Equilibrium Product Lines: Competing Head-to-Head May Be Less Competitive

By PAUL KLEMPERER*

I suggest a new model of demand for variety that explains why competing firms may choose very similar product lines: if firms offer different product ranges, some consumers use multiple suppliers to increase variety, and since these consumers' purchases will be sensitive to the difference in firms' prices, the market may be fairly competitive. If, instead, firms offer identical product ranges, each consumer purchases from one firm only, because of costs of using additional suppliers, so the market may be less competitive and equilibrium prices higher. This contrasts with the standard intuition that firms minimize competition by differentiating their products. (*JEL* L13, D43, L81)

Do competing firms choose products that "fill in the gaps" between competitors' products, or do they compete "head-to-head" by making product choices that directly match their competitors' products? The simplest economic intuition is that firms will choose different product locations from their opponents' in order to reduce competition and so raise prices. This paper, however, shows that directly matching opponents' product choices may result in *less* competition (hence, higher prices) than choosing products to fill in the gaps between opponents' products, if consumers are brand-loyal or have costs of using additional suppliers. In showing this, I propose a new model of demand for variety that may be of independent interest in explaining other aspects of competition between multiproduct firms.

Consumers often prefer to concentrate their purchases with a single supplier. It is more convenient to do one's grocery shopping in a single supermarket than to visit several. Airlines prefer to concentrate their aircraft purchases with a single manufacturer because this economizes on training and maintenance costs,[1] and businesses, likewise, often buy their entire car fleets from a single producer. "Frequent-flyer" programs reward passengers for making all their trips on a single airline, and even passengers not enrolled in these programs prefer to use a single airline for the different segments of a single journey.[2] In mar-

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[1]"Boeing claims that if an airline buys an aeroplane of a [different range], the retraining and new maintenance equipment needed will make it 10–20% more expensive than an equivalent aeroplane of a familiar range." United "...said it expects big savings from its [Boeing] 757's because of their commonality with [its existing Boeing fleet]," and British Airways extolled the "...virtues of...family ties...," and said that "...'commonality' means less training and cuts down on the costs of maintenance and spares...," when these two airlines (independently) reordered Boeing aircraft in 1988 (*The Economist*, 30 January 1988, p. 51; 3 September 1988, pp. 8–9; 29 October 1988, pp. 107–8).

Computers provide another obvious example of products for which savings in system-learning costs and in the use of complementary products can be made by using a single supplier.

[2]Passengers prefer to have a single airline responsible for ticketing, baggage handling (and recovering lost bags), and helping them make their connections (including delaying connecting flights as necessary). Dennis W. Carlton et al. (1980 p. 73) estimated that "...the provision of single-carrier service [but not single-plane service, so that passengers must still change

kets like these, consumers have good reason to make purchases from a single company rather than patronize multiple suppliers. In others, feelings of brand loyalty that are harder for economists to rationalize may make consumers repeat-purchase from a supplier from whom they have previously bought similar or related goods, in preference to trying a new supplier. For example, auto companies, among others, base their strategies on a belief that their consumers repeat-purchase.[3]

I will refer to the consumers' real or perceived costs of using additional suppliers as "shopping costs."[4] These shopping costs can explain why firms produce product lines rather than single products.[5] For example, Airbus's explanation for producing a full line of aircraft is that "...without a family of aeroplanes to rival Boeing's, Airbus would be at a serious disadvantage in the market" (*The Economist*, 3 September 1988, p. 9; see also footnote 1). Consumer shopping costs can likewise explain mergers that broaden product lines and other activities that increase compatibility such as the grouping together of stores selling different products in a single shopping center (see Konrad Stahl, 1987). Similarly, marketing practitioners often recommend strategies of "umbrella branding" (selling goods in related markets under the same brand name) and "brand extension" (selling a new product under a brand name that is well-established in a related market) (see e.g., Philip Kotler, 1980). Consumer shopping costs may even explain the internal organization of firms. For example, British Telecom (Britain's dominant telecommunications company) reorganized its structure "...to revolve around the customer rather than products and geography..." and so to "...allow British Telecom to provide a world-wide service to multi-national clients," because, its chairman said, "...big companies want to deal with one supplier" (*The Times* [London], 30 March 1990, p. 21).

In this paper I show that consumer shopping costs can also affect how similar are the product lines that firms offer. Consider, in the absence of these costs, two identical firms, each first choosing the characteristics of a single product and then subsequently choosing prices. (Since prices are more flexible than product-selection or product-design decisions, it is most natural to think of prices as being fixed last.) Because selling identical products results in zero profits in price competition, the firms will choose different characteristics (see e.g., Claude d'Aspremont et al., 1979; Avner Shaked and John Sutton, 1982; Xavier Martinez-Giralt

planes] on a city pair now receiving only multicarrier service (and assuming single and multiple carriers have the same number of flights, scheduled travel time, and unobservable factors) would be worth between $13.10 and $17.75 per traveler [in 1978 dollars, which] represents about 11.2 to 15.2 percent of the average fare of $117 in [their] sample city pairs."

Passengers enrolled in "frequent-flyer" programs are given prizes the values of which are convex in the number of miles traveled.

[3]Industry experts say that auto companies accept lower profits on their bottom-of-the-line models than they need to (and than on other models; see Timothy F. Bresnahan, 1981), in order to attract new customers who will later become valuable repeat-purchasers. For example, *CAR* magazine (April 1989, p. 99) stated, "The Metro will...entice buyers into the bottom end of the Rover range, where they will be ready to climb higher."

[4]The economies of scope of buying related products, arising from these "shopping costs," are similar to the economies of scale in repeat-purchasing a product that are discussed in the "switching-costs" literature (e.g., Klemperer, 1987a, b, 1989; Joseph Farrell and Carl Shapiro, 1988; Alan W. Beggs and Klemperer, 1992). In Birger Wernerfelt's (1985) terminology, consumers using a brand develop "user skills" that may not be transferable to *ex ante* identical alternative brands (see also Wernerfelt [1989]). Thus, this literature has already developed economic reasons for (and implications of) "brand loyalty," but it has concentrated on intertemporal issues and has said little about the choice of "real" product characteristics (as distinct from perceived or nonfunctional characteristics that exist purely to affect compatibility across suppliers). The current paper will focus on the costs of using more than one supplier even in a single period, and the behavior of consumers who do use more than one supplier will be crucial in my analysis of the real product characteristics that firms choose.

[5]This explanation for multiproduct firms parallels that provided by economies of scope on the production side (see John C. Panzar and Robert C. Willig, 1981).

and Damien J. Neven, 1988).[6] Ceteris paribus, this applies as much to the case in which each firm chooses a range of products as to the case of the single-product firm: prices are higher when each firm chooses a different product line than when the firms compete head-to-head with products at the same points in characteristics space. The point of this paper is that introducing shopping costs of using additional suppliers changes this calculation and may mean that firms prefer to compete head-to-head.

Consider, as an example, two supermarkets some distance from each other in a town. If they compete head-to-head, each selling the same brands, types, and qualities of breads, fruits, vegetables, meats, dairy products, and so on, then no consumer will shop at more than one store for reasons of product choice alone. Cutting price attracts only consumers who are currently indifferent between the two supermarkets based on consideration of their prices and physical locations. If only a few consumers (or no consumers) live equidistant between the two stores, then cutting price from a point of equal prices will attract very few additional customers, and prices in the noncooperative equilibrium may therefore be high. In contrast, if the supermarkets differ in the brands, types, and qualities of products that they sell, then consumers with low physical transport costs will shop at both stores. In this case, cutting the price on one or more products will capture more of the business of those shoppers who shop at both stores and will also attract some of the consumers with high physical transport costs who shop at only one supermarket. Therefore, there may be a greater incentive to cut prices than when firms stock identical product lines, and so the prices that result in noncooperative equilibrium may be lower. Thus, supermarkets may stock similar ranges of items. Analogously, auto companies may choose models closely matched to their competitors', and airlines may cluster their departure times, in order to avoid competition!

The paper formalizes this idea in a model in which each consumer wishes to buy a range of products. Section I presents the model, which is an adaptation of Harold Hotelling's (1929) now-standard model of product differentiation. Of course in the present context the standard model, in which each consumer demands only a single product variety, would completely miss the point. A natural simplifying assumption in the present context is, instead, that each consumer demands the entire range of product varieties.

As in the standard model, each consumer's total costs include purchase costs and utility losses from substituting products with less-preferred characteristics for the preferred product(s) not actually purchased. In my model, consumers also face shopping costs that are increasing in the number of suppliers used.

I think that this model is the natural development of the standard model to incorporate demand for variety and costs of using multiple suppliers. It may therefore be of independent interest in explaining other aspects of competition between multiproduct firms that are not addressed by the current analysis.

Section II develops first-order conditions for the equilibrium prices in the model, and Section III compares the profitability of competition when firms offer matching ("head-to-head") product lines, with the profitability of competition when firms offer different ("interlaced") product lines. The latter section shows how this comparison depends on the distribution of shopping costs across consumers and on the nature of consumers' preferences for product variety. In particular, if there are many consumers whose shopping costs are different at the different suppliers, head-to-head competition may not be very competitive. If, in addition, these costs are not too large relative to the value of variety, many consumers buy from both firms if firms offer different product ranges, so interlaced-products competition may be more competitive. However, although firms may make more profits

[6] Harold Hotelling (1929) argued that firms would choose similar characteristics, but this was due to an error in his analysis corrected by subsequent authors.

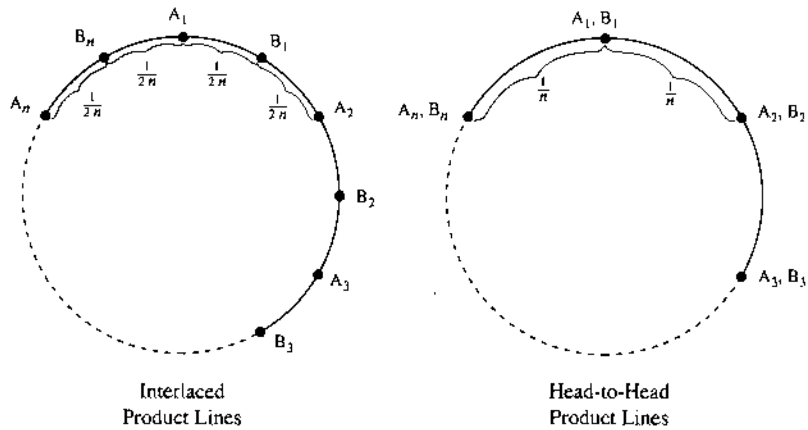

FIGURE 1. THE PRODUCT SPACE

when they offer matching (head-to-head) product lines, social welfare is always higher when firms offer different (interlaced) product lines.

Section IV considers extensions and modifications to the basic model. The main result—that firms may choose identical products to avoid giving any customers incentive to patronize more than one firm and so to avoid the competition that such "loyalty-free" customers induce—is unaffected.[7] Section V summarizes and concludes.

[7]Perhaps the closest work to this paper, although it addresses a different issue, is that of Carmen Matutes and Pierre Regibeau (1988) and Nicholas Economides (1989). They study whether duopolists choose to make their product lines compatible (zero shopping costs in my terminology) or incompatible (infinite shopping costs), whereas I assume that shopping costs are different for different consumers. More importantly, these authors take the functional characteristics of each firm's product line as given, whereas I focus on what product choices firms make. That is, I ask whether firms choose to offer functionally identical (head-to-head) product lines or functionally differentiated (interlaced) product lines, whereas these authors simply assume the latter.

Papers on other aspects of multiproduct firms than those I will discuss include Donald A. Hay (1976), Richard Schmalensee (1978), James A. Brander and Jonathan Eaton (1984), Jeremy I. Bulow et al. (1985), Kenneth L. Judd (1985), Asher Wolinsky (1986), Christopher J. Bliss (1988), Giovanni de Fraja (1989), Rajiv Lal and Matutes (1989), B. Douglas Bernheim and Michael D. Whinston (1990), and Richard Gilbert and Matutes (1990).

I. The Model

Two firms A and B each produce n products within a range indexed by $x \in (0,1]$. The products' characteristics can be thought of as distributed on the circumference of a circle, with product x a fraction x of the distance around the circle from an arbitrary starting point.

Each consumer has inelastic demand for a total of one unit of the product class. Each consumer would like to consume an equal amount of every possible variety $x \in (0,1]$, but the limited number of brands on offer prevents consumers from achieving this ideal. The per-unit cost to any consumer of substituting product x' for a desired product x is a strictly increasing function, g, of the minimum distance around the circle between x and x' $(\min\{|x - x'|, 1 - |x - x'|\})$. Thus, these "substitution costs" correspond exactly to the (psychic) "transport costs" of standard models à la Hotelling (1929). However, my model is unlike standard models in that every consumer has identical tastes for variety, and every consumer wishes to purchase the entire range of possible products.

Consumers also have fixed costs of using suppliers: density $f(y,z)$ of consumers each incurs a fixed shopping cost of y if he buys any output from firm A and a shopping cost of z if he buys any output from firm B. Assume that $f(\cdot,\cdot)$ is continuous and symmetric: $f(y,z)=f(z,y)$ for all y,z; and define $F(\bar{y},\bar{z})=\int_{z=0}^{\bar{z}}\int_{y=0}^{\bar{y}}f(y,z)\,dy\,dz$.

There is a single period of production and sale. Firms have constant, equal marginal costs for n products each, whose locations are taken as fixed. Each firm simultaneously and independently sets a price (p_{A} and p_{B}, respectively) that applies to each of its n products.

I will compare the (symmetric) noncooperative equilibrium prices of two alternative cases: (i) head-to-head competition in which each firm's product line comprises the products located at $x=i/n$, $i=1,\ldots,n$, and (ii) interlaced-product-lines competition in which A's products are located at $x=i/n$, $i=1,\ldots,n$, while B's products are located at $x=(i-\frac{1}{2})/n$, $i=1,\ldots,n$. These two different configurations of firms' product lines are illustrated in Figure 1.

Without further loss of generality I assume that the total mass of consumers is 1 and that firms' constant marginal costs are zero. Many of the assumptions of the model can be relaxed, but I defer discussion of this to Section IV.

II. Equilibrium Prices

A. *Interlaced-Products Competition*

In interlaced-products competition, firm A sets prices p_{A} for products located at i/n, and firm B sets prices p_{B} for products located at $(i-\frac{1}{2})/n$, for $i=1,\ldots,n$. A consumer buying from both suppliers therefore satisfies his demand for the good located at $(i/n)-x$ by buying A's nearest product if

$$p_{\mathrm{A}}+g(x)<p_{\mathrm{B}}+g\left(\frac{1}{2n}-x\right)$$

and by buying B's nearest product otherwise, for $x\in[0,1/2n]$. The same condition applies for the good located at $(i/n)+x$. Let $\hat{x}(p_{\mathrm{A}},p_{\mathrm{B}})$ be the distance from A's closest product of those goods for which the consumer is indifferent between satisfying his demand at A or at B. Then,

$$(1)\quad p_{\mathrm{A}}+g(\hat{x})=p_{\mathrm{B}}+g\left(\frac{1}{2n}-\hat{x}\right).$$

Therefore, excluding shopping costs, a consumer's total costs (purchasing costs plus substitution costs) of buying from both firms are

$$(2)\quad \gamma=2n\left(\int_{x=0}^{\hat{x}}[p_{\mathrm{A}}+g(x)]\,dx+\int_{x=\hat{x}}^{1/2n}\left[p_{\mathrm{B}}+g\left(\frac{1}{2n}-x\right)\right]dx\right).$$

Similarly, net of shopping costs, a consumer's costs of buying only from A are

$$(3)\quad \alpha=2n\int_{x=0}^{1/2n}[p_{\mathrm{A}}+g(x)]\,dx=p_{\mathrm{A}}+2n\int_{x=0}^{1/2n}g(x)\,dx$$

and those of buying only from B are

$$(4)\quad \beta=2n\int_{x=0}^{1/2n}\left[p_{\mathrm{B}}+g\left(\frac{1}{2n}-x\right)\right]dx=p_{\mathrm{B}}+2n\int_{x=0}^{1/2n}g(x)\,dx.$$

(I am suppressing the dependence of α, β, γ, and $\hat{x}$ on p_{A} and p_{B} in order to reduce the burden of notation.)

Now a consumer whose shopping costs at A and B are y and z, respectively, buys only at A if $\alpha+y<\min\{\beta+z,\gamma+y+z\}$, buys only at B if $\beta+z<\min\{\alpha+y,\gamma+y+z\}$, and buys from both suppliers otherwise. Since consumers purchase one unit each in total, and a consumer who buys from both suppliers purchases $2n\hat{x}$ units from A, one can write A's total sales (summed across across all its brands) as

$$(5)\quad q_{\mathrm{A}}=\int_{z=\alpha-\gamma}^{\infty}\int_{y=0}^{z+\beta-\alpha}f(y,z)\,dy\,dz+(2n\hat{x})\int_{z=0}^{\alpha-\gamma}\int_{y=0}^{\beta-\gamma}f(y,z)\,dy\,dz.$$

Since A's total profits are $\pi_{\mathrm{A}} = p_{\mathrm{A}} q_{\mathrm{A}}$, it follows that in equilibrium

$$0 = \frac{\partial \pi_{\mathrm{A}}}{\partial p_{\mathrm{A}}} = q_{\mathrm{A}} + p_{\mathrm{A}} \frac{\partial q_{\mathrm{A}}}{\partial p_{\mathrm{A}}}$$

$$\Rightarrow p_{\mathrm{A}} = \frac{q_{\mathrm{A}}}{(-\partial q_{\mathrm{A}} / \partial p_{\mathrm{A}})}. \tag{6}$$

Now, differentiating (5),

$$\begin{aligned} \frac{\partial q_{\mathrm{A}}}{\partial p_{\mathrm{A}}} &= \frac{\partial(\beta - \alpha)}{\partial p_{\mathrm{A}}} \int_{z=\alpha-\gamma}^{\infty} f(z + \beta - \alpha, z)\, dz \\ &\quad - \frac{\partial(\alpha - \gamma)}{\partial p_{\mathrm{A}}} \int_{y=0}^{\beta-\gamma} f(y, \alpha - \gamma)\, dy \\ &\quad + 2n \frac{\partial \hat{x}}{\partial p_{\mathrm{A}}} \int_{z=0}^{\alpha-\gamma} \int_{y=0}^{\beta-\gamma} f(y, z)\, dy\, dz \\ &\quad + 2n\hat{x} \frac{\partial(\beta - \gamma)}{\partial p_{\mathrm{A}}} \int_{z=0}^{\alpha-\gamma} f(\beta - \gamma, z)\, dz \\ &\quad + 2n\hat{x} \frac{\partial(\alpha - \gamma)}{\partial p_{\mathrm{A}}} \int_{y=0}^{\beta-\gamma} f(y, \alpha - \gamma)\, dy. \end{aligned} \tag{7}$$

Equations (1), (2), (3), and (4) can be used to obtain $\partial\alpha / \partial p_{\mathrm{A}} = 1$, $\partial\beta / \partial p_{\mathrm{A}} = 0$, $\partial\gamma / \partial p_{\mathrm{A}} = 2n\hat{x}$ [making use of (1)], and

$$\frac{\partial \hat{x}}{\partial p_{\mathrm{A}}} = \frac{-1}{g'(\hat{x}) + g'\left(\frac{1}{2n} - \hat{x}\right)}.$$

Furthermore, in symmetric equilibrium, $p_{\mathrm{A}} = p_{\mathrm{B}} \equiv p_{\mathrm{I}}$, $q_{\mathrm{A}} = \frac{1}{2}$, $2n\hat{x} = \frac{1}{2}$, and $\alpha - \gamma = \beta - \gamma \equiv \Delta$, so one obtains

$$\frac{\partial q_{\mathrm{A}}}{\partial p_{\mathrm{A}}} = -\left[\int_{z=\Delta}^{\infty} f(z, z)\, dz + \frac{1}{2} \int_{y=0}^{\Delta} f(y, \Delta)\, dy + nF(\Delta, \Delta) \Big/ g'\left(\frac{1}{4n}\right)\right]. \tag{7'}$$

Provided the first-order conditions specify firms' global best responses, substituting $q_{\mathrm{A}} = \frac{1}{2}$ and (7′) into (6) yields a unique symmetric equilibrium price in the case of interlaced products, namely,

$$p_{\mathrm{I}} = \frac{1/2}{\int_{z=\Delta}^{\infty} f(z, z)\, dz + \frac{1}{2} \int_{z=0}^{\Delta} f(z, \Delta)\, dz + \dfrac{nF(\Delta, \Delta)}{g'(1/4n)}} \tag{8}$$

where

$$\Delta = 2n \int_{x=0}^{1/4n} \left[g\left(x + \frac{1}{4n}\right) - g(x) \right] dx \tag{9}$$

is the saving in substitution costs from buying from both firms rather than just one (in symmetric equilibrium).[8] Thus, Δ is also the incremental utility that a consumer buying from only one firm would receive if that firm were to offer double the number of equally spaced brands at the same prices.

The interpretation of (8) is straightforward. The cost to firm A of a small price cut of ε on all its products would be a loss of ε on the number ($\frac{1}{2}$) of units it sells (in equilibrium). The benefits to firm A of the price cut would be the increased revenues from four groups of consumers: (i) those who switch from buying only from B to buying only from A, (ii) those who switch from buying only from B to buying from both firms, (iii) those who switch from both firms to buying only from A, and (iv) those who continue to buy from both firms but who now buy more units from firm A. Consider

[8]The second-order conditions for p_{I} to be both firms' local best response can be written

$$1 \geq p_{\mathrm{I}}^2 \left[\frac{1}{2} f(\Delta, \Delta) - \int_{z=\Delta}^{\infty} \frac{\partial}{\partial p_{\mathrm{A}}} f(z + p_{\mathrm{B}} - p_{\mathrm{A}}, z)\, dz - 2n \frac{\partial^2 \hat{x}}{\partial p_{\mathrm{A}}^2} F(\Delta, \Delta) \right] \Bigg|_{p_{\mathrm{A}} = p_{\mathrm{B}} = p_{\mathrm{I}}}$$

The conditions for p_{I} to be both firms' global best response are exceedingly cumbersome but are satisfied for the special cases I will discuss below.

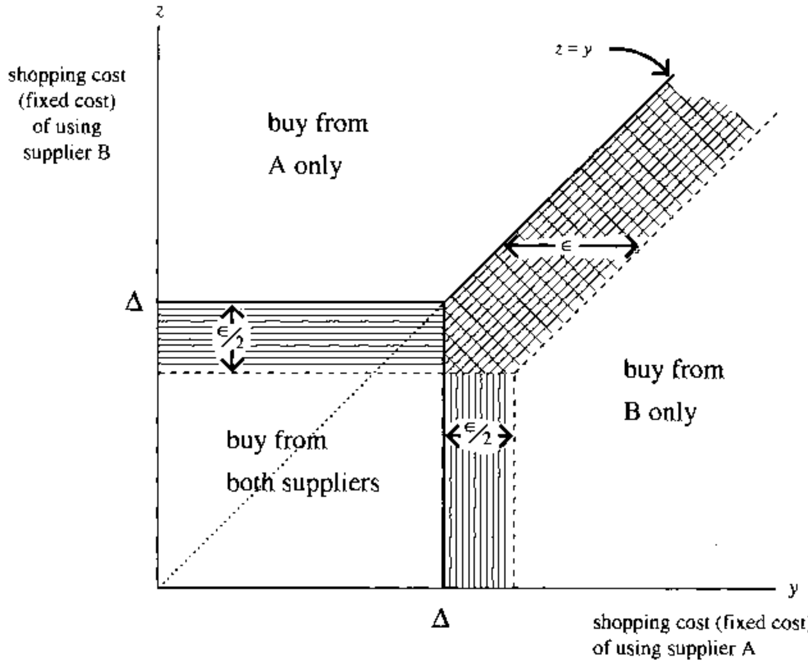

FIGURE 2. EFFECT OF FIRM A CUTTING PRICE BY ε FROM SYMMETRIC EQUILIBRIUM WITH INTERLACED PRODUCT LINES

these four groups of consumers in turn (see Fig. 2).

First, the gain to consumers from buying only from A increases by ε relative to buying only from B. This induces those consumers whose shopping costs lie in the cross-hatched area of Figure 2 (between the solid diagonal and the new dashed "indifference line" distance ε to its right) to buy one unit each (versus none previously) from A at price $p_A - \varepsilon$. Their mass approximates $\varepsilon \int_{z > \Delta} f(z, z)\, dz$ for small ε [because $f(\cdot, \cdot)$ is continuous]. This explains the first term in the denominator of (8).

Second, the gain to consumers from buying from both firms rather than just from firm B increases by approximately $\varepsilon/2$. (Around equal prices, consumers buying from both firms buy approximately $\frac{1}{2}$ unit from each firm.) This induces those consumers with shopping costs in the vertically shaded area of Figure 2 to buy from both firms rather than just firm B, and to buy approximately $\frac{1}{2}$ unit (versus none previously) from A at price $p_A - \varepsilon$. Since the mass of these consumers is approximately $(\varepsilon/2)\int_{z=0}^{\Delta} f(\Delta, z)\, dz$, for small ε, this yields incremental revenue of approximately $(\varepsilon/4)p_A \int_{z=0}^{\Delta} f(\Delta, z)\, dz$. [This explains half of the middle term in the denominator of (8).]

Third, the gain to consumers from buying from both firms, rather than just from firm A, decreases by approximately $\varepsilon/2$, so that those consumers with shopping costs in the horizontally shaded area of Figure 2, who prefer A to B but who previously used both suppliers, now use only supplier A. This yields an additional incremental revenue of approximately $(\varepsilon/4)p_A \int_{y=0}^{\Delta} f(y, \Delta)\, dy$. This adds to the second component to yield (approximately) $(\varepsilon/2)p_A \int_{z=0}^{\Delta} f(\Delta, z)\, dz$ [using the symmetry of $f(\cdot, \cdot)$] and hence the middle term in the denominator of (8).

Finally, a fraction $F(\Delta, \Delta)$ (approximately) of consumers have low enough shopping costs that they use both suppliers, and these consumers make a larger proportion of their purchases from the supplier that offers the lower prices. A price cut of ε

on each of A's n products induces these consumers to switch purchases from B to A at each of the $2n$ points on the product circle at which these consumers are indifferent between buying A's nearest product and buying B's nearest product. At each of these $2n$ margins, shifting δ units of purchases from B to A increases the substitution cost of the marginal purchase from A to $g([1/4n]+\delta)$ per unit, and reduces the substitution cost of making the marginal purchase from B to $g([1/4n]-\delta)$ per unit. For consumers to be in equilibrium, therefore, $\varepsilon = g([1/4n]+\delta) - g([1/4n]-\delta) \approx 2\delta g'(1/4n)$. Thus $\delta \approx \varepsilon / 2g'(1/4n)$ units are shifted from B to A at each margin in response to a price cut of ε, yielding a total incremental revenue of approximately

$$\varepsilon p_{\mathrm{A}}\left[\frac{n}{g'(1/4n)}\right]F(\Delta,\Delta).$$

This explains the last term in the denominator of (8). In equilibrium, the cost of a small price cut equals the sum of the four benefits, so one obtains (8).

The first three benefits stem from a small number of consumers each switching a large amount of business between the firms. This is analogous to the benefits of a price cut in head-to-head competition. However, the fourth benefit of a price cut (that each of the large number of consumers who buy from both firms switches a small amount of business between the firms) arises only in interlaced-products competition. (In head-to-head competition, no consumers buy from both firms.) Thus this last effect can play a critical role in making interlaced-products competition more competitive than head-to-head competition.

B. *Head-to-Head Competition*

In head-to-head competition in which both firms locate products at i/n, for all $i = 1,\dots,n$ (identical product lines), and in which each firm sets a single price for all its brands, no consumer finds it worthwhile to buy from more than one firm. A consumer with shopping costs y and z of buying from A and B, respectively, will buy only from A if $p_{\mathrm{A}} + y < p_{\mathrm{B}} + z$ and only from B otherwise, so A's sales are

$$(10)\quad q_{\mathrm{A}} = \int_{z=0}^{\infty}\int_{y=0}^{z+p_{\mathrm{B}}-p_{\mathrm{A}}} f(y,z)\,dy\,dz.$$

Since A's total profits are $\pi_{\mathrm{A}} = p_{\mathrm{A}} q_{\mathrm{A}}$, the first-order condition for equilibrium for firm A is

$$(11)\quad 0 = \frac{\partial \pi_{\mathrm{A}}}{\partial p_{\mathrm{A}}}$$

$$= q_{\mathrm{A}} - p_{\mathrm{A}}\int_{z=0}^{\infty} f(z+p_{\mathrm{B}}-p_{\mathrm{A}}, z)\,dz.$$

In symmetric equilibrium $q_{\mathrm{A}} = \frac{1}{2}$, so provided (11) specifies firms' global best responses, the unique symmetric equilibrium price in head-to-head competition is

$$(12)\quad p_{\mathrm{H}} = \frac{1}{2\left[\int_{z=0}^{\infty} f(z,z)\,dz\right]}$$

$$= \frac{1/2}{\int_{z=\Delta}^{\infty} f(z,z)\,dz + \int_{z=0}^{\Delta} f(z,z)\,dz}.$$

This price depends only on the density of consumers who have equal shopping costs at the two firms. In this equilibrium, these are the only consumers whose purchases are attracted by a small price cut.

III. Comparison of Equilibria

Absent shopping costs, head-to-head competition yields equilibrium price $p_{\mathrm{H}} = 0$, while interlaced-products competition yields equilibrium price $p_{\mathrm{I}} = g'(1/4n)/2n > 0$. However, in the presence of shopping costs there is no general ranking of p_{H} and p_{I}. To understand this, observe from (8) and (12) that p_{H} depends only on the density of consumers with equal shopping costs for the two firms, while p_{I} also depends importantly on other parts of the density function of shopping costs and on the form of the substitution-cost function.

Assume first that substitution costs are linear in distance between ideal and actually purchased products and that consumers' shopping costs are uniformly distributed on an interval $[0,s]$ for each firm and are independent across firms. That is, $g(x)=tx$ and $f(x,y)=1/s^2$ for $x,y \in [0,s]$. Then, using (9), the saving in substitution costs from buying from both firms rather than just one when firms' products are interlaced is $\Delta = t/8n$. If $\Delta < s$, so that not all consumers buy from both firms in interlaced-products competition, one can use (8) and (12) to compute that

$$p_{\mathrm{H}} = \frac{s}{2} \tag{13a}$$

(13b)

$$p_{\mathrm{I}} = \frac{1}{2\left[\dfrac{s-(t/8n)}{s^2} + \frac{1}{2}\left(\dfrac{t/8n}{s^2}\right) + \dfrac{n(t/8ns)^2}{t}\right]} = \frac{s}{2}\left[\frac{1}{1-(3t/64ns)}\right].$$

Thus, in the special case, head-to-head competition is always more competitive than interlaced-products competition, though the difference is not large and decreases in n.[9]

However, if the density $f(z,z)$ of consumers who have the same shopping costs at both firms is decreased, this increases the head-to-head price by proportionately more than the interlaced-products price. (If this density is decreased only for consumers with shopping costs below Δ, then p_{H} is increased, but p_{I} is unaffected by the change.) Similarly, altering the density in other critical areas can lower p_{I} but leave p_{H} unaffected.

Likewise, changing the substitution-cost function can increase the sensitivity to price competition of the group of consumers that buys from both firms in interlaced-products competition and so make the interlaced-products equilibrium more competitive. Assuming, as above, uniform consumer shopping costs on $[0,s]$ independent across firms, but allowing general substitution costs $g(x)$, would yield

$$p_{\mathrm{H}} = \frac{s}{2} \tag{14a}$$

$$p_{\mathrm{I}} = \frac{s}{2}\left[\frac{1}{1+\dfrac{\Delta}{2s}\left(\dfrac{2n\Delta}{g'(1/4n)} - 1\right)}\right] \tag{14b}$$

with Δ defined as in (9), provided $\Delta < s$ and the first-order conditions specify firms' global best responses. Reducing the marginal substitution cost at the midpoint between competing brands, $g'(1/4n)$, relative to the total substitution costs saved by buying from both firms rather than just one firm, Δ, reduces p_{I} while leaving p_{H} unaffected. Thus, it is possible to construct examples in which head-to-head competition yields higher prices than interlaced-products competition.[10]

Although firms may find head-to-head competition more profitable, social welfare (as conventionally measured by consumer surplus plus industry profits) is always higher in interlaced-products competition. The reason is that, because demand is inelastic, social welfare depends only on substitution costs and shopping costs incurred, and it

[9]In head-to-head competition, p_{H} is a global best response for both firms for all values of the parameters. In interlaced-products competition, p_{I} is a global best response for both firms provided $t < 7ns$.

[10]An extreme example in which both the distribution of shopping costs and the substitution-cost function have been chosen in the manner suggested in the preceding discussion to increase the relative profitability of head-to-head competition, and for which head-to-head equilibrium profits are $\frac{1}{2}(1+\sqrt{2})$ per firm while interlaced-products equilibrium profits are only $\frac{1}{2}$, has $g(x)=2nx$ for $x \leq X$ for X close to $1/2n$, $g(\cdot)$ continuous and increasing such that $2n\int_0^{1/2n} g(x) = \frac{3}{2}$, and $f(\cdot,\cdot)$ consisting of equal atoms at $(0,1)$ and $(1,0)$. [For this example I have dropped the assumption that $f(\cdot,\cdot)$ is continuous, and firms use mixed strategies in head-to-head equilibrium, but it is easy to obtain similar examples involving pure-strategy equilibria by imposing a finite reservation price.] Another numerical example with $p_{\mathrm{H}} > p_{\mathrm{I}}$ is developed in the Appendix.

does not depend directly on prices. Social welfare in the interlaced-products equilibrium (SW_I) and in the head-to-head equilibrium (SW_H) would thus be the same if all consumers were restricted to buying from only one firm. It follows that welfare is higher in the interlaced-products equilibrium, by an amount equal to the savings in substitution costs made by those consumers who buy from both firms, less the additional shopping costs that these consumers incur in that equilibrium; that is,

$$(15)\quad SW_I - SW_H = \int_{z=0}^{\Delta}\int_{y=0}^{\Delta}[(\Delta - \max(y,z))f(y,z)]\,dy\,dz > 0$$

in which Δ is defined as in (9).

In the Appendix, I discuss a model with elastic demand and show that in this case head-to-head competition results in an additional welfare loss, relative to interlaced-products competition, of the usual kind (the greater deadweight loss resulting from a smaller output) when this mode of competition is preferred by firms to interlaced-products competition.

Note that firms' preference between head-to-head and interlaced-products competition is sensitive to different factors from those that are most important in determining how great are the extra social costs of head-to-head competition. Prices depend on the numbers of consumers who are marginal between using the different suppliers, or marginal between using one or both suppliers, but the extra social costs of head-to-head competition depend on the savings in substitution costs less shopping costs of the inframarginal consumers who strictly prefer to use both suppliers in interlaced-products competition. Likewise, the relative competitiveness of the two modes of competition may vary in any way with the absolute magnitude of the substitution-cost function, because although increasing the value of product variety increases the proportion of consumers who buy from both firms in interlaced products competition, it also reduces the sensitivity of these consumers' purchases to firms' prices. However, the social benefit from interlaced product ranges, $SW_I - SW_H$, always increases *more* than proportionately to an increase in substitution costs.[11]

IV. Extensions

This section explains that my main result —that firms may earn greater profits from head-to-head competition than from interlaced-products competition, in either single-product competition ($n = 1$) or product-line competition ($n > 1$)—is robust to altering or generalizing many of the assumptions.

In the Appendix, I provide an example in which firms choose quantities rather than prices and in which industry demand is elastic. In this case, when firms prefer head-to-head product lines, social welfare is reduced relative to interlaced-product lines for two reasons: head-to-head product lines not only reduce variety, but because demand is elastic and competition is reduced, they also lower total industry output and thus increase deadweight losses of the standard kind.[12] In fact, for some parameter values of this example, allowing firms to collude on both their product locations and their outputs would make both firms and consumers better off than under head-to-head competition: colluding firms always prefer interlaced products, and although the price would be higher than in head-to-head competition, the total cost (price plus substitution costs plus shopping costs) that each consumer pays would be lower.

I assumed that every consumer would like to consume an equal amount of every possible product. The working-paper version of this paper (Klemperer, 1990) shows that

[11] Substitution costs saved, less fixed shopping costs, increase more than proportionately to substitution costs for those who buy from both firms anyway, and furthermore, more consumers will make savings by buying from both firms; see equation (15).

[12] When firms prefer interlaced product lines, welfare is indeterminate, because head-to-head product lines may then provide lower variety but greater output.

neither generalizing to allow consumers to have demand $h(x)$ for the good located at $x \in (0,1]$ nor further generalizing to allow different consumers to have different demands and different substitution-cost functions (e.g., individual consumers may have positive demand for only some product varieties) alters the basic results.

The working-paper version also discusses extensions to alternative product spaces. I conjecture that head-to-head competition is an even more likely outcome when the product space can be represented by a straight line, because moving a brand's location toward the middle of the line moves it closer to most demand, which may provide an additional pressure toward the agglomeration of competing products.[13]

Almost all of my analysis would be unaffected by allowing firms to choose different prices, $p_A^1, \dots, p_A^n$ and $p_B^1, \dots, p_B^n$, for different brands. This is because the first-order conditions for any equilibrium in which $p_A^1 = \cdots = p_A^n$ and $p_B^1 = \cdots = p_B^n$ would be exactly those that I obtained.

Probably the most important limitation of my analysis is that I have not shown that either of the two polar opposite location patterns I have compared is necessarily the equilibrium outcome of any very general game.[14] Ideally, one would solve for the equilibrium of a two-stage game in which firms first choose the number and locations of their brands (with a fixed cost of producing each additional variety) and then choose prices.[15] It is very hard to make much progress in analyzing such a general model,[16] but the questions that it suggests form a natural agenda for future research that could be pursued using versions of my model.

V. Conclusion

Industry profits may be higher in a noncooperative equilibrium in which firms compete head-to-head with identical products than in one in which their product offerings are interspersed. The intuition is that identical products give a consumer no reason to buy from more than one supplier and so reinforce brand loyalty; if few consumers make the additional investment of buying and using more than one firm's products, then the price-sensitive fraction of the market is small, and equilibrium prices may be high.

[13]In the product space of my model (the circumference of a circle) there is no *ex ante* best location. This shows that my result is not simply an example of the "maxmin" phenomenon (see e.g., Damien Neven and Jacques-François Thisse, 1987) that firms that are differentiated in one dimension may all choose the best (e.g., most central) location on another.

[14]The configuration I find firms to prefer is the equilibrium of the following three-stage game. Stage 1: firm A chooses equally spaced locations for its n products. Stage 2: firm B chooses locations for its n products that are either identical to A's locations or interlaced with, and maximally differentiated from, A's locations. Stage 3: firms noncooperatively and simultaneously choose prices for their products.

The configuration is also the (pure-strategy) equilibrium of the following two-stage game. Stage 1: firms simultaneously choose n equally spaced product varieties with the first variety either at a specified point or distance $1/2n$ from that point. Stage 2: firms set prices.

One can also say that if head-to-head competition yields greater profits than interlaced-products competition, then a state of maximally differentiated interlaced product lines is not an equilibrium of any natural game.

[15]One might also add a prior stage in which firms make decisions that affect the shopping costs. A further extension is to model consumers who buy in several periods but need to pay shopping costs only once (equivalently, consumers develop brand loyalty after one purchase). In this case, issues raised in the switching-costs literature (see footnote 4) arise, but I expect the effect I have emphasized to remain important.

[16]There are very few results for even the standard Hotelling model (in the absence of shopping costs) when the locations of more than two brands are endogenous. The reason is that many location choices—even symmetric ones between firms—result in no symmetric pure-strategy equilibrium in prices, because firm's demands and, hence, their profits are discontinuous at points at which some brand's price is low enough that it just undercuts a competing brand at the competing brand's location.

See footnote 19 and Klemperer and Jorge Padilla (1992), for conjectures about the equilibrium of a model in which each firm can choose the number of brands it offers.

When firms do compete head-to-head in order to reduce competition, there are, in general, both deadweight losses from high prices and restricted output and also welfare losses from reduced product variety. If, for example, this analysis were relevant to the air-travel market (I do not claim that my analysis considers more than one among several relevant factors), forcing airlines to space their departure times further apart might lower prices as well as increase the options available to travelers. In fact, even allowing airlines to collude on both prices and product locations (departure times) could, at least in theory, by giving the airlines an incentive to provide socially desirable product variety (more widely spaced departures), make both consumers and firms better off. More generally, I have shown that firms' incentives to choose head-to-head competition rather than interlaced-products competition may not be closely related to the social costs of their doing so.

However, my analysis provides no presumption that firms will necessarily prefer head-to-head competition to interlaced-products competition: the "real" product differentiation created by interlaced-product lines directly benefits firms even though, by encouraging consumers to patronize multiple suppliers, it undoes the effects of the "artificial" product differentiation created by consumers' "shopping costs" of using more than one supplier. Section III's results about the relative profitabilities of the two modes of competition give little reason to suppose that either mode will very generally be the more profitable in practice. (Of course this contrasts with the case without shopping costs in which interlaced-products competition is the more profitable.)

Determining whether competition in reality more closely approximates head-to-head or interlaced products is difficult. It is often said, for example, that major (mass-market) auto manufacturers are competing approximately head-to-head at specific points along the product line. In the air-travel market, quantification is easy along the dimension of departure time, and there seem to be examples of both modes of competition. However, analysis and interpretation of these markets are complicated by many other factors that may be more important than the effects of consumers' costs of using additional suppliers (or brand loyalty) on which I have focused.[17]

Most firms market product *lines* rather than individual products. Furthermore, consumers prefer to buy from a single line; that is, consumers act as if they have "shopping costs" of buying from additional product lines. This paper has shown that these shopping costs tend to reduce the variety between firms' product lines. I expect that explicit recognition of these shopping costs, together with modeling consumers as I have done as each demanding a range of products rather than a single good, will yield insights into other aspects of competition between multiproduct firms.[18]

Appendix: Quantity Competition and Elastic Demand

I generalize the original model by assuming that the Qth consumer has reservation price $\phi(Q)$ for a total of one unit of the product class distributed uniformly across the product class (the consumer obtains no utility from consumption of less than one unit and incurs substitution costs of substituting products within the product class, exactly as before). Consumers are ordered so that $\phi(Q)$ is a decreasing function, twice-differentiable as necessary. (Thus, the original model corresponds to the special case in which $\phi(Q) = r$ for all $Q \leq 1$, and $\phi(Q) = 0$ otherwise, for some sufficiently large r.) Unfortunately this generalization and the substitution of quantity competition for price competition introduce considerable additional complexity, so I solve only a special case: I assume linear substitution costs, $g(x) = tx$; one-half of consumers have shopping cost R of buying from firm A and shopping cost $S > R$ of buying from firm B,

[17]See the working-paper version of this paper (Klemperer, 1990) for further discussion of these examples.

[18]For example, Klemperer and Padilla (1992) examine the implications of shopping costs for the number of brands each firm offers.

while the remaining consumers have shopping cost S of buying from firm A and shopping cost R of buying from firm B; and consumers' shopping costs are independent of their reservation prices for the product.

One can compute the interlaced-products equilibrium as follows: if consumers' shopping costs are small enough, all consumers who purchase any product use both suppliers in order to minimize substitution costs, provided that the firms' total outputs, q_A and q_B, are not too different. (I am assuming that each firm splits its output equally among all its brands.) In this case, since shopping costs are fixed costs and all consumers face the same prices and substitution costs, each consumer buys the same fraction, σ_A, of his purchases from firm A. Thus, $\sigma_A = q_A/(q_A + q_B)$, and it follows that p_A and p_B satisfy

$$(16) \qquad p_A + \frac{\sigma_A t}{2n} = p_B + \frac{(1-\sigma_A)t}{2n}$$

and

$$(17) \qquad \phi(q_A + q_B) = R + S + \sigma_A\left(p_A + \frac{\sigma_A t}{4n}\right) + (1-\sigma_A)\left(p_B + \frac{(1-\sigma_A)t}{4n}\right).$$

Equation (16) equates the per-unit price plus substitution cost of each consumer's *marginal* purchase from firm A (which satisfies demand for an ideal variety a distance $\sigma_A/2n$ from the purchase) to that from firm B. Equation (17) equates the marginal consumer's reservation price, $\phi(q_A + q_B)$, to his total shopping costs, $R + S$, plus his cost of purchasing σ_A units from firm A at a per-unit price plus *average* substitution cost of $p_A + \sigma_A t/4n$, plus his cost of purchasing $1 - \sigma_A$ units from firm B. Using (16) to substitute for p_B into (17) one obtains

$$(18) \qquad p_A = \phi(q_A + q_B) - (R+S) - \frac{t}{4n}\left[1 - 2\left(\frac{q_B}{q_A + q_B}\right)^2\right]$$

In quantity-setting Nash equilibrium, A maximizes profits, $\pi_A = p_A q_A$, taking B's output q_B as given, yielding the first-order condition

$$(19) \qquad 0 = \frac{\partial \pi_A}{\partial q_A} = \phi(q_A + q_B) - (R+S) - \frac{t}{4n}\left[1 - 2\left(\frac{q_B}{q_A + q_B}\right)^2\right] + q_A\left[\phi'(q_A + q_B) - \frac{t}{nq_B}\left(\frac{q_B}{q_A + q_B}\right)^3\right]$$

and a symmetric condition for firm B. In symmetric equilibrium $q_A = q_B$, so (19) reduces to

$$(19') \qquad 0 = \phi(2q_A) + q_A\phi'(2q_A) - \left(R + S + \frac{t}{4n}\right).$$

The solution of (19′) specifies symmetric equilibrium outputs with interlaced products if (i) consumers do in fact wish to buy from both firms (i.e., their saving in substitution costs from buying from both rather than just one firm [in symmetric equilibrium], $t/8n$, exceeds the incremental shopping cost of buying from both rather than just one firm, S), and (ii) this first-order condition specifies a global best response for each firm.

In head-to-head competition, by contrast, in or near an equilibrium in which both firms' brands have the same prices, no consumer wishes to buy from more than one firm, since firms produce identical product lines. If firms produce identical total outputs, $q_A = q_B = q$, the market prices will be $p_A = p_B = \phi(2q) - R - t/4n$, since the marginal consumer has reservation price $\phi(2q)$, pays shopping cost R, and has total substitution costs of buying from a single firm $t/4n$. Furthermore, every consumer strictly prefers (by the amount $S-R$) purchasing from the firm from which he has the lower shopping cost to purchasing from the other firm. Thus, around equal outputs, a small increase in either firm's output would attract only consumers who have lower shopping costs of purchasing from that firm. Locally, then, firm A's demand is $p_A = \phi(2q_A) - R - t/4n$, exactly as if it were a monopolist in its half of the market. (The q_Ath consumer whose shopping cost at A is lower than his shopping cost at B has reservation price $\phi(2q_A)$. The first-order condition for a symmetric equilibrium is therefore

$$(20)\quad 0 = \frac{\partial \pi_A}{\partial q_A} = \phi(2q_A) + 2q_A\phi'(2q_A) - \left(R + \frac{t}{4n}\right).$$

The solution of (20) specifies symmetric equilibrium outputs in head-to-head competition if this first-order condition specifies firms' global best responses, which requires that $S-R$ is large enough that neither firm would want to increase its output far enough that it begins to attract consumers whose shopping costs are lower at the other firm. (The working-paper version of this paper (Klemperer, 1990) provides a detailed analysis of when (19′) and (20) in fact specify firms' global best responses.)

A simple example for which it is not hard to check that (19′) and (20) do indeed specify the equilibria of interlaced-products and head-to-head competition, respectively, has $R=0$, $S=1$, $t/n=9$, and $\phi(Q)=11\frac{1}{4}-Q$. In interlaced-products competition, the equilibrium quantities are $q_A = q_B = 2\frac{2}{3}$ [using (19′)]; hence, the equilibrium prices are $p_A = p_B = 3\frac{19}{24}$ [using (18)], and profits are $10\frac{1}{9}$ per firm. In head-to-head competition, on the other hand, the equilibrium quantities are $q_A = q_B = 2\frac{1}{4}$ [using (20)], the prices are $p_A = p_B = 4\frac{1}{2}$, and profits are $10\frac{1}{8}$ per firm.

From the firms' viewpoint, the advantage of head-to-head product lines over interlaced product lines is that with the former they act just like a collusive duopoly in this example, whereas with the latter they are forced to act more competitively. The disadvantage is that head-to-head competition increases consumers' shopping plus substitution costs (because the extra shopping costs that consumers choose to pay in the interlaced-products case must be more than outweighed by their savings in substitution costs), so market prices are lower with head-to-head product lines for any given symmetric outputs.[19]

From society's point of view, however, both factors make interlaced-products competition preferable when firms prefer head-to-head competition: in this case, head-to-head product lines reduce the variety of products available, and they also reduce competition between the firms thereby lowering output and increasing standard deadweight losses. (When firms prefer interlaced-products competition, the social comparison between the two modes of competition is indeterminate.)

In fact, in this example, allowing firms to collude on both their product locations and their outputs would make both firms and all purchasing consumers better off, and no consumers worse off, than in head-to-head competition: colluding firms would choose interlaced products and produce a total output of $4\frac{9}{16}$ at price $4\frac{9}{16}$. Although the price would be slightly higher than in head-to-head competition, the total cost (price plus substitution costs plus shopping costs) that each purchasing consumer pays would be lower.

[19]Increasing the number of products, n, that firms can offer increases the relative profitability of head-to-head competition by reducing the value of the extra variety provided by interlaced product lines, thereby reducing the importance of this second effect. Thus, increasing n in a similar example to this one can make consumers worse off (and lower social welfare) if it induces firms to switch from interlaced-products competition to head-to-head competition. Furthermore, this example suggests the possibility that, if n were endogenous, firms might choose n large enough that competing with head-to-head rather than interlaced product lines would not significantly reduce variety, but then choose to compete head-to-head to maintain the "artificial" differentiation created by shopping costs.

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