w}$ is strictly smaller than the profit at w^U_{NE}, which is given by $L^U_{NE}(w^U_{NE}) = (a-c)^2/6$. Note that this expression is independent of Δ. Comparing L^U_E and L^U_{NE} we obtain the unique threshold value $\widetilde{\Delta} = (3-2\sqrt{2})(a-c)$, with $L^U_E < L^U_{NE}$, for all $\Delta > \widetilde{\Delta}$, and $L^U_E > L^U_{NE}$, for all $\Delta < \widetilde{\Delta}$. Note that $\widetilde{\Delta} > (a-c)/6$ so that w^U_{NE} is a feasible pricing option for the monopolist for all $\Delta > \widetilde{\Delta}$. In addition, $\widetilde{\Delta} < 3(a-c)/17$. Hence, for all $\Delta \in [\widetilde{\Delta}, 3(a-c)/17]$ the input monopolist decides to serve only the incumbent firms at w^U_{NE} even though he could also serve three firms at w^U_E. It follows that the monopolist sets the entry blockading input price, w^U_{NE}, for all $\Delta \geq \widetilde{\Delta}$, and the monopoly input price, w^U_E, with all three firms being active for all $\Delta < \widetilde{\Delta}$.

Proof of Proposition 1. *Part i):* We have to compare social welfare, W^R_ψ, (the sum of upstream and downstream producer surplus plus consumer surplus) under the two regimes $R \in \{D, U\}$. Under price discrimination, D, social welfare is defined as $W^D = L^D + \sum_i \pi^D_i + CS^D$ which gives $W^D = (26c\Delta - 26a\Delta - 78ac + 39a^2 + 39c^2 + 47\Delta^2)/128$. Similarly, with two firms active under uniform input pricing welfare is given by $W^U_{NE} = L^U_{NE} + \sum_{i=1}^2 \pi^U_{i,NE} + CS^U_{NE} = 5(a-c)^2/18$. Solving $W^D - W^U_{NE} = 0$ we obtain the threshold value $\Delta^U := 31(a-c)/141$. Moreover, welfare under regime U with all three firms active can be expressed as $W^U_E = [78c\Delta - 78a\Delta - 234ac + 117a^2 + 117c^2 + 269\Delta^2]/384$. The welfare comparison then yields $W^D - W^U_E = -\Delta^2/3 < 0$. Hence, $W^U_E > W^D$ holds for all $\Delta \in (0, \widetilde{\Delta})$.

Part ii): Equilibrium consumer surplus, CS^R, under the two regimes, $R \in \{D, U\}$, is proportional to total output, Q^R, with $CS^R = (Q^R)^2/2$. Comparison yields that total output (and hence, consumer surplus) is always at least as large under regime D as under regime U, as $Q^D = Q^U_E = [3(a-c) - \Delta]/8$ is strictly larger than $Q^U_{NE} = (a-c)/3$ for all $\Delta < \widehat{\Delta}$. It follows that $CS^D > CS^U_{NE}$ if $\Delta > \widetilde{\Delta}$ and $CS^D = CS^U_E$ if $\Delta \leq \widetilde{\Delta}$.

Derivation of Assumption 2. The threshold $\bar{\alpha}$ follows from substituting (10) and (11) into the derived demand of firm 3 (see 9). It is then straightforward to check that firm 3 is strictly active for all $\alpha < \overline{\alpha}$, while it does not enter the market for all $\alpha \geq \overline{\alpha}$.

Proof of Proposition 2. For regime $R \in \{D, U\}$ and market structure $\psi = \{E, NE\}$ we denote the upstream monopolist's profit L^R_ψ, firm i's profit $\pi^R_{i,\psi}$ and consumer surplus CS^R_ψ. For market structure $\psi = E$, welfare W^R_E can be calculated as

$$W^R_E = L^R_E + \sum_{i=1}^{3} \pi^R_{i,E} + CS^R_E = Q^R_E(a - \frac{Q^R_E}{2}) - (\alpha - 1)w^R_3 q^R_3.$$

For market structure $\psi = NE$, welfare W^R_{NE} is given by

$$W^R_{NE} = L^R_{NE} + \sum_{i=1}^{2} \pi^R_{i,NE} + CS^R_{NE} = Q^R_{NE}(a - \frac{Q^R_{NE}}{2}).$$

First, we consider regime U with buyer power. In case of $1 < \alpha < 2$ we obtain $CS^U_E = a^2(3\alpha + \sqrt{\alpha(7\alpha-4)})^2/(128\alpha^2)$ and $W^U_E = (a^2/64)(184\alpha^3 - 326\alpha^2 - 59\alpha^2\sqrt{\alpha(7\alpha-4)}) + 148\alpha\sqrt{\alpha(7\alpha-4)} + 328\alpha - 44\sqrt{\alpha(7\alpha-4)} - 24)/(\alpha(\alpha+2)^2)$. In case $\alpha > 2$ we obtain $W^U_{NE} = 2a^2(\alpha-1)(2\alpha-1)/(3\alpha-2)^2$ and $CS^U_{NE} = 2a^2(\alpha-1)^2/(3\alpha-2)^2$.

Next, we consider regime D with buyer power. We obtain $W^D_E = (a^2/192)(-840\sqrt{6}\alpha^2 - 121\alpha - 152\alpha^2 + 1216\sqrt{6}\alpha^3 + 296\alpha^4\sqrt{6} + 5642\alpha^3 - 2400\alpha^4 + 24 + 495\alpha^5 - 168\alpha^5\sqrt{6} + 136\sqrt{6}\alpha)/(\alpha(-10\alpha + \alpha^2 + 1)^2)$ and $CS^D_E = (a^2/1152)(120\alpha - 24\alpha^2 + 20\sqrt{6}\alpha + 3\sqrt{6}\alpha^2 - 7\sqrt{6} - 24)^2/(-10\alpha + \alpha^2 + 1)^2$. Comparing these terms shows that consumer surplus is higher under a discriminatory regime for $\alpha > 2$, whereas welfare is higher for a discriminatory regime in case $2 < \alpha < \widehat{\alpha}$ with $\widehat{\alpha} \approx 6.311$.

Derivation of Assumption 3. The threshold value $\widehat{\theta}$ guarantees that the non-innovating incumbent firm 2 remains active under regime U when firm 1 undertakes the innovation project. To see this, note that the optimal input prices for given downstream market structures are given by

$$\begin{aligned} w^U(n=3) &= (a - c - (\Delta - \theta)/3)/2, \\ w^U(n=2) &= (a - c + \theta/2)/2, \\ w^U(n=1) &= (a - c + \theta)/2, \end{aligned}$$

from which we obtain the following output levels produced by firm 1

$$\begin{aligned} q^U_1(n=3) &= (3(a-c) + 7\Delta + 17\theta)/24, \\ q^U_1(n=2) &= (2(a-c) + 7\theta)/12, \\ q^U_1(n=1) &= (a - c + \theta)/4. \end{aligned}$$

Comparison of the upstream monopolist's profits yields that $w^U(n=3)$ is optimal for all $\Delta < \Delta'$ and $\theta < \widehat{\theta}$, while $w^U(n=2)$ is optimal for all $\Delta > \Delta'$ and $\theta < \widehat{\theta}$. To see this, compare $L^U(n=1)$ and $L^U(n=2)$, which are given by $L^U(n=1) = (a-c+\theta)^2/8$ and $L^U(n=2) = (2a-2c+\theta)^2/24$. As can easily be checked, $L^U(n=2) = L^U(n=1)$ if $\theta = \widehat{\theta}$. To show that it is feasible for the input monopolist to set an input price of $w^U(n=1) = (a-c+\theta)/2$ for $\theta \geq \widehat{\theta}$ without drawing demand from firm 2, note that for $n=2$ firm 2's best response is given by $q_2 = \frac{1}{3}(a - c - w - \theta)$, which is only positive for $\theta \leq (a-c)/3$. Since $\widehat{\theta} > (a-c)/3$ it is feasible and optimal for the input monopolist to charge $w^U(n=1) = (a-c+\theta)/2$ for $\theta \geq \widehat{\theta}$. Similarly, we can show by comparing $L^U(n=3)$ and $L^U(n=1)$ that $w^U(n=3)$ is feasible and optimal if and only

if $\theta < \widehat{\theta}$ holds. Hence, the parameter restriction restriction $\theta < \widehat{\theta}$ assures that at least the two incumbent firms remain active under regime U when the innovation project $I(\theta)$ is implemented by firm 1.

It remains to show that Assumption 3 assures that the non-innovating incumbent firm 2 stays active when the innovation is undertaken. For that purpose we have to compare the upstream monopolist's profit from serving only one and from serving two downstream firms under both regimes D and U. Hence, let us start and first derive the optimal production quantities and input prices under regime D. Substituting the derived demands (2) and (3) into the upstream monopolist's profit function and maximizing over the input price(s) we obtain

$$w_i^D = (a - \beta_i)/2, \text{ for } i = 1, 2, 3,$$

where β_i are the firms' marginal costs given by $\beta_1 = c - \theta$, $\beta_2 = c$ and $\beta_3 = c + \Delta$. Substituting the optimal input prices into the inverse demands for the input, we obtain the equilibrium output levels

$$\begin{aligned} q_1^D &= \tfrac{1}{8}(a - c + 3\theta + \Delta), \\ q_2^D &= \tfrac{1}{8}(a - c + \Delta - \theta), \text{ and} \\ q_3^D &= \tfrac{1}{8}(a - c - 3\Delta - \theta), \end{aligned} \tag{12}$$

for $3\Delta + \theta < a - c$. For $3\Delta + \theta > a - c$ we receive $q_3^D = 0$, and also $q_1^D = \frac{1}{6}(a - c + 2\theta)$ and $q_2^D = \frac{1}{6}(a - c - \theta)$, while the input prices w_1 and w_2 remain unchanged. It is now straightforward to check that firm 2 remains active for all $\theta \leq \widehat{\theta}$ and $\Delta < \widehat{\Delta}$ under regime D.

Proof of Proposition 3. Note that since the downstream firms' profits are given by $\pi_i = q_i^2$ taking into account Lemmas 1 to 4, it is straightforward to calculate firm 1's innovation incentives $\Psi^D(n_\theta, n_0)$, where the arguments n_θ and n_0 stand for the downstream market structure after and before innovation, respectively. We then obtain

$$\begin{aligned} &\Psi^D(3,3) = \tfrac{1}{64}\left[(a - c + \Delta + 3\theta)^2 - (a - c + \Delta)^2\right], \text{ for } \theta < a - c - 3\Delta, \text{ and} \\ &\Psi^D(2,3) = \tfrac{1}{36}(a - c + 2\theta)^2 - \tfrac{1}{64}(a - c + \Delta)^2, \text{ for } a - c > \theta \geq a - c - 3\Delta. \end{aligned}$$

Similarly, we can calculate firm 1's innovation incentives $\Psi^U(n_\theta, n_0)$ under regime U, which are given by

$$\begin{aligned} &\Psi^U(3,3) = \tfrac{1}{576}\left[(3(a - c) + 7\Delta + 17\theta)^2 - (3(a - c) + 7\Delta)^2\right], \text{ for } \Delta < \Delta', \\ &\Psi^U(2,3) = \tfrac{1}{144}(2(a - c) + 7\theta)^2 - \tfrac{1}{576}(3(a - c) + 7\Delta)^2, \text{ for } \widetilde{\Delta} > \Delta \geq \Delta', \\ &\Psi^U(2,2) = \tfrac{1}{36}\left[(a - c + \tfrac{7}{2}\theta)^2 - (a - c)^2\right], \text{ for } \Delta \geq \widetilde{\Delta}. \end{aligned}$$

We now have to pairwise compare $\Psi^U(n_\theta, n_0)$ and $\Psi^D(n_\theta, n_0)$ for $n_0 = 2, 3$ and all $n_\theta \leq n_0$ in order to prove the two parts of our proposition.

Part (i): Given that $\Delta'' > \widetilde{\Delta} > \Delta'$ for all $\widehat{\theta} > \theta > 0$ we have to compare $\Psi^U(3,3)$ versus $\Psi^D(3,3)$ for the case where $\Delta < \Delta'$. In addition, we have to compare $\Psi^U(2,2)$ versus $\Psi^D(3,3)$ and $\Psi^D(2,3)$ for cases where $\Delta \geq \widetilde{\Delta}$. Firstly, note that $\Psi^U(3,3) - \Psi^D(3,3) > 0$ can be rewritten as $48\theta(a-c)+184\Delta\theta+208\theta^2 > 0$, which is clearly always fulfilled. Secondly, we can rewrite $\Psi^U(2,2)-\Psi^D(3,3) > 0$ as $58(a-c)-54\Delta+115\theta > 0$. This inequality unambiguously holds for all $\Delta < \widehat{\Delta}$ which we have assumed in A1. And thirdly, note that $\Psi^U(2,2) - \Psi^D(2,3) = 0$ if

$$(48\theta + 18\Delta)(a-c) - 7(a-c)^2 + 132\theta^2 + 9\Delta^2 = 0.$$

Note that the left-hand side of this equation is increasing in Δ and that

$$\Delta^{**} := \frac{2}{3}\sqrt{4(a-c)^2 - 12\theta(a-c) - 33\theta^2} - (a-c)$$

is the only non-negative solution to this equation. Also note that $\Delta^{**} < \Delta''$ for all $\theta > 0$, so that $\Delta \geq \Delta''$ implies $\Delta > \Delta^{**}$and, thereby, $\Psi^U(2,2) > \Psi^D(2,3)$.

Part (ii): We proceed in four steps to show that $\Psi^D(3,3) > \Psi^U(2,3)$ *if and only if* $\Delta \in [\Delta^*, \widetilde{\Delta})$. First, let us derive Δ^*. Straight forward calculus yields that $\Psi^U(2,3) - \Psi^D(3,3) = 0$ if $(7(a-c)^2 + 58\theta(a-c) + 115\theta^2 - 42(a-c)\Delta - 49\Delta^2 - 54\Delta\theta) = 0$. Note again that the left-hand side of this equation is decreasing in Δ and that

$$\Delta^* = -3(a-c)/7 - 27\theta/49 + 2\sqrt{\left(196(a-c)^2 + 994\theta(a-c) + 1591\theta^2\right)}/49$$

is the only feasible non-negative solution for the equation. Secondly, note that $\frac{d\Delta^*}{d\theta} > 0, \frac{d\widetilde{\Delta}}{d\theta} = 0, \frac{d\Delta'}{d\theta} < 0$ for all θ, and, thirdly, note that at $\theta = 0$ we obtain $\Delta'(0) = \widetilde{\Delta} > \Delta^*(0)$. Now let us define $\widehat{\widehat{\theta}}$ such that $\Delta^*(\widehat{\widehat{\theta}}) = \widetilde{\Delta}$, which holds for $\widehat{\widehat{\theta}} = (52 - 54\sqrt{2} + 4\sqrt{7376 - 5181\sqrt{2}})(a-c)/115$. Since $\widehat{\widehat{\theta}} < \widehat{\theta}$, this proves the existence of $\Delta^* \in [\Delta', \widetilde{\Delta})$.

Proof of Proposition 4. According to Proposition 3, it is possible that an innovation project $I(\theta)$ is only carried out under D and not under regime U. Given $\Delta \in [\Delta^*, \widetilde{\Delta})$, then it follows from Lemma 2 that the entrant enters the market if the innovation is not carried out under regime U. In that case, total output is given by (7), $Q_E^U = [3(a-c) - \Delta]/8$. If the innovation is undertaken under regime D, equilibrium quantities are stated in the derivation of Assumption 3 and are given by (12). Using part ii) of Lemma 3 and $\Delta < \tilde{\Delta} < \Delta''$, the entrant is active and overall quantity is given by $Q_E^D = [3(a-c) + \theta - \Delta]/8$, which is larger than Q_E^U. Thus, Proposition 4 is proven.

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