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Spatial Price Discrimination in Input Markets with an Endogenous Market Boundary

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Abstract This paper examines the welfare effect of third-degree price discrimination in a vertically related market with one upstream monopolist that sells its input to a continuum of downstream markets. Assume that the market boundary of the monopolist is endogenously determined. It is found that social welfare is necessarily lower under discriminatory than uniform pricing, even if the market area of the former is greater than that of the latter. This finding is contrary to that in the extant literature on price discrimination in final goods markets.

Keywords Endogenous market boundary · Input price discrimination · Spatial price discrimination · Third-degree price discrimination

JEL Classification D4 · L1 · R3

1 Introduction

Third-degree price discrimination, which is a common practice, is regulated by competition authorities of many countries. For example, there is the Robinson–Patman

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Act in the US and Article 102 (c) of the Treaty on the Functioning of the European Union (TFEU) in the EU.[1]

Price discrimination can occur in input or final product markets. However, price discrimination in input markets is of particular importance and deserves more attention for two reasons: First, price discrimination is prevalent in many wholesale markets, such as those for gasoline, steel, tobacco, pharmaceuticals, and dairy products.[2] Second, the vast majority of legal and policy disputes over price discrimination concern input markets rather than final goods markets.[3]

In this paper, we build on the work by Holahan (1975) but assume that the monopolist does not sell its goods directly to final consumers but to downstream firms/retailers. Each downstream firm/retailer is a local monopolist that operates in an independent market of identical size. In line with Holahan (1975), we show that price discrimination results in more markets being served and a higher total output. Contrary to Holahan (1975), however, we find that permitting price discrimination harms social welfare.

The remainder of this paper is organized as follows: Sect. 2 reviews the related literature. Section 3 introduces the basic model. The input price and market area of an upstream monopolist under discriminatory and uniform pricing are derived in Sect. 4. In Sect. 5, we compare the levels of social welfare under the two pricing regimes. Section 6 concludes the paper.

2 Related Literature

Theoretical literature on third-degree price discrimination can be dated back to Robinson (1933). Since her pioneering work, it is well-known that banning third-degree price discrimination on final goods markets improves social welfare if demands are linear and the number of markets being served is fixed. This point of view has been criticized by Chicago school scholars, e.g., Bork (1978). They argue that price discrimination is likely leading to more markets being served, which in turn improves social welfare. A model with a continuum of downstream markets, which combines the two aforementioned opposing effects in a continuous fashion, was analyzed by Holahan (1975).

[1] See Schwartz (1986) for a summary of the issues in the Robinson–Patman Act and Geradin and Petit (2006) for discussions on price discrimination under TFEU competition law.

[2] Villas-Boas (2009, p. 30) shows that the main coffee manufacturers in Germany charge retailers different prices. For example, the manufacturer Jacobs charges the four main retail chains, Edeka, Markant, Metro and Rewe, 6.815, 6.537, 7.093 and 7.039 (prices are in Deutsche Mark per 500 g), respectively. Moreover, Hastings (2009) finds that price discrimination is prevalent in the wholesale gasoline market and also examines the potential impact of banning wholesale price discrimination by using panel data from gasoline stations in the metropolitan area of San Diego, CA. Coloma (2003) also finds that there is geographic price discrimination in the Argentine gasoline market.

[3] For example, in the US, legislation that bans wholesale price discrimination has been proposed in all West Coast states as well as in New York, Connecticut, and Maryland (Hastings 2009). In China, the law on price discrimination against firms (not consumers) was enacted in 1997 and took effect in 1998 [i.e., the Price Law Article 14 (5)]; but price discrimination against final product markets was not prohibited until the Antidumping Law took effect in 2008. China's 2007 Antimonopoly Law, which took effect in 2008, prohibits price discrimination in all markets, including final product markets. See Article 17 (6) in the following link: http://www.lawyer86.com/htm/4208.html.

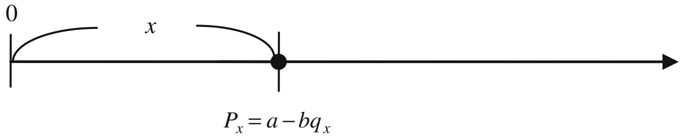

Fig. 1 The market line

He shows that price discrimination leads to more markets being served, a higher total output, and higher social welfare than uniform pricing.

Our paper is also related to the literature on input price discrimination, such as Katz (1987), DeGraba (1990) and Yoshida (2000), among others. They also consider the pricing policies of a monopolistic input supplier and find that input price discrimination tends to reduce social welfare. Our model differs from theirs in two respects: First, we assume that there is a continuum of input markets and that the number of the markets that are served is endogenously determined. But in their models, the number of the markets is kept constant. Second, they assume that downstream firms compete in the final good market, whereas in our model, downstream firms are local monopolists that operate in independent markets.

3 The Basic Model

The basic model is similar to that in Greenhut and Ohta (1972) and Holahan (1975). Assume that there is a continuum of symmetric and uniformly distributed markets for a final good along a market line as shown in Fig. 1. The inverse demand function at market x takes the following form: $P_x = a - bq_x$, where $a, b > 0$, P_x and q_x are the corresponding price and output of the final good, respectively. The subscript "x" denotes the distance from the market to the location of an upstream monopolist who is assumed to be located at point 0 on the market line and $x \geq 0$.

In each market, there is one downstream firm that buys inputs from the upstream monopolist and uses them to produce the final good. We assume that each downstream firm is a monopolist in its own market, charging a monopolistic price in the basic model (but in Sect. 5.1 we will replace this with a competitive price; i.e., the price being set equal to the downstream firm's marginal cost).

The upstream monopolist adopts either uniform pricing or discriminatory pricing while selling the input to the downstream firms. For simplicity, the marginal cost of the upstream monopolist is assumed to be zero. All the downstream firms are assumed to have the same production technology—it takes one unit of the input to produce one unit of the final good.[4] In addition to the input price, a downstream firm located in market x also incurs a transport cost $tx(t > 0$ is the transport rate) when buying one unit of the input.

The cost function of the downstream firms takes the following form: $cq + vq^2/2$, where $c \in [0, a)$ and v measures the convexity of the cost function. Hence, the marginal

[4] The fixed-coefficient technology is a popular assumption in the literature on input price discrimination. See, for example, Katz (1987), DeGraba (1990) and Yoshida (2000).

cost of the final output is $c + vq$. If the value of v is positive (zero, negative), it implies that the production technology of the downstream firms exhibits decreasing (constant, increasing) returns to scale.

The game consists of two stages: In the first stage, the upstream monopolist adopts either discriminatory pricing or uniform pricing to determine the optimal mill prices of the input, in anticipation of the equilibrium in the second stage. In the second stage, each downstream producer, given the input price that is offered by the upstream monopolist, chooses its optimal price for its local market. We solve the equilibrium by backward induction.

Given the specifications of the model, the profit of the downstream firm in market x is defined as follows:

$$\pi_x = (P_x - w_x - tx)q_x - (cq_x + vq_x^2/2), \tag{1}$$

where π_x is the profit of the downstream firm in market x and w_x is the input price.

From (1), it is straightforward to derive the equilibrium quantity in market x for the second-stage game as follows:[5]

$$q_x(w_x) = \frac{a - c - w_x - tx}{2b + v}. \tag{2}$$

Equation (2) is also the derived demand of the downstream firm that is located at x.

Furthermore, by setting (2) to zero, we can derive the aggregate market boundary condition as follows:

$$\bar{x} = \frac{a - c - w_x}{t}, \tag{3}$$

where $\bar{x}$ stands for the aggregate market boundary of the upstream monopolist. We shall utilize the derived demand in (2) and the aggregate market boundary condition in (3) to solve for the optimal input prices and market boundaries under the two pricing regimes in the next section.

4 The Upstream Market Equilibrium

If the monopolist adopts uniform pricing, it sets the same unit wholesale price w^u to all downstream firms. Utilizing the derived demand in Eq. (2) and following the assumption of zero marginal cost, we can specify the profit of the upstream monopolist Ω^u as follows:

$$\Omega^u(w^u) = w^u \int_0^{\bar{x}^u} q_x(w^u)dx, \tag{4}$$

[5] We shall assume, throughout the rest of the analysis, that $2b + v > 0$ to ensure that the second-order conditions for profit maximization of the downstream firms are satisfied.

where variables wear a superscript "u" indicating that they are associated with the uniform pricing regime and $\bar{x}^u$ is the corresponding aggregate market boundary which by (3) is defined as follows:

$$\bar{x}^u = \frac{a - c - w^u}{t}. \tag{5}$$

Substituting (5) into (4) and taking the maximization, we can derive the optimal input price under uniform pricing as follows:[6]

$$w^u = \frac{a - c}{3}. \tag{6}$$

The equilibrium output of the final good in market x and the equilibrium market boundary are then derivable as follows:

$$q_x^u = \frac{2a - 2c - 3tx}{3(2b + v)} \tag{7}$$

and

$$\bar{x}^u = \frac{2(a - c)}{3t}. \tag{8}$$

By contrast, under the discriminatory pricing regime, the upstream monopolist charges a personalized unit wholesale price w_x^d, which depends on a downstream firm's effective marginal cost (i.e., marginal cost plus unit transport cost). The profit of the upstream monopolist under discriminatory pricing is specified as follows:

$$\Omega^d(w_x^d) = \int_0^{\bar{x}^d} w_x^d q_x(w_x^d) dx,$$

where variables with a superscript "d" are associated with the discriminatory pricing regime and $\bar{x}^d$ is the corresponding aggregate market boundary.

The equilibrium input price in market x is derivable as follows:[7]

$$w_x^d = \frac{a - c - tx}{2}. \tag{9}$$

Substituting it into (2) and (3), we can derive the equilibrium output of the final good in market x and the corresponding market boundary as follows:

$$q_x^d = \frac{a - c - tx}{2(2b + v)} \tag{10}$$

[6] The second-order condition for profit maximization is satisfied as $\partial^2\Omega^u/\partial w^{u2} = -(2a - 2c - 3w^u)/(2b + v) < 0$. The denominator is positive by note 5.

[7] The second-order condition for profit maximization is satisfied given the linear demand and cost assumptions (i.e., $\partial^2\Omega_x^d/\partial w_x^{d2} = -2 < 0$).

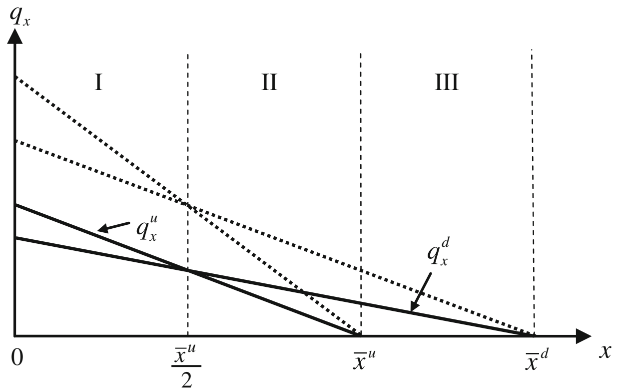

Fig. 2 The output schedules: uniform versus discriminatory pricing

and

$$\bar{x}^d = \frac{a - c}{t}. \tag{11}$$

Using the derived equilibrium outcomes, we shall compare the welfare between discriminatory pricing and uniform pricing in the next section.

5 Welfare Comparison Between Discriminatory and Uniform Pricing

Before comparing the welfare levels under the two pricing regimes, let us first compare their market areas and outputs.

From (8) and (11), we can derive $\bar{x}^u = 2\bar{x}^d/3$ which implies that the aggregate market area is larger under discriminatory than uniform pricing.[8] This result is quite intuitive and similar to the finding in Holahan (1975): Under discriminatory pricing, the monopolist charges each market an individual price and serves markets until the marginal profit from an additional market becomes nil.

The output difference between the two pricing policies can be best explained by their output schedules. Using (7) and (10), we can draw the output schedules q_x^d and q_x^u. As depicted in Fig. 2, the two schedules (i.e., the two solid lines) are linear, negatively sloped and cross each other at $\bar{x}^u/2$ of the linear market.[9] Furthermore, the schedule for discriminatory pricing, as compared to that for uniform pricing, has a flatter slope and a farther market boundary.

As shown in Fig. 2, the market area is divided into three regions—Regions I, II and III. Regions I and II are served by the upstream monopolist under both pricing schemes, while Region III is served only under discriminatory pricing.

[8] Clearly, this result is obtainable for a general demand function.

[9] The dotted lines in the figure are the corresponding output schedules if the downstream market is competitive. They will be discussed in Sect. 5.1.

Table 1 Consumer surplus, profits, and social welfare

Regions	Uniform pricing			Discriminatory pricing		
	I	II	III	I	II	III
Consumer surplus	$\frac{7b\alpha}{162(2b+v)^2}$	$\frac{b\alpha}{162(2b+v)^2}$	0	$\frac{19b\alpha}{648(2b+v)^2}$	$\frac{7b\alpha}{648(2b+v)^2}$	$\frac{b\alpha}{648(2b+v)^2}$
Downstream profits	$\frac{7\alpha}{162(2b+v)}$	$\frac{\alpha}{162(2b+v)}$	0	$\frac{19\alpha}{648(2b+v)}$	$\frac{7\alpha}{648(2b+v)}$	$\frac{\alpha}{648(2b+v)}$
Upstream profits	$\frac{\alpha}{18(2b+v)}$	$\frac{\alpha}{54(2b+v)}$	0	$\frac{19\alpha}{324(2b+v)}$	$\frac{7\alpha}{324(2b+v)}$	$\frac{\alpha}{324(2b+v)}$
Social welfare	$\frac{(39b+16v)\alpha}{162(2b+v)^2}$	$\frac{(9b+4v)\alpha}{162(2b+v)^2}$	0	$\frac{(133b+57v)\alpha}{648(2b+v)^2}$	$\frac{(49b+21v)\alpha}{648(2b+v)^2}$	$\frac{(7b+3v)\alpha}{648(2b+v)^2}$

α is set equal to $(a-c)^3/t > 0$

It is shown that for markets in Region I (II), the output of the final good is lower (higher) under discriminatory pricing than under uniform pricing. This is because the upstream monopolist, if adopting discriminatory pricing, charges a higher input price to a more adjacent downstream firm as it incurs a lower transportation cost and thus has a higher derived demand. It is straightforward to show that the output loss in Region I from discriminatory pricing is equal to the output gain in Region II. It implies that the total outputs in terms of the two regions are the same under the two pricing regimes.[10] Furthermore, Region III represents the extra market area that is served by the upstream monopolist if it adopts discriminatory pricing. Hence, the total output is necessarily higher under discriminatory pricing.

From the above discussions, we can establish the following proposition:

Proposition 1 *Assume that there is an upstream monopolist that sells an input to a continuum of downstream markets along a linear line and that the aggregate market boundary is endogenously determined. The aggregate market area and the total output of the final good are both larger under discriminatory than uniform pricing.*

We now turn to examine the welfare effect of price discrimination when (as in our model) each downstream market has a single seller that acts as a profit-maximizing monopolist. Social welfare is defined as the sum of consumer surplus and profits of all the downstream firms and the upstream firm. Consumer surplus, downstream profits, upstream profits and social welfare in each of the three regions under the two pricing regimes are summarized in Table 1.[11] From Table 1, the welfare levels under uniform and discriminatory pricing are derivable as: $[(24b + 10v)\alpha]/[81(2b + v)^2]$ and $[(7b + 3v)\alpha]/[24(2b + v)^2]$, respectively. By comparing the welfare levels, we can establish the following proposition:

Proposition 2 *Assume that there is an upstream monopolist that sells an input to a continuum of downstream markets (that each has a monopolist that sells to final consumers) along a linear line and that the market boundary is endogenously determined.*

[10] The finding is similar to the conclusion that is made by Beckmann (1976), who compares the output levels under the two pricing schemes in a model that is similar to Holahan (1975) except for an exogenously determined market boundary. He shows that the total outputs under the two pricing policies are the same.

[11] See "Appendix 1" for the mathematical details of Table 1.

Uniform pricing is definitely socially more desirable than discriminatory pricing if the production technology of the downstream firms is constant returns to scale (*i.e.,* $v = 0$) *or not too decreasing returns to scale* (*i.e.,* $v < 3b$).

Three remarks are warranted with respect to Proposition 2: First, our result is in sharp contrast to that in Holahan (1975), who employs a similar linear market model and concludes that price discrimination in final good markets definitely increases social welfare. We shall explain why our result is different from Holahan's in Sect. 5.1.

Second, the welfare implication of this proposition is in line with the empirical finding in Villas-Boas (2009), who estimates the welfare gains from banning wholesale price discrimination in a German coffee retail market and finds that the ban can improve social welfare if the downstream firms differ in their costs.[12]

Third, according to the legal rules in the US and the EU—the Robinson–Patman Act and Article 102 TFEU—price discrimination is considered as illegal (abuse of dominance) only if a downstream firm is placed at a competitive disadvantage (for secondary-line injury cases). In our model, due to the assumption that downstream firms are local monopolists that operate in independent markets, no downstream firm is placed at a "competitive" disadvantage. Nevertheless, downstream firms that are located closer to the upstream monopolist are at a disadvantage after price discrimination as they are charged higher input prices. Furthermore, in the EU, geographic price discrimination across member states is also forbidden and typically falls under Article 102(c) TFEU, which might also be a case where the obtained welfare findings apply.[13]

Finally, our model can be extended in three different ways. We shall discuss the extensions as follows:

5.1 Competitive Downstream Markets

The difference between our result and that of Holahan (1975) can be attributed to the effect of double marginalization, which exists in our model but is absent in Holahan's. To highlight the importance of double marginalization in the welfare calculation, let us purposely assume in this subsection that each downstream firm has *no* market power and sets a competitive price (i.e., the price is set equal to the marginal cost) in its local market. This assumes away the double marginalization, since the market price is now equal to the effective marginal cost of the downstream firms; that is, $P_x = c + vq_x + w_x + tx$. Under such a circumstance, the derived demand perceived by the upstream monopolist in market x becomes: $q_x = (a - tx - c - w_x)/(b + v)$, which is larger than that in (2).

With the enlarged derived demand, we can proceed as before to draw the output schedules and calculate the resulting consumer surplus, profits, and social welfare levels under the two pricing schemes. The former are depicted as the two dotted lines in Fig. 2. The steeper (flatter) one is the output schedule under the uniform

[12] In our model, the downstream firms differ in their transport costs. Our results remain robust if this cost difference is caused by different production technologies.

[13] We are indebted to a referee for bringing this to our attention.

Table 2 Consumer surplus, profits, and social welfare under downstream perfect competition

Regions	Uniform pricing			Discriminatory pricing		
	I	II	III	I	II	III
Consumer surplus	$\frac{7b\alpha}{162(b+v)^2}$	$\frac{b\alpha}{162(b+v)^2}$	0	$\frac{19b\alpha}{648(b+v)^2}$	$\frac{7b\alpha}{648(b+v)^2}$	$\frac{b\alpha}{648(b+v)^2}$
Downstream profits	$\frac{7v\alpha}{162(b+v)^2}$	$\frac{v\alpha}{162(b+v)^2}$	0	$\frac{19v\alpha}{648(b+v)^2}$	$\frac{7v\alpha}{648(b+v)^2}$	$\frac{v\alpha}{648(b+v)^2}$
Upstream profits	$\frac{\alpha}{18(b+v)}$	$\frac{\alpha}{54(b+v)}$	0	$\frac{19\alpha}{324(b+v)}$	$\frac{7\alpha}{324(b+v)}$	$\frac{\alpha}{324(b+v)}$
Social Welfare	$\frac{8\alpha}{81(b+v)}$	$\frac{2\alpha}{81(b+v)}$	0	$\frac{19\alpha}{216(b+v)}$	$\frac{7\alpha}{216(b+v)}$	$\frac{\alpha}{216(b+v)}$

(discriminatory) pricing regime. Note that the sizes of and boundaries for the three regions are the same for the downstream competitive pricing case as compared to the downstream monopoly pricing case.[14] The latter are reported in Table 2.[15] As is shown in Table 2, the welfare levels under uniform and discriminatory pricing are derivable as $(10\alpha)/[81(b+v)]$ and $\alpha/[8(b+v)]$, respectively. It shows that social welfare is higher under price discrimination, which is the same as that in Holahan (1975). This gives rise to the following proposition:

Proposition 3 *Assume that there is an upstream monopolist that sells an input to a continuum of downstream markets along a linear line and that the market boundary is endogenously determined. Discriminatory pricing is definitely more socially desirable than uniform pricing, if the downstream markets are perfectly competitive.*

From Propositions 2 and 3, it seems that double marginalization plays a role in causing the "flipping" of the result as to the comparative welfare consequences of uniform versus discriminatory pricing for the case of downstream monopoly pricing (where double marginalization is present) as compared with the case of downstream competitive pricing (where double marginalization is absent).

Before explaining this welfare effect of input price discrimination, we review the results derived by Holahan (1975) and Beckmann (1976) first. In their models, there is a monopolist that produces and sells a final good directly to consumers that are located along a line market. Beckmann (1976) assumes that the market boundary is *exogenously* given and finds that price discrimination necessarily worsens social welfare. This is because price discrimination does not change the total output but results in efficiency loss: Consumers who incur a high transport cost are charged a low price. Holahan (1975), by contrast, assumes the market area to be *endogenously* determined and concludes that price discrimination is welfare-improving. This is because the

[14] Given the assumptions of linear demand and constant-returns-to-scale technology, the equilibrium output at each downstream market always decreases by half if the pricing of the downstream firm changes from competitive pricing to monopoly pricing. This result holds regardless of whether the upstream monopolist adopts uniform or discriminatory pricing.

[15] See "Appendix 2" for the details of the calculation.

monopolist now serves a greater market area under discriminatory pricing and the resulting welfare gain outweighs the welfare loss from inefficiency.[16]

Let us turn to the current case of downstream monopoly. If the upstream monopolist engages in price discrimination, the market area is also greater as compared to that under uniform pricing, but the resulting welfare gain decreases significantly due to double marginalization. Specifically, as shown in Fig. 2, the output of the final good in Region III, which is the source of the welfare gain for discriminatory pricing, is cut by half, if the pricing of the downstream markets switches from competitive pricing to monopoly pricing. The welfare gain from the greater market area becomes smaller than the welfare loss from inefficiency. The welfare loss of discriminatory pricing in the combined regions is due to the fact that the "wrong" (or "higher cost") retailers are selling more output.[17] As a result, the welfare ranking between discriminatory and uniform pricing is necessarily reversed.

Furthermore, if the downstream cost functions become more convex (i.e., a greater v), the equilibrium outcomes (price and output) in each downstream market are closer to the competitive ones, mitigating the problem of double marginalization.[18] This explains why discriminatory pricing becomes more socially desirable than uniform pricing when the cost function is sufficiently convex (i.e., $v > 3b$).

5.2 Non-linear Wholesale Tariffs

We have so far assumed that the upstream monopolist is always restricted to linear wholesale tariffs. If we allow the upstream monopolist to charge two-part wholesale tariffs, price discrimination becomes welfare-improving.[19] Specifically, under discriminatory pricing, the upstream monopolist would set the per-unit input price equal to its marginal cost and then use an *individual* fixed fee to extract the residual rent from each market. This outcome is the same as that for competitive downstream markets. In contrast, under uniform pricing, the monopolist charges a common per-unit price and fixed fee (w, F) for all downstream firms. As this common fixed fee is not able fully to extract rents from downstream markets, the per-unit input price must be higher than the marginal cost. As the upstream monopolist tends to charge a higher price and

[16] This can be easily verified in Table 2. Discriminatory pricing results in a welfare gain in Region III but a welfare loss in the combined Regions I and II. According to the table, the welfare gain from Region III (i.e., $\alpha/(216(b+v))$) outweighs the welfare loss from the combined Regions I and II (i.e., $\alpha/(324(b+v))$).

[17] From Table 1, it is straightforward to derive the welfare loss to be $((5b+v)\alpha)/\left(324(2b+v)^2\right)$ and the welfare gain to be $((7b+3v)\alpha)/\left(648(2b+v)^2\right)$. The loss dominates the gain if the downstream cost function is not sufficiently convex.

[18] We thank an anonymous referee for providing this explanation.

[19] Similar results can be found in O'Brien and Shaffer (1994), Inderst and Shaffer (2009) and Arya and Mittendorf (2010). They assume that the number of markets is fixed and find that input price discrimination is welfare-improving if the input monopolist adopts non-linear tariffs for its input. Herweg and Müller (2014) is an exception. They examine a monopolistic supplier's optimal non-linear tariffs when downstream firms are privately informed about their retail costs. In their model, the monopolist offers nonlinear tariffs not only to reduce double marginalization but also to screen downstream firms according to their efficiency. As a result, discriminatory pricing may not expand the total output and is thus welfare-reducing.

serve a smaller market area under uniform than discriminatory pricing, social welfare is definitely higher under the latter.[20]

5.3 Entry into the Downstream Markets

We can also compare our finding with that in Herweg and Müller (2012). They employ a non-spatial framework to find that price discrimination can lead to a larger market as it encourages new entry into the downstream market. There are two markets in their model: an incumbent market, and a new market. As there is only one incumbent market in their model, input price discrimination does not change the equilibrium outcome of the incumbent market, causing no inefficient output allocation.[21] But it induces an entry to the downstream market. Due to this entry, input price discrimination necessarily improves social welfare.

By contrast, price discrimination in our model has two opposing effects on social welfare. It encourages new entry (Region III in Fig. 2), which is beneficial to social welfare. Meanwhile, it causes inefficient output allocation among incumbent markets (Regions I and II in Fig. 2), which is detrimental to social welfare. In fact, this intuition can be applied to a non-spatial framework with more than two incumbent markets. In the absence of entry, input price discrimination is necessarily detrimental to social welfare as it causes inefficient output allocation among the incumbent markets. Nevertheless, if price discrimination induces new entry, social welfare may increase or decrease, depending on which effect dominates.

6 Concluding Remarks

This paper sets up a spatial model in which the aggregate market boundary is endogenously determined to examine the welfare implications of discriminatory pricing by an upstream monopolist that sells an input to a set of downstream monopolists that are distributed along a line.

It is found that discriminatory pricing is definitely inferior to uniform pricing if the production technology of the downstream firms exhibits constant returns to scale, even though the former can serve a larger market area and more consumers. The result implies that a larger market area (or greater output) is not a sufficient condition for discriminatory pricing to be welfare-improving. Moreover, if the marginal cost function of the downstream firms is increasing or decreasing with output, the above-mentioned welfare ranking is still robust as long as the marginal cost is not sufficiently increasing.

It is important to note that spatial price discrimination is only one interpretation of the model but not a unique feature that distinguishes the model from other papers

[20] There are papers that assume that the upstream monopolist adopts a *linear* pricing contract and find that price discrimination in input markets is welfare-improving. See for example Chen et al. (2011) and Kao and Peng (2012), among others.

[21] The inefficient output allocation takes place only if the number of the incumbent markets equals or exceeds two.

on price discrimination in input markets. In our paper, downstream firms differ in their locations and incur shipping costs when procuring the input from the upstream monopolist: The transport cost depends on the distance and the amount bought. Thus, downstream firms differ with respect to their effective (constant) marginal cost of production; this is an assumption shared by almost all papers in the literature on third-degree price discrimination in input markets. The source of these cost differences is completely irrelevant for the analysis and the welfare findings. The extant literature considers a discrete number of downstream markets (typically two), whereas our paper assumes that there is a continuum of downstream markets.

We have assumed that the market structure of the downstream market is that of a monopoly, regardless of the pricing policies of the upstream monopolist. It is of interest to consider an endogenous structure of the downstream market when analyzing the policy implications of input price discrimination. We may assume that consumers are evenly and continuously distributed on a bounded space (or a line), whereas there are free-entry downstream competitors. The pricing behavior of the upstream monopolist affects the entry decisions of the downstream firms. From this setting, we can further investigate the welfare effects of input price discrimination in a spatial market where the downstream market structure is endogenously determined. Since most of the studies in the literature on input price discrimination assume that there is no change in market structure after price discrimination, this is an issue that is worth resolving.

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Appendix 1

In order to compare the welfare levels of the two pricing policies in Table 1, we first use the equilibria that are derived in the text to calculate consumer surplus, the profits of the downstream firm and the upstream monopolist, and then social welfare in market x under the two pricing policies.

In the case of uniform pricing, they can be derived as follows:

$$
\begin{aligned}
cs_x^u(v) &= \frac{b(2a-2c-3tx)^2}{18(2b+v)^2}, \pi_x^u(v) = \frac{(2a-2c-3tx)^2}{18(2b+v)},\\
\Omega_x^u(v) &= \frac{(a-c)(2a-2c-3tx)}{9(2b+v)},\\
sw_x^u(v) &= cs_x^u + \pi_x^u + \Omega_x^u = \frac{[(10b+4v)(a-c)-(9b+3v)tx](2a-2c-3tx)}{18(2b+v)^2},
\end{aligned}
$$

and the total social welfare under uniform pricing is:

$$
SW^u = \int_0^{\bar{x}^u} sw_x^u dx = \frac{2(12b+5v)(a-c)^3}{81t(2b+v)^2}. \tag{12}
$$

In the case of discriminatory pricing, we have the following:

$$cs_x^d(v) = \frac{b(a-c-tx)^2}{8(2b+v)^2}, \quad \pi_x^d(v) = \frac{(a-c-tx)^2}{8(2b+v)}, \quad \Omega_x^d(v) = \frac{(a-c-tx)^2}{4(2b+v)},$$
$$sw_x^d = cs_x^d + \pi_x^d + \Omega_x^d = \frac{(7b+3v)(a-c-tx)^2}{8(2b+v)^2},$$

and the total social welfare is:

$$SW^d = \int_0^{\bar{x}^d} sw_x^d dx = \frac{(7b+3v)(a-c)^3}{24t(2b+v)^2}. \tag{13}$$

By subtracting (12) from (13), we obtain the difference in social welfare between discriminatory pricing and uniform pricing as follows:

$$\Delta SW = SW^d - SW^u = \frac{(v-3b)(a-c)^3}{648t(2b+v)^2},$$

which leads to Proposition 2.

Appendix 2

When the downstream markets are perfectly competitive, consumer surplus, the profits of the downstream firm and the upstream monopolist, the social welfare at market x, and the sum of the social welfare under the uniform pricing regime can be derived as follows:

$$cs_x^u(v) = \frac{b(2a-2c-3tx)^2}{18(b+v)^2}, \quad \pi_x^u(v) = \frac{v(2a-2c-3tx)^2}{18(b+v)^2},$$
$$\Omega_x^u(v) = \frac{(a-c)(2a-2c-3tx)}{9(b+v)},$$
$$sw_x^u(v) = cs_x^u + \pi_x^u + \Omega_x^u = \frac{(2a-2c-3tx)(4a-4c-3tx)}{18(b+v)},$$

$$SW^u = \int_0^{\bar{x}^u} sw_x^u dx = \frac{10(a-c)^3}{81t(b+v)}. \tag{14}$$

Under the discriminatory pricing regime, they are:

$$cs_x^d(v) = \frac{b(a-c-tx)^2}{8(b+v)^2}, \pi_x^d(v) = \frac{v(a-c-tx)^2}{8(b+v)^2},$$
$$\Omega_x^d(v) = \frac{(a-c-tx)^2}{4(b+v)},$$

$$sw_x^d = cs_x^d + \pi_x^d + \Omega_x^d = \frac{3(a-c-tx)^2}{8(b+v)},$$

$$SW^d = \int_0^{\bar{x}^d} sw_x^d dx = \frac{(a-c)^3}{8t(b+v)}. \tag{15}$$

By subtracting (14) from (15), we obtain the difference in social welfare between the two regimes as follows:

$$\Delta SW = SW^d - SW^u = \frac{(a-c)^3}{648t(b+v)} > 0,$$

which leads to Proposition 3.

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