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PRODUCT VARIETY AND WELFARE UNDER DISCRIMINATORY AND MILL PRICING POLICIES

George Norman and Jacques-François Thisse

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Centre for Economic Policy Research
25-28 Old Burlington Street
London W1X 1LB
Tel: (44 71) 734 9110

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ABSTRACT

Product Variety and Welfare under Discriminatory and Mill Pricing Policies*

We re-examine the economic justification for the regulation of firms' spatial price policies. Existing analysis, by treating market structure as exogenous, loses an important trade-off. Discriminatory pricing is more competitive between incumbents but acts as a strong deterrent against entry. Product variety is determined by the degree of spatial contestability of the market (the ability of entrants to make binding location commitments) and by whether firms can price discriminate. The entry deterring effect of discriminatory pricing is dominant whatever the degree of spatial contestability or the nature of demand but welfare effects depend upon the degree of spatial contestability. The lower the degree of spatial contestability, the more effective is discriminatory pricing at limiting entry and the more likely is it that mill pricing is socially desirable.

JEL classification: L13, L40, R32
Keywords: discriminatory pricing, mill pricing, product variety, regulation, spatial contestability

George Norman
Department of Economics
University of Edinburgh
William Robertson Building
Edinburgh
EH8 9JY
UK
Tel: (44 31) 650 8359

Jacques-François Thisse
CERAS
Ecole Nationale des Ponts et Chaussées
28 rue des Saints Pères
75343 Paris Cedex 05
FRANCE
Tel: (33 1) 4458 2870

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NON-TECHNICAL SUMMARY

It is generally believed that price deregulation is pro-competitive and should therefore be favoured in most industries. For example, one subtle form of price regulation which has been weakened over the past decade, especially in the United States and the European Union, is the power to deny firms the ability to discriminate between spatially separated consumers. The ability to price discriminate implies that a firm can cut its prices in one part of its market without the need to change its prices elsewhere. This effectively reduces the power of the firm to commit to a set of prices and so strengthens price competition. But fiercer price competition will not necessarily work to the benefit of consumers. On the one hand, for a given degree of product variety stronger price competition will, indeed, reduce the prices charged by incumbent firms. On the other hand, stronger price competition can also be expected to act as an entry deterrent, and so may benefit incumbent firms. We show that the entry deterrence effect is dominant: *discriminatory pricing leads to less product variety than mill (non-discriminatory) pricing.* This power of price discrimination to limit product proliferation is particularly marked when relocation costs are high.

It is unlikely that free entry will lead to the socially optimal degree of product variety. The welfare comparison of discriminatory and mill pricing is affected in large part by firms' relocation costs. If these costs are low free entry always gives too much product variety. By contrast, very high relocation costs may limit product proliferation excessively and always do so when firms are allowed to price discriminate. In the former case the entry deterrence effect of discriminatory pricing weakens the tendency towards excessive product variety and tends to generate greater consumer surplus. In the latter case, the entry deterrence effect acts primarily to increase incumbent firms' profits (individually and in the aggregate) at the expense of consumers.

This might be seen as leaving the case against price discrimination not proven. We prefer to interpret our analysis, however, as indicating that price deregulation, allowing firms to price discriminate, is more likely to benefit consumers the easier it is for firms to change a product's location *ex post.* This implies that there is more likely to be a need for some price regulation when relocation costs are fairly high, a condition that is easily verifiable by antitrust and other regulatory bodies.

1 Introduction

This paper re-examines the economic justification for regulatory authorities imposing controls upon firms' pricing policies.

It was widely accepted up to the early 1980's that regulating firms' pricing polices was in the public interest. Examples of such controls were common: they included regulation of the US and European airline industries, the application of resale price maintenance, the policies articulated by the UK Price Commission attacking discriminatory pricing. The most extreme cases arose when the French government decided to freeze prices on several occasions up to the mid 1980s.

The last decade has seen an almost total reversal of this policy stance. For example, there has been no use of the Robinson-Patman Act in the US, the Price Commission was abolished in the UK, and in general firms have been left freer to set their prices as they see fit. This has been justified in part by the view that unregulated markets would be more competitive.

At least two bodies of economic theory have been used to justify (sometimes *ex post*) this more liberal policy. First, there is the theory of contestable markets based on the work of Baumol, Panzar and Willig (1982) according to which even a monopolist will set price at the competitive level because of the existence of *potential* entrants. Secondly, there are the modern developments in spatial pricing in which it is shown that spatial price discrimination leads to market outcomes that are often preferable to those that arise under non-discriminatory, mill pricing: see, for example, Anderson, de Palma and Thisse (1989), Norman (1983), Thisse and Vives (1988). The underlying idea is that discriminatory pricing is tougher than mill pricing and so is pro- rather than anti-competitive. Thus, discriminatory prices can be defended against action under the Robinson-Patman Act or international anti-dumping legislation if they are intended to "meet the competition"

The deficiencies of contestability are familiar and will not be discussed in this paper. By contrast, the benefits claimed for discriminatory spatial pricing have not been called into question. A major limitation of the existing analysis, however, is that it treats market structure (e.g. the number and locations of firms) as exogenous.[1] This loses an important trade-off. *Precisely because discriminatory pricing is more competitive between incumbents, it acts as a strong entry deterrent.* The benefits of lower prices with a given number of firms may be more than offset by a reduction in the number of firms that can enter the market. This effect can be illustrated by two examples. In the UK there has been a sharp decline in the number of small grocers as a result of the discriminatory pricing practices of the large retail chains after the passage of the Resale Prices Act in 1964 abolishing resale price maintenance (Everton (1993)). At the other extreme, it is well known in France that the "Lang" Law forbidding discounts on books was intended to preserve a large network of small bookstores.[2]

We evaluate this trade-off by comparing the effects of discriminatory and mill pricing on product variety, consumer and producer surplus in a horizontally differentiated product market with free entry. It is well-known that free entry can lead to too much or too little product variety (Spence (1976), Dixit and Stiglitz (1977), Salop (1979), MacLeod, Norman and Thisse (1988)). We also know that consumer and producer surplus is affected by the pricing policy that firms are allowed to employ, in particular, by whether firms are allowed to price discriminate between consumers (Greenhut, Norman and Hung (1987), Norman (1989)). What is not known is the impact of pricing policy on the extent and social consequences of entry.

In the type of market we consider, entry continues to the point at which no further entrant perceives the possibility of at least breaking even, but this leaves a wide range of potential free-entry equilibria. The ability of incumbents to make binding location commitments is critical in determining where within this range the actual equilibrium will lie. This ability is determined in turn by the ease with which

1 A recent exception is d'Aspremont & Motta (1994) who show that in a spatial duopoly Bertrand competition may prvent the entry of a third firm whereas (weaker) Cournot competition permits the emergence of a triopoly that may be socially more desirable.

2 The Net Book Agreement in the UK between book publishers and retailers preventing price discounting is argued by the publishers and small booksellers to be justifiable on the same grounds. The large booksellers are pressing for the abolition of the Agreement.

incumbents can revise their location decisions. We provide a detailed analysis of the two polar cases (see e.g. Salop (1979) and Eaton & Lipsey (1978) respectively):

(i) *spatial contestability (SC)* defined as a case in which relocation is costless;

(ii) *spatial non-contestability (SNC)* defined as a case in which relocation is prohibitively costly, i.e. in which location is once-for-all.[3]

Equilibrium product variety is also influenced by the nature of consumer demand. We contrast two types of demand:

(i) *inelastic demand* in the tradition of Hotelling (1929) and Salop (1979);

(ii) *elastic demand* in the tradition of Smithies (1941) and Greenhut (1974).

We show that the greater competitiveness of discriminatory pricing leads to less product variety than mill pricing no matter the degree of spatial contestability or the nature of demand. If demand is inelastic, the welfare consequences of firms' pricing policies depend upon the degree of spatial contestability. With SNC (SC) mill pricing has greater (smaller) consumer surplus than does discriminatory pricing. If demand is elastic, mill pricing gives higher consumer surplus unless, with SC, fixed costs are low. With SNC mill pricing generates lower excess profits for both types of demand but, for elastic demand, higher total surplus. This implies that *a high degree of spatial contestability is necessary for consumers to benefit from price deregulation.*

In the next section we detail the model, define our equilibrium concept and present some preliminary results. Product variety in a free-entry equilibrium is analysed in section 3 and the welfare properties are discussed in section 4. Section 5 summarises our main conclusions.

2 The Model

2.1 Model Description

Our analysis is based on a spatial model that has become standard in the literature on product differentiation. The economy is represented by a one-dimensional

[3] We leave to subsequent analysis the intermediate case of *spatial partial contestability* in which relocation costs are non-zero but not prohibitive.

space Λ of length L over which consumers are uniformly distributed at density D. Without loss of generality we normalise $D = 1$. The space, which may for convenience be considered to be circular, is assumed to be of sufficient extent that we can ignore integer problems. When firms do not price discriminate the interpretation of our model as a model of horizontal product differentiation is so familiar that we need not present it here. With discriminatory pricing: the firm produces a 'base product' which is then redesigned to the customers' specifications. This means that the firm supplies a *band* of horizontally differentiated products, i.e. a large number of varieties, instead of a single product as in the standard model. (MacLeod *et al.* 1988). Product variety is then defined as the number of base products.[4]

Entrant firms are assumed to produce goods that are homogeneous in all respects other than their locations. Production costs are identical for all firms and exhibit economies of scale. Individual product variant costs are:

(1) $C(Q) = f + c.Q$

where f = fixed costs; c = constant marginal cost; Q = total output of the product variant. We normalise by assuming $c = 0$ for all firms and confine our attention to cases in which each firm produces a single (base) product.[5]

We denote by ϑ the set of all potential firms and by ϑ_n the set of firms that choose to enter the market where n is the number of (base) products. The location of firm $i \in \vartheta$ is denoted by x_i where $x_i \in \Lambda$ if firm i chooses to enter the market and $x_i = \varnothing$ otherwise. We refer to the infinite vector $x = (x_i)$ as a *location configuration* and assume that the set ϑ_n corresponds to the first n elements of x.

The delivered price charged by firm $i \in \vartheta_n$ to consumers at location r for any location configuration x is denoted $p_i(r \mid x)$ and we define $p(r \mid x) \equiv \{p_i(r \mid x)\}$ We follow Salop (1979) and assume that transport costs are linear in distance and quantity transported. With mill pricing, firm i's delivered price to consumers at location r is:

(2) $p_i(r \mid x) = m_i + t\|x_i - r\| \qquad \forall i \in \vartheta_n, r \in \Lambda$

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[4] The relevance of this case to the analysis of flexible manufacturing systems should be clear.

[5] We might also consider a case in which firms produce more than one base product provided they are assumed not to produce neighbouring products.

where m_i is the (fob) mill price and t is the transport cost rate. With discriminatory pricing the only restriction we impose on $p_i(r)$ is that:

(3) $\quad p_i(r|x) \geq c + t\|x_i - r\| \qquad \forall\, i \in \vartheta_n,\ r \in \Lambda.$

In other words, firms never price below marginal costs. We denote by P_i the set of feasible price functions $p_i(\cdot|x)$ and we normalise by setting $t = 1$ without loss of generality.

Consumers buy from the firm offering the product at the lowest delivered price. In the event of a price tie we assume that consumers act in a socially optimal manner and purchase from the nearest low-cost firm (MacLeod *et al.* 1988). In equilibrium the set of consumers for which there is a price tie has zero measure. Demand from consumers at location r for the output of firm $i \in \vartheta_n$ is assumed to be given by one of two demand functions:

(i) *inelastic demand:*

(4a) $\quad q_i(p(r|x);r) = 1 \qquad$ if $p_i(r|x) \leq v$ and $p_i(r|x) = \min_j(p_j(r|x))$;

$\qquad\qquad = 0 \qquad$ otherwise;

(ii) *elastic demand:*

(4b) $\quad q_i(p(r|x);r) = a - p_i(r|x) \quad$ if $p_i(r|x) \leq a$ and $p_i(r|x) = \min_j(p_j(r|x))$;

$\qquad\qquad = 0 \qquad$ otherwise;

where v and a are consumer reservation prices.

Profit of firm $i \in \vartheta_n$ is

(5) $$\pi_i(x, p(\cdot|x)) = \int_{\Lambda} \left[p_i(r|x) - c - \|x_i - r\|\right] q_i(p(r|x);r)\, dr - f.$$

Competition is modelled as a two-stage game. In the first stage firms choose whether to enter the market and their locations. In the second stage each entrant firm chooses its prices $p_i(\cdot|x)$ given the total number of firms in the market and their locations. The Nash equilibrium for the price subgame for any location configuration x is defined in the usual way as the set of price functions

$$p^*(\cdot|x) = \{p_i^*(\cdot|x)\} \in P_1 \times \ldots \times P_n$$

such that for all $i \in \vartheta_n$.

$$(6) \qquad \pi_i(x, p^*(\cdot|x)) \geq \pi_i(x, p_i(\cdot|x), p_{-i}^*(\cdot|x)) \quad \forall\ p_i(\cdot|x) \in P_i.$$

In the first stage the profit of firm $i \in \vartheta$ is

$$\pi_i^*(x) = \begin{cases} \pi_i(x, p^*(\cdot|x)) & \text{for } i \in \vartheta_n \\ 0 & \text{otherwise} \end{cases}$$

and an equilibrium for the first stage game is a location configuration x^* such that:

$$(7) \qquad \pi_i^*(x^*) \geq \pi_i(x_i, x_{-i}^*) \qquad \text{for all } x_i \in \Lambda \cup \varnothing \text{ and } i \in \vartheta.$$

In order to keep the analysis reasonably short we make the assumption that incumbent firms are always symmetrically located around the circle and, in the SC case, relocation in response to entry establishes a new symmetric configuration. Consequently, our first-stage analysis deals only with the equilibrium *number* of firms, and not with their locations. This simplifying assumption is not restrictive since it can be shown that the symmetric configuration is a locational equilibrium (see, for example, Novshek (1980), MacLeod *et al.* (1988), Kats (1994)) and so, with our equilibrium number of firms, corresponds to an equilibrium for the first-stage game.

For x^* to be an equilibrium location configuration for the first-stage game it must be that all incumbent products at least break even and that no new entrant product will be able to cover its fixed costs.

2.2 Price Equilibria

In this section we identify the Nash equilibrium pricing policy for the second-stage sub-game:

(i) for any symmetric location configuration x_n^0;

(ii) for x_n^0 in the event of entry between any pair of incumbents given that the incumbents do not relocate.

For simplicity we assume throughout the paper that the reservation prices v and a are high enough with respect to fixed costs f that no firm has monopoly power in any segment of its market area.[6]

2.2.1 Price Equilibria at a Symmetric Location Configuration

The Nash equilibrium discriminatory pricing schedule is identified in Gee (1976), Lederer and Hurter (1986), MacLeod *et al.* (1988) and is the same for both types of demand:

$$(8) \quad p_i^*(r \mid x) = c + \max\left[\|x_i - r\|, \min_{j \neq i}\|x_j - r\|\right] \; \forall \; i \in \vartheta_n, \; r \in \Lambda.$$

In other words, the Nash equilibrium discriminatory price of firm i to consumers at location r is the supply costs of its lowest-cost competitor, provided that firm i is the lowest cost supplier to r and otherwise is its own supply costs.

With mill pricing the Nash equilibrium price is determined by the level of fixed costs and can be expressed as a function of the representative firm's market radius ρ.

(i) inelastic demand:[7]

$$(9a) \quad m_i^*(\rho) = 2\rho \qquad \text{for all } i \in \vartheta_n,$$

(ii) elastic demand:

Mill price is given by the implicit equation (Greenhut, Norman & Hung (1987, p. 59):

$$(9b) \quad m_i^*(\rho) = c + \frac{2\rho\left(a - m_i^*(\rho) - \rho/2\right)}{\left(a - m_i^*(\rho) + \rho\right)} \qquad \text{for all } i \in \vartheta_n.$$

2.2.2 Price Equilibria with Entry

Now consider the Nash equilibrium pricing policy in the event of entry by a new product between any two incumbents *given that the incumbents do not relocate*. We assume that if entry takes place it will do so midway between two incumbents: this makes intuitive sense as the natural focal point and is consistent with Novshek (1980) and Eaton & Wooders (1985).

6 We can show that our analysis is not significantly affected by this assumption.

7 See Salop (1979).

With discriminatory pricing the resulting price equilibrium is still given by equation (8). This implies that an entrant will take half the market area of its immediate neighbours, but there will be no impact on the pricing policies or markets of non-neighbouring firms.

With mill pricing matters are not so simple. If the entrant's immediately neighbouring competitors change their prices, this will affect the second-nearest firms who can be expected to change their prices, which will affect the third-nearest firms who can be expected to change their prices ..... : a chain effect is set up. This case has been analysed by Eaton & Wooders (1985) for quadratic transport costs and we repeat their analysis for linear transport costs.[8]

(i) inelastic demand:

Denote the entrant by 0 and its nearest neighbours by 1 and -1. Assume that the market radius of incumbent firms is ρ. The Nash equilibrium mill price charged by the entrant with SNC and inelastic demand is:

$$(10) \qquad m_0^*(\rho) = \frac{3\left(1+\sqrt{3}\right)\rho}{3+2\sqrt{3}}$$

and the mill prices the entrant expects the neighbouring firms 1, -1 and 2, -2 to charge are:

$$(11) \qquad m_1^*(\rho) = m_{-1}^*(\rho) = \frac{\left(3+4\sqrt{3}\right)\rho}{3+2\sqrt{3}}\,;\; m_2^*(\rho) = m_{-2}^*(\rho) = \frac{\left(7\sqrt{3}\right)\rho}{3+2\sqrt{3}}.$$

(ii) elastic demand

Repetition of the Eaton & Wooders analysis with elastic demand gives a series of second order non-linear difference equations for which there exist no analytic solution methods. We have used the following heuristic approach.

Assume that the ith nearest neighbouring firms to the entrant are expected to change their mill prices from $m^*(\rho)$ to $\lambda_i.m^*(\rho)$ (where λ_i is only restricted to be non-negative). Then it is optimal for the entrant to charge the mill price given by equation

[8] Details are available from the authors on request.

(9b) for its anticipated market area. The λ_i are calculated using numerical analysis in which we assume that the chain reaction in prices damps down by the time it reaches the tenth-nearest firm to the entrant. In other words, we set m^e_{10} and m^e_{-10} to $m^*(\rho)$ where a superscript "e" indicates the optimal post-entry price for an incumbent. Table A1 gives the calculated values of $\lambda_i^*(\rho)$ for different assumed market radii. Note that $\lambda_i^*(\rho)$ approaches unity rapidly, making our assumption that we can limit analysis to chain reactions over the nine nearest neighbouring firms reasonably innocuous. This is also consistent with Eaton & Wooders who indicate that "competition created by entry is *fierce* ... but decidedly *local*." (p. 289) The critical values of $\lambda_i^*(\rho)$ are those for the nearest neighbours to the entrant (i = 1, -1): they are summarised in Table 1.

Table 1: Optimal Price Reaction of The Nearest Neighbouring Incumbents

Market Radius ρ	0.05	0.1	0.2	0.3	0.4	0.5
Price Reaction $\lambda_1^*(\rho), \lambda_{-1}^*(\rho)$	0.7774	0.7906	0.8262	0.8671	0.9070	0.9439

3 Free-Entry Nash Equilibrium Product Variety

3.1 Inelastic Demand and Spatial Contestability

Clearly, the SC free-entry Nash equilibrium degree of product variety is the maximum number of firms that can just break even (this corresponds to the densest packing of firms).

With discriminatory pricing this is:[9]

(12) $n_d^{max} = L.(2f)^{-1/2}$

whereas with mill pricing it is

(13) $n_f^{max} = L.(f)^{-1/2}$

Hence we have:

[9] We use a subscript d to denote discriminatory pricing and a subscript f to denote mill (fob) pricing.

Theorem 1:

If the market is SC and demand is inelastic, mill pricing will lead to greater product variety than discriminatory pricing. The ratio of mill to discriminatory product variety is $n_f^{max}/n_d^{max}=\sqrt{2}$. ■

The greater competitiveness of discriminatory pricing imposes more severe restrictions on product proliferation than does mill pricing.

3.2 Inelastic Demand and Spatial Non-Contestability

When the market is SNC there is a range of potential free-entry equilibria. We take as the Nash equilibrium the location configuration that maximises the profits of each of the incumbent products while preventing the entry of any further firm: i.e. a potential entrant just fails to break even (this corresponds to the loosest packing of firms). At this equilibrium the incumbents fully exploit the entry-deterring advantage of being committed to their locations.

The free-entry equilibrium degree of product variety with SNC, inelastic demand and discriminatory pricing has half as many product variants as with SC:

(14) $$n_d^{min}=L.(8f)^{-1/2}$$

The mill pricing policy in response to entry between two incumbents is given by equations (10) and (11) and the free-entry equilibrium degree of product variety is:

(15) $$n_f^{min}=L.\frac{\sqrt{3/2}}{\sqrt{\left(2+\sqrt{3}\right)f}}$$

from which we conclude:

Theorem 2:

If the market is SNC and demand is inelastic, mill pricing will lead to greater product variety than discriminatory pricing. The ratio of mill:discriminatory product variety with SNC and inelastic demand is $n_f^{min}/n_d^{min}\approx 1.793$. ■

Comparison of the ratio n_f^{min}/n_d^{min} with the ratio n_f^{max}/n_d^{max} shows that with SNC discriminatory pricing is even more effective in limiting product proliferation. If the incumbents can price discriminate *and* can make binding location commitments, the anticipated price reaction is fiercer and entry deterrence stronger than is the case without price discrimination.

3.3 <u>Elastic Demand and Spatial Contestability</u>[10]

Again, the SC free-entry Nash equilibrium degree of product variety is the maximum number of firms that can just break even. It is, in principle, possible to derive an analytic expression for the free-entry Nash equilibrium market radius ρ with SC and elastic demand. With discriminatory pricing this is the solution to the profit equation:

(16) $$\rho_d \,.\, 2\rho_d^2(3a-5\rho_d)/3-f=0$$

With mill pricing it is the solution to the profit equation:

(17) $$\rho_f : \rho_f^2\left(a-25\rho_f+7\sqrt{a^2-2\rho_f a+13\rho_f^2}\right)/2-f=0.$$

These equations are analytically intractable and have been solved using numerical techniques. In doing so we set $a = 1$ without loss of generality: substituting $\rho = \kappa.a$ into the gross profit functions implicit in (16) and (17) yields $a^3 g_d(\kappa)$ and $a^3 g_f(\kappa)$ respectively. Furthermore, since we confine our attention to values of the reservation price and fixed costs for which no firm has monopoly power with either price policy this implies for $a = 1$ that $f \leq 0.11$[11] Figure 1 and Table A2 give the results which can be summarised as follows:

Proposition 1:[12]

> *Assume that the market is SC and demand is elastic. A free-entry SC equilibrium in which incumbents earn zero profit will contain more firms with mill pricing than with discriminatory pricing.* ■

It can also be seen that product variety falls as fixed costs increase, this effect being more marked with mill pricing.

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10 Analysis for elastic demand has been performed using *Mathematica* and *MATLAB*. The authors will be happy to supply further details on request.

11 Details of the calculations are available from the authors on request.

12 We state as Propositions results based at least in part on numerical computations.

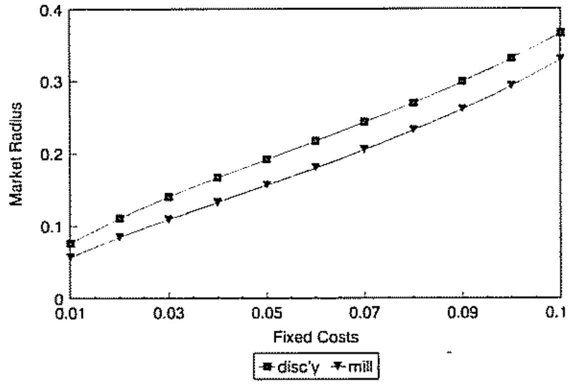

Figure 1: Equilibrium Market Radius:

spatial contestability and elastic demand(a); $a = 1$

(a) Note: $n_{*}^{max} = L / 2\rho_{*}^{min}$

3.4 Elastic Demand and Spatial Non-Contestability

As in section 3.2 we take as the SNC equilibrium the symmetric Nash equilibrium location configuration that maximises the profits of incumbents.

With discriminatory pricing the price equilibrium is given by equation (8b). The equilibrium market radius for incumbent firms is obtained by solving equation (16) for ρ_{de} and setting $\rho_{d}^{max} = 2\rho_{de}$. With mill pricing the numerical analysis is more involved and requires some approximation. For details see the Mathematical Appendix The results are given in Figure 2 and Table A3. We have the same conclusion for SNC as in Proposition 1 for SC.

Tables A2 and A3 indicate that the ratio $\rho_{d}^{max}/\rho_{f}^{max}$ is greater than the ratio $\rho_{d}^{min}/\rho_{f}^{min}$. As with inelastic demand, when the market is SNC discriminatory pricing is even more effective in limiting product proliferation than mill pricing.

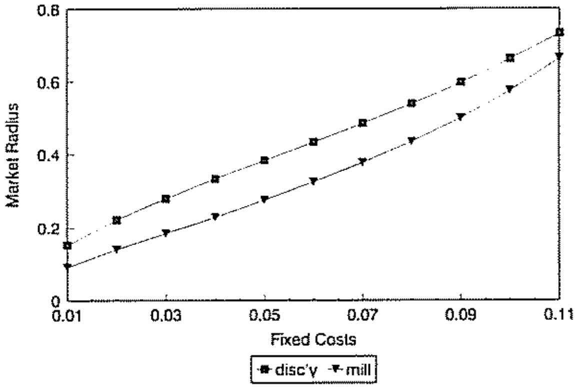

Figure 2: Equilibrium Market Radius:

spatial non-contestability and elastic demand(a); $a = 1$

(a) Note: $n_{\bullet}^{min} = L/2p_{\bullet}^{max}$.

4 Welfare Comparisons

We compare the free entry equilibria for the two pricing systems with respect to the socially optimal degree of product variety, their social welfare and the excess profits they generate with SNC.

With inelastic demand the socially optimal degree of product variety is the number of product variants n^0 that minimises total transport and fixed costs $TC(n)$. MacLeod *et al.*, (1988) show that:

(18) $$n^0 = (4f)^{-1/2}$$

It is readily verified that:

(19) $$TC\left(n_f^{\max}\right) = \frac{5\sqrt{f}}{4}, \quad TC\left(n_d^{\max}\right) = \frac{3\sqrt{f}}{2\sqrt{2}}$$
$$TC\left(n_f^{\min}\right) = \frac{\left(8+\sqrt{3}\right)\sqrt{f}}{\sqrt{24}\sqrt{2+\sqrt{3}}}, \quad TC\left(n_d^{\min}\right) = \frac{3\sqrt{f}}{2\sqrt{2}}$$

Firms' total revenue is denoted $TR(n)$ and consumer surplus $CS(n)$. Note that $CS(n) = v.L - TR(n)$. It is straightforward to show that:

$$TR\left(n_f^{\max}\right)=\frac{5\sqrt{f}}{4};\quad TR\left(n_d^{\max}\right)=\frac{3\sqrt{f}}{2\sqrt{2}}$$

(20)

$$TR\left(n_f^{\min}\right)=\frac{5\sqrt{2+\sqrt{3}}\sqrt{f}}{\sqrt{24}},\quad TR\left(n_d^{\min}\right)=\frac{3\sqrt{f}}{\sqrt{2}}$$

Finally, when the market is SNC incumbents earn supernormal profits in the free-entry equilibrium. Let $\pi_i(n)$ be the excess profit for incumbent firm i and $\Pi(n)$ the aggregate excess profit. We have:

$$\pi_i\left(n_f^{\min}\right)=\frac{1+2\sqrt{3}}{3}f;\quad \pi_i\left(n_d^{\min}\right)=3f$$

(21)

$$\Pi\left(n_f^{\min}\right)=\frac{\left(1+2\sqrt{3}\right)\sqrt{f}}{\sqrt{6}\sqrt{2+\sqrt{3}}};\quad \Pi\left(n_d^{\min}\right)=\frac{3\sqrt{f}}{2\sqrt{2}}$$

With elastic demand the socially optimal degree of product variety requires the planner to choose both the pricing policy and the level of entry. The planner will choose marginal cost pricing and finance fixed costs by a lump-sum tax on consumers. Optimal product variety maximises consumer surplus net of the lump-sum tax.[13] The analysis relies on numerical techniques in which it proves convenient to describe the degree of product variety by the market radius ρ of a representative firm. Recall that the number of product variants is $n = L/2\rho$, indicating that the number of firms is inversely proportional to market radius, and that we confine attention to values of fixed costs for which firms are in the competitive regions of their demand functions, no matter the degree of contestability or their price policy, i.e. to $f \leq 0.11$.

Table 2 and Figure 3 summarise the calculations. Detailed numerical results are given in Tables A2 and A3.

In commenting on the comparisons of pricing policies we need to bear in mind the potentially conflicting effects of discriminatory pricing. On the one hand discriminatory pricing strengthens price competition between entrant firms, lowering prices and the profits of incumbents. On the other hand, discriminatory pricing deters entry for precisely the same reasons, raising prices and the profits of incumbents.

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13 It is easy to show that this is an identical definition of social optimality to that used for inelastic demand.

Which effect is dominant will be determined by the degree of spatial contestability: the less spatially contestable is the market the more dominant is the entry deterrence effect likely to be.

Table 2: Welfare Comparisons

	SC	SNC
Inelastic Demand		
Social Optimum	$n_f^{max} \geq n_d^{max} > n^0$	$n_f^{min} > n^0 > n_d^{min}$
Total Costs	$TC\left(n_f^{max}\right) > TC\left(n_d^{max}\right)$	$TC\left(n_f^{min}\right) < TC\left(n_d^{min}\right)$
Excess Profit	---	$\pi_i\left(n_f^{min}\right) < \pi_i\left(n_d^{min}\right)$ $\Pi\left(n_f^{min}\right) < \Pi\left(n_d^{min}\right)$
Consumer Surplus	$CS\left(n_f^{max}\right) < CS\left(n_d^{max}\right)$	$CS\left(n_f^{min}\right) > CS\left(n_d^{min}\right)$
Elastic Demand		
Social Optimum	$n_f^{max} > n_d^{max} > n^0$	$n_f^{min} > n^0 > n_d^{min}$ for $f < 0.03$ $n^0 > n_f^{min} > n_d^{min}$ for $f > 0.03$
Excess Profit	---	$\pi_i\left(n_f^{min}\right) < \pi_i\left(n_d^{min}\right)$ $\Pi\left(n_f^{min}\right) < \Pi\left(n_d^{min}\right)$
Consumer Surplus	$CS\left(n_f^{max}\right) < CS\left(n_d^{max}\right)$ if f<0.0895 $CS\left(n_f^{max}\right) > CS\left(n_d^{max}\right)$ if f>0.0895	$CS\left(n_f^{min}\right) > CS\left(n_d^{min}\right)$
Total Surplus	---	$TS\left(n_f^{min}\right) > TS\left(n_d^{min}\right)$

4.1 Inelastic Demand

Equations (12)-(15) and (18) show that *with SC there is too much product variety with both discriminatory and mill pricing* whereas *with SNC mill pricing gives too much and discriminatory pricing too little product variety.*

Discriminatory pricing, by limiting product variety, reduces fixed costs but increases transport costs. Whether the savings in fixed costs are sufficient to offset the additional transport costs depends upon the degree of spatial contestability. If the market is SC (SNC) mill pricing imposes higher (lower) total costs than discriminatory pricing.

Whether or not consumers benefit from discriminatory pricing is also dependent upon the degree of spatial contestability. If the market is SC (SNC) mill pricing generates higher (lower) total revenues and so gives lower (higher) consumer surplus than discriminatory pricing.

With SNC discriminatory pricing gives greater supernormal profits to the individual firm and in the aggregate than does mill pricing. *The entry deterrence effect of the fierce price competition of discriminatory pricing more than offsets the additional price competition between incumbents.*

In summary, when demand is inelastic the lower the degree of spatial contestability (the greater are relocation costs) the more effective is discriminatory pricing at limiting entry and the more likely is it that discriminatory pricing will favour producers at the expense of consumers.

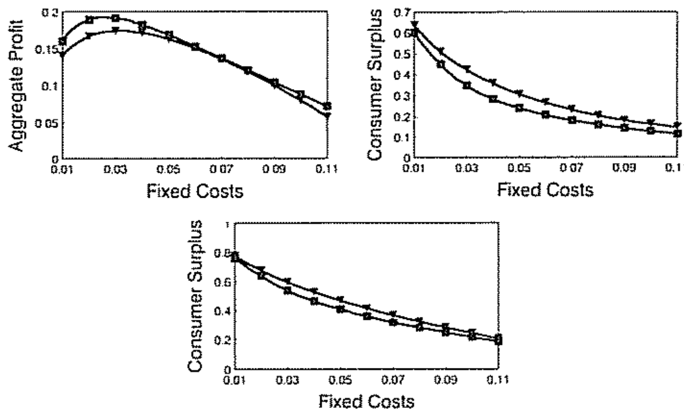
4.2 Elastic Demand

With SC there is too much product variety under both discriminatory and mill pricing. With SNC there is too little product variety with both discriminatory and mill pricing unless fixed costs are low ($f < 0.03$), in which case mill pricing gives too much and discriminatory pricing too little product variety.

With SC discriminatory pricing gives greater consumer and total surplus provided that fixed costs are not too high ($f < 0.0895$) whereas with SNC mill pricing gives higher consumer and total surplus. With SNC discriminatory pricing gives higher individual and aggregate supernormal profits.

As with inelastic demand, discriminatory pricing works to the benefit of producers. The greater are relocation costs the more likely is it that the producers' gains from discriminatory pricing will be at the expense of consumers.

(a) Spatial Non-Contestability (SNC)



(b) Spatial Contestability (SC)

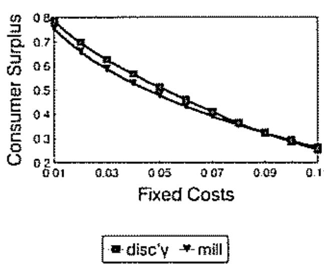


Figure 3: Welfare Comparisons – Elastic Demand

5 Conclusions

In this paper we have shown that product variety in a monopolistically competitive market is determined: (i) by the degree of spatial contestability of the market; that is, by the ability of entrants to make binding location commitments (which is determined by relocation costs) and (ii) by the pricing policy that firms are allowed to employ: in particular, by whether firms are allowed to price discriminate.

Our analysis highlights the potentially conflicting effects of discriminatory pricing. The ability to price discriminate implies that a firm can cut its prices in one part of its market without the need to change its prices elsewhere. This effectively reduces the power of the firm to commit to a set of prices and so strengthens price competition. But fiercer price competition will not necessarily work to the benefit of consumers. On the one hand, for a *given* degree of product variety stronger price competition will, indeed, reduce the prices charged by incumbent firms. On the other hand, stronger price competition can also be expected to act as an entry deterrent, and so may benefit incumbent firms. We have shown that the entry deterrence effect is dominant: *discriminatory pricing leads to less product variety and larger firms than mill pricing*. The power of price discrimination to limit product proliferation is particularly marked when relocation costs are high.[14]

It is unlikely that free entry will lead to the socially optimal degree of product variety. The welfare comparison of discriminatory and mill pricing is affected in large part by the degree of spatial contestability. If the market is SC free entry always gives too much product variety. SNC by contrast, may limit product proliferation excessively and always does so when firms are allowed to price discriminate. With SC the entry deterrence effect of discriminatory pricing weakens the tendency towards excessive product variety and tends to generate greater consumer surplus. With SNC the entry deterrence effect acts primarily to increase incumbent firms' profits (individually and in the aggregate) at the expense of consumers.

Our analysis might be seen as leaving the case against price discrimination not proven. We prefer to interpret our analysis, however, as indicating that price deregulation, allowing firms to price discriminate, is more likely to benefit consumers the easier it is for firms to change a product's location *ex post*. If it is difficult for firms to revise their location decisions after they have entered (what we have referred to as spatial non-contestability) the entry deterring effect of discriminatory pricing is

[14] This is consistent, for example, with the observation made by Collomb and Ponssard (1984) that cement plants in the US, where antitrust policy is more aggressive, are smaller than in Europe.

strengthened and favours producers at the expense of consumers. By contrast, if location decisions can be revised at low cost discriminatory pricing is more likely to favour consumers than mill pricing.

This implies that there is more likely to be a need for some price regulation when relocation costs are fairly high, a condition that is easily verifiable by antitrust and other regulatory bodies. To the extent that regional planning is concerned with encouraging greater geographical dispersion of industry, mill pricing might turn out to be more socially desirable both in terms of consumer welfare and regional planning.

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MATHEMATICAL APPENDIX

Calculation of Optimal Price Response: Elastic Demand

We need to identify $\lambda_1^*(\rho)$ and $\lambda_{-1}^*(\rho)$ but ρ is itself identified from a zero profit condition which is a function of λ and we do not have an explicit equation for λ. We have used the polynomial curve-fitting routine in *MATLAB®* to obtain an approximation for $\lambda_1^*(\rho)$ and $\lambda_{-1}^*(\rho)$:

(A1) $\lambda_1^*(\rho) = \lambda_{-1}^*(\rho) \approx 0.7662 + 0.1799\rho + 0.7668\rho^2 - 0.8357\rho^3$

Solution for equilibrium product variety with fob pricing requires that we solve a system of simultaneous equations consisting of equation (A1) and the equations:

(i) optimal mill price m of an incumbent with market radius ρ (see (9b)):

(A2) $m.(1 - m + \rho) - 2\rho(1 - m - \rho/2) = 0$

(ii) optimal mill price of the entrant (m^e):

(A3) $(1 - m^e)(\lambda.m + \rho - 2m^e) - (\lambda.m + \rho - m^e).(m^e + \lambda.m + \rho)/4 = 0$

(iii) market radius of the entrant (ρ^e)

(A4) $m^e + 2\rho^e - \lambda.m - \rho = 0$

(iv) zero profit condition for the entrant

(A5) $2(1 - m^e).m^e.\rho^e - m^e.(\rho)^2 - f = 0.$ ∎

APPENDIX TABLES

Table A.1: Calculated Values of $\lambda_i^*(\rho)$

i	Market Radius ρ				
	0.05	0.15	0.25	0.35	0.45
1, -1	0.7774	0.8072	0.8465	0.8874	0.9258
2, -2	0.9459	0.9655	0.9833	0.9942	0.9992
3, -3	0.9869	0.9940	0.9983	0.9997	1.0000
4, -4	0.9968	0.9989	0.9998	1.0000	1.0000
5, -5	0.9992	0.9998	1.0000	1.0000	1.0000
6, -6	0.9998	1.0000	1.0000	1.0000	1.0000
7, -7	1.0000	1.0000	1.0000	1.0000	1.0000
8, -8	1.0000	1.0000	1.0000	1.0000	1.0000
9, -9	1.0000	1.0000	1.0000	1.0000	1.0000

Table A.2: Welfare Comparisons – SC

f	ρ_d^{min}	ρ_f^{min}	ρ^0	$m_i^*(\rho)$	$CS(\rho_d^{min})$	$CS(\rho_f^{min})$
0.01	0.0756	0.0562	0.1036	0.1024	0.7864	0.7563
0.02	0.1108	0.0844	0.1490	0.146	0.6964	0.6596
0.03	0.1399	0.1090	0.1850	0.1797	0.6261	0.5875
0.04	0.1664	0.1325	0.2162	0.208	0.5655	0.5282
0.05	0.1917	0.1558	0.2444	0.2327	0.5107	0.4772
0.06	0.2167	0.1797	0.2706	0.2547	0.4595	0.4323
0.07	0.2423	0.2047	0.2952	0.2743	0.4101	0.3921
0.08	0.2694	0.2313	0.3187	0.2918	0.3630	0.3555
0.09	0.2986	0.2603	0.3413	0.3073	0.3218	0.3221
0.10	0.3306	0.2924	0.3633	0.3208	0.2857	0.2912
0.11	0.3659	0.3289	0.3846	0.3322	0.2536	0.2624

Table A.3: Welfare Comparisons – SNC

f	ρ_d^{max}	ρ_f^{max}	ρ^0	$m_i^*(\rho)$	$\pi_i(\rho_d^{max})$	$\pi_i(\rho_f^{max})$
0.01	0.1513	0.0915	0.1036	0.1562	0.0242	0.0128
0.02	0.2215	0.1404	0.1490	0.2168	0.0419	0.0234
0.03	0.2797	0.1851	0.1850	0.2592	0.0536	0.0322
0.04	0.3327	0.2295	0.2162	0.2907	0.0606	0.0393
0.05	0.3833	0.2754	0.2444	0.3141	0.0646	0.0448
0.06	0.4334	0.3240	0.2706	0.3309	0.0662	0.0487
0.07	0.4846	0.3766	0.2952	0.3420	0.0662	0.0510
0.08	0.5388	0.4343	0.3187	0.3478	0.0649	0.0514
0.09	0.5973	0.4991	0.3413	0.3486	0.0622	0.0498
0.10	0.6611	0.5738	0.3633	0.3443	0.0580	0.0457
0.11	0.7317	0.6632	0.3846	0.3338	0.0524	0.0381

f	$\Pi(\rho_d^{max})$	$\Pi(\rho_f^{max})$	$CS(\rho_d^{max})$	$CS(\rho_f^{max})$	$TS(\rho_d^{max})$	$TS(\rho_f^{max})$
0.01	0.1602	0.1401	0.5995	0.6375	0.7597	0.7776
0.02	0.1892	0.1667	0.4500	0.5101	0.6391	0.6767
0.03	0.1917	0.1739	0.3474	0.4232	0.5391	0.5971
0.04	0.1823	0.1713	0.2835	0.3579	0.4658	0.5293
0.05	0.1684	0.1628	0.2400	0.3069	0.4085	0.4697
0.06	0.1529	0.1504	0.2078	0.2659	0.3607	0.4163
0.07	0.1367	0.1354	0.1824	0.2325	0.3191	0.3679
0.08	0.1204	0.1184	0.1614	0.205	0.2818	0.3234
0.09	0.1041	0.0998	0.1436	0.1822	0.2476	0.2821
0.10	0.0878	0.0797	0.1282	0.1635	0.2160	0.2432
0.11	0.0716	0.0575	0.1149	0.1486	0.1864	0.2061