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Competitive cross-subsidization

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Cross-subsidization arises naturally when firms with different comparative advantages compete for consumers with heterogeneous shopping patterns. Firms then face a form of co-opetition, as they offer substitutes for one-stop shoppers and complements for multi-stop shoppers. When intense competition for one-stop shoppers drives total prices down to cost, firms subsidize weak products with the profits made on strong products. Moreover, firms have incentives to seek comparative advantages on different products. Finally, banning below-cost pricing increases firms' profits at the expense of one-stop shoppers, which calls for a cautious use of below-cost pricing regulations in competitive markets.

1. Introduction

■ Multiproduct firms compete using a variety of pricing strategies. One commonly observed strategy is cross-subsidization, in which firms price some products below cost and compensate the resulting loss with profits from other products. Competition between Apple and Amazon in e-book and tablet computer markets offers an illustration. In 2010, Amazon was selling the "Kindle Fire" below cost,[1] while Apple preloaded 30,000 books free of charge on the iBooks store.[2] It was commonly recognized that Apple's iPad offered more functions than the Kindle Fire, whereas Amazon—with more than two million e-books—provided more variety and thus a higher match value than the iBooks store. Hence, each firm had a comparatively stronger product in relation to its rival. Furthermore, both firms were selling their comparatively weaker products

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[1] The Kindle Fire, which offered access to the Amazon Appstore, streaming movies, and TV shows, was sold in the United States. at a retail price of $199. Amazon's hardware cost for a Kindle Fire was estimated at $201.70, not including "additional expenses such as software, licensing, royalties, or other expenditures." See: technology.ihs.com/389433/amazon-kindle-fire-costs-20170-to-manufacture.

[2] See AppleInsider's report, available at: appleinsider.com/articles/10/03/25/apple_loads_up_new_ibooks_store_with_free_public_domain_ipad_titles.

below cost, and deriving profits from their strong products.[3] Moreover, consumers could combine the two firms' strong products, but not the weak ones: iPad users could download a free Kindle Application to access Amazon's e-books, whereas Kindle Fire users had no option to access the iBooks store.

This strategy in competitive markets, such as tablets and e-books, is somewhat at odds with the existing theory. According to this theory, cross-subsidization arises in the context of regulated or monopolistic markets,[4] or in markets characterized by friction, such as consumers' limited information or bounded rationality (see the literature review below). Here, we develop a new approach, based on the diversity of purchasing patterns.

The literature on competitive multiproduct pricing often assumes that customers engage in "one-stop shopping" and purchase all products from the same supplier. Yet, in practice, many customers engage in multi-stop shopping and rely on several suppliers to fulfill their needs. The choice between these purchasing patterns is driven not only by the diversity and the relative merits of suppliers' offerings, but also by the transaction costs that buyers must bear in order to enjoy the products. As mentioned by Klemperer (1992), these transaction costs include physical costs, such as transportation costs, and nonphysical costs, such as the opportunity cost of time and the adoption cost of using a new electronic device. Following the terminology of the literature, we will refer to these costs as "shopping costs." Obviously, these costs vary across customers. For example, some consumers may face tighter time constraints and/or dislike shopping, whereas others may be less time-constrained and/or enjoy shopping. Indeed, some users, already familiar with the Kindle system, may be reluctant to switch to the iPad because of the associated learning costs,[5] whereas others may enjoy the adoption of a new device. All other things being equal, customers with high transaction costs tend to favor "one-stop shopping," whereas others prefer "multi-stop shopping."

We first note that the diversity of purchasing patterns gives rise to a form of "co-opetition": on the one hand, firms offer substitutes for one-stop shoppers, who look for the best basket of products; on the other hand, firms offer complements for multi-stop shoppers, who seek to combine suppliers' best products. We show that this duality drastically affects firms' pricing strategies and can lead to cross-subsidization, even in competitive markets.

Specifically, we consider a setting in which two firms offer the same product line (which consists of two products, for simplicity). Consumers are perfectly informed about prices, as is indeed the case for e-books and tablets. To discard price-discrimination motives, we further assume that consumers have inelastic demands. Altogether, these assumptions allow us to abstract from the motivations already highlighted in the literature on cross-subsidization (see the literature review below). Our key ingredients are instead that: (i) consumers have heterogeneous shopping costs; and (ii) through lower costs and/or higher consumer value, each firm enjoys a comparative advantage over one product. For the sake of exposition, we initially assume that firms have similar comparative advantages; that is, each firm has a stronger product than its rival, but overall, their baskets generate the same surplus. In equilibrium, consumers with high shopping costs engage in one-stop shopping, and competition for these consumers drives firms' aggregate prices down to cost. By contrast, consumers with low shopping costs engage in multi-stop shopping and buy each firm's strong product; thus, the firms make a profit. Cross-subsidization therefore arises naturally, with each firm pricing its weak product below cost and subsidizing the resulting loss with the profit from its strong product.

[3] Before 2010, Amazon was also selling newly released e-books below cost. However, prices were raised after Apple proposed the controversial "agency model" for e-books. More recently, Amazon has introduced a more sophisticated version of its reader (e.g., the Oasis), which offers additional features. Still, the pattern of cross-subsidizing weaker products with stronger ones appears to have persisted from 2010 to 2016.

[4] For instance, Faulhaber (2005) asserts that "under competitive conditions, the issue of cross-subsidy simply does not arise."

[5] Before the launch of the iPad and the Kindle Fire, readers of Amazon's e-books were mainly using the original Kindle device.

This provides some insights on the outcome of co-opetition. On the one hand, aggregate price levels are "competitive": firms supply one-stop shoppers at cost. If firms could coordinate their pricing strategies, they would raise total prices in order to exploit one-stop shoppers. At the same time, however, a lack of coordination over the prices charged to multi-stop shoppers leads to "double marginalization," as each firm charges a margin on its strong product. This causes excessive cross-subsidization and results in not enough multi-stop shopping: limiting cross-subsidization would benefit both firms and consumers.

These insights are quite robust and remain valid in more general environments. We extend the analysis to the setting with heterogeneous consumer preferences, and show that firms cross-subsidize weak products as long as competition for one-stop shoppers remains sufficiently intense and/or the number of consumers who demand the weak product only is relatively small. We also show that the analysis applies when the dispersion of shopping costs is limited (as long as both shopping patterns arise in equilibrium), or when one firm offers a better basket than the other, thus enjoying market power over one-stop shoppers.

We then explore the implications of these insights for firms' product positioning. We do so by introducing a preliminary stage during which they can improve their offerings (e.g., by investing in quality or cost reduction, or by dedicating more resources to negotiating better conditions with their suppliers). We find that firms have incentives to target different products: this gives rise to asymmetric comparative advantages—as described above—regardless of whether improvement decisions are public or private, and with both mixed and pure strategies.

The prevalence of cross-subsidization in retailing markets has led to many countries adopting specific regulations that prohibit or restrict certain forms of below-cost pricing. These regulations are, however, quite controversial and have triggered an intense policy debate.[6] To shed some light on this debate, we consider a variant where firms cannot price below cost. The equilibrium then involves mixed strategies: firms sell weak products at cost but randomize the prices of their strong products. Banning below-cost pricing thus results in higher prices for one-stop shoppers (who can no longer purchase the products at cost), and greater profitability for firms (in fact, their expected profits more than double). The impact on multi-stop shoppers is less obvious. However, when weak products offer relatively low value, there are few one-stop shoppers; hence, firms are not too concerned about losing them and, as a result, charge higher prices to multi-stop shoppers as well. Depending on the distribution of shopping costs, this reduction in consumer surplus may exceed the increase in firms' profits and thus result in lower total welfare. This suggests that regulations on below-cost pricing in competitive markets should be carefully evaluated.[7]

Related literature. Cross-subsidization has been extensively studied in the context of regulated markets such as telecommunications, energy, and postal markets, in which historical incumbents may fight entry by pricing below cost in liberalized segments,[8] and subsidize their losses with profits earned in protected segments. There is a small literature of cross-subsidization in unregulated, competitive markets; however, it typically assumes that consumers engage in one-stop shopping, and relies either on consumers' limited information or on bounded rationality.

In a setting where consumers are initially unaware of prices, Lal and Matutes (1994) show that firms advertise a loss-leader product in order to attract consumers.[9] Rhodes (2015) develops a multiproduct search model where competing firms randomly advertise one product at a low price, and may even set its advertised price below cost. By contrast, when consumers are aware of prices,

[6] For instance, OECD (2007) argues that these laws are more likely to harm consumers than benefit them. See Section 5 for a more detailed discussion.

[7] By contrast, Chen and Rey (2012) show that banning below-cost pricing in concentrated markets can discipline the pricing behavior of a dominant firm competing with smaller firms. Such a ban then benefits both consumers and smaller rivals, and enhances social welfare.

[8] Such an exclusionary motive does not appear relevant for the tablet and e-book markets. Amazon can hardly hope to drive the iPad out of the market and, conversely, Apple is probably not primarily aiming to exclude Amazon's e-books.

[9] In equilibrium, consumers stop searching after the first visit, and thus all consumers are one-stop shoppers in their setting.

Ambrus and Weinstein (2008) show that below-cost pricing does not arise when consumers have inelastic demands or when consumers have sufficiently diverse preferences.[10]

Ellison (2005) and Gabaix and Laibson (2006) study add-on pricing and product shrouding. Firms may price a leading product below cost (such as a hotel room fee) to lure consumers and subsidize the loss with the profit from shrouded add-on prices (such as telephone call charges and Internet access fees). Grubb (2009) considers consumers with behavioral biases (such as overconfidence about the usage management) in the mobile-phone-service market, and shows that such bias can lead firms to price below cost on some units within a mobile-service plan. Recently, Johnson (2017) considers a setting in which one-stop shoppers may underestimate their needs, and shows that below-cost pricing may arise when consumers have different biases across products.[11]

In the case of tablets and e-books, as already noted, information about Apple and Amazon's prices was readily available to consumers. Furthermore, bounded rationality may be less relevant for simple goods such as e-books than for more complex products such as mobile telephone services. Yet, accounting for the diversity of purchasing patterns enables us to offer a rationale for the observed cross-subsidization, even in the absence of any limitation on consumers' information and rationality.

Chen and Rey (2012) also account for heterogeneous purchasing patterns; however, the two articles focus on different situations, which leads to drastically different policy implications. Our previous article focused on markets in which a dominant firm (e.g., a platform monopoly or a large retailer carrying a broad range of products) competes with smaller rivals (e.g., application developers or specialty stores), and showed that the dominant firm can profitably engage in loss leading by selling competitive products below cost. However, banning below-cost pricing then *hurts the dominant firm*, and it *unambiguously benefits consumers* (as well as smaller rivals) and *increases social welfare*. By contrast, we focus here on firms with similar product ranges: cross-subsidization then arises as a form of "co-opetition," which allows the firms to extract surplus from multi-stop shoppers while competing for one-stop shoppers. In this type of situation, banning below-cost pricing then *benefits the firms*, and *unambiguously harms one-stop shoppers*; it is also likely to harm consumers as a whole, as well as social welfare.

The empirical literature on multiproduct pricing and heterogeneous purchasing patterns remains limited. For instance, the empirical literature on platform competition in media or healthcare industries[12] outlines the multiplicity of products (TV channels or doctors and hospitals), but tends to focus on one-stop shopping. On the other hand, the literature on retail competition—where supermarkets offer a large number of products—tends to focus on specific product categories, such as breakfast cereals or mineral water, or on store-level competition (e.g., to assess the impact of a merger), thus ignoring shopping patterns. Recently, however, Thomassen et al. (2017) provide an interesting quantitative analysis of supermarket pricing that accounts for price effects across product categories, as well as the heterogeneity (and endogeneity) of shopping patterns. It finds, in particular, that different product categories exhibit price complementarity within a given retailer and that this "cross-category complementarity derives from the consumer's shopping costs rather than from any intrinsic complementarity between the categories." It also finds that competition appears to be more intense for one-stop shoppers than for multi-stop shoppers.

The article is organized as follows. Section 2 develops the baseline framework and presents our main insights. Section 3 extends the baseline model to account for heterogeneous preferences,

[10] They find that below-cost pricing arises only when consumers have elastic demands exhibiting a very specific form of complementarity.

[11] There is also a marketing literature on loss leading that focuses on impulsive purchases. For instance, Hess and Gerstner (1987) show that firms can use loss-leader products to lure consumers, who will purchase some other products impulsively. Such impulsive purchases are similar to the "unplanned purchases" analyzed by Johnson (2017).

[12] See, for example, Crawford and Yurukoglu (2012) and Crawford et al . (2018) for media, and Gowrisankaran, Nevo, and Town (2015) and Ho and Lee (2017) for healthcare.

whereas Section 4 explores its implications for firms' product positioning. Section 5 studies the impact of a ban on below-cost pricing. Finally, Section 6 concludes.

2. Baseline model and main results

□ **Setting.** There are two product markets, A and B, and two firms, 1 and 2. Consumers are willing to buy one unit of A and one unit of B. Each firm $i = 1, 2$ can produce a variety of each good, A_i and B_i, at constant unit costs c_i^A and c_i^B.[13] Consumers have homogeneous preferences, and derive utility $u_i^h > c_i^h$ from firm i's variety of good $h = A, B$.[14]

Throughout the analysis, we assume that firm 1 enjoys a comparative advantage in the supply of good A, whereas firm 2 enjoys a comparative advantage for good B. This may reflect a specialization in different product lines, and be driven by better product quality (i.e., $u_1^A > u_2^A$), a lower cost (i.e., $c_1^A < c_2^A$), or a combination of both. For the sake of exposition, we initially focus on the case where firms enjoy the same comparative advantage for their strong products:

$$u_1^A - c_1^A - \left(u_2^A - c_2^A\right) = u_2^B - c_2^B - \left(u_1^B - c_1^B\right) \equiv \delta > 0, \tag{1}$$

implying that their baskets offer the same total value:

$$u_1^A - c_1^A + u_1^B - c_1^B = u_2^A - c_2^A + u_2^B - c_2^B \equiv w > \delta. \tag{2}$$

Later, we consider asymmetric comparative advantages and endogenous specialization (see Section 4).

Our key modelling feature is that consumers incur a shopping cost, s, to visit a firm, and that this cost varies across consumers, reflecting the fact they may be more or less time-constrained or that they value the shopping experience in different ways. Buying both products from the same firm thus generates one-stop shop benefits by saving the cost of a second visit. Alternatively, the one-stop shop benefit s may be interpreted as consumption synergies stemming from purchasing both products from the same supplier.

Intuitively, consumers with high shopping costs favor one-stop shopping, whereas those with lower shopping costs can take advantage of multi-stop shopping. Shopping patterns are, however, endogenous and depend on firms' prices. To ensure that both types of shopping patterns arise, we will assume that the shopping cost s is sufficiently dispersed, namely:

Assumption A. The shopping cost s is distributed according to a cumulative distribution function $F(\cdot)$ with positive density function $f(\cdot)$ over $\mathbb{R}_+$.

Finally, we assume that firms compete in prices; that is, firms simultaneously set their prices, (p_1^A, p_1^B) and (p_2^A, p_2^B), and, having observed all prices, consumers then make their shopping decisions. We will look for the subgame-perfect Nash equilibria of this game.

□ **Competitive cross-subsidization.** We first show that, in equilibrium, multi-stop and one-stop shopping patterns coexist, with multi-stop shoppers buying strong products, and competition for one-stop shoppers driving firms' basket prices down to cost:

Lemma 1. Under Assumption A, in equilibrium:

(i) There are both multi-stop shoppers and one-stop shoppers;
(ii) Multi-stop shoppers buy firms' strong products, A_1 and B_2; and
(iii) Firms sell their baskets at cost.

[13] For the sake of exposition, we suppose that these costs are large enough to ensure that relevant prices are all positive.

[14] We focus here on independent demands for A and B; however, the analysis carries over when there is partial substitution or complementarity; that is, when the utility derived from enjoying both A_i and B_i is either lower or higher than $u_i^A + u_i^B$.

Proof. See the online web Appendix A. ■

The first two insights are intuitive. Consumers with very low shopping costs (s close to 0) are willing to visit both firms, so as to combine products with better value. Conversely, consumers with high shopping costs (s close to w, and thus such that $s > \delta$) are willing to visit one firm at most. The last insight follows directly from firms' symmetry vis- à-vis one-stop shoppers: as their baskets generate the same value w, Bertrand-like competition drives their prices down to cost.

Building on Lemma 1 leads to our main insight:

Proposition 1. Under Assumption A, in equilibrium, firms sell their weak products below cost.

Proof. See Appendix A. ■

The intuition is fairly simple. From Lemma 1, one-stop shoppers buy firms' baskets at cost, and multi-stop shoppers only buy firms' strong products. Hence, firms either sell both products at cost, or cross-subsidize weak products with strong ones (cross-subsidizing strong products with weak ones would yield negative profits). Suppose now that a firm sells both of its products at cost, and consider the following "cross-subsidization" deviation: the firm slightly raises the price of its strong product and reduces the price of its weak product by the same amount. This deviation does not affect the total price of the basket, which remains offered at cost to one-stop shoppers, but generates a profit from multi-stop shoppers, who now pay a higher price for the strong product. As the deviation decreases the value of multi-stop shopping, it may also induce some consumers to switch to one-stop shopping. However, this does not affect the firm, which was initially earning zero profit from multi-stop shoppers, and still earns zero profit from one-stop shoppers, regardless of which firm they go to. Hence, cross-subsidization is profitable.

To go further, we introduce the following regularity condition:

Assumption B. The density function $f(\cdot)$ is continuous and $h(\cdot) \equiv F(\cdot)/f(\cdot)$ is strictly increasing.

The following proposition then establishes the existence of a unique equilibrium:

Proposition 2. Under Assumptions A and B, there exists a unique equilibrium, in which both firms sell their weak products below cost and cross-subsidize them with their strong products. More precisely, defining:

$$j(x) \equiv x + 2h(x), \tag{3}$$

we have:

(i) Consumers with a shopping cost $s < s^*$, where:

$$0 < s^* \equiv j^{-1}(\delta) < \delta(< w),$$

engage in multi-stop shopping (they visit both firms and buy their strong products), whereas consumers with a shopping cost $s^* < s < w$ engage in one-stop shopping and buy both products from the same firm (either one); and

(ii) Both firms offer their baskets at cost, but charge the same margin $\rho^* = h(s^*) > 0$ on their strong products and the same margin $-\rho^* < 0$ on their weak products.

Proof. See Appendix B. ■

The characterization of this equilibrium builds on Lemma 1. Firms only derive a profit from selling their strong products to multi-stop shoppers; that is, those consumers with a sufficiently low shopping cost, namely:

$$s < \delta - \rho_1 - \rho_2,$$

where $\rho_1 \equiv p_1^A - c_1^A$ and $\rho_2 \equiv p_2^B - c_2^B$, respectively, denote firm 1 and 2's margins on their strong products. Hence, firm i's profit can be expressed as:

$$\pi_i(\rho_1, \rho_2) = \rho_i F(\delta - \rho_1 - \rho_2). \quad (4)$$

The monotonicity of $h(\cdot)$ ensures that the profit function $\pi_i(\cdot)$ is strictly quasiconcave in ρ_i. Together with the "aggregative game" nature of $\pi_i(\cdot)$, which depends on ρ_i only through the sum $\rho_1 + \rho_2$, it also ensures that the equilibrium is unique and symmetric. Specifically, both firms charge the same positive margin ρ^* on their strong products,[15] characterized by the first-order condition:

$$\rho^* = h(\delta - 2\rho^*).$$

The equilibrium threshold for multi-stop shopping, s^*, satisfies:

$$s^* = \delta - 2\rho^* = \delta - 2h(s^*),$$

and is therefore given by $s^* = j^{-1}(\delta)$, where $j^{-1}(\cdot)$ is strictly increasing. Finally, in equilibrium, each firm earns a positive profit, equal to:

$$\pi^* = \rho^* F(s^*) = h(s^*)F(s^*).$$

As mentioned in the Introduction, firms face a form of co-opetition: they compete for one-stop shoppers, but offer complementary products to multi-stop shoppers. Indeed, the firms' baskets are perfect substitutes for one-stop shoppers, and fierce competition for these consumers drives basket prices down to cost. Firms instead make a profit on multi-stop shoppers, who visit both firms in order to buy their strong products. Furthermore, a *reduction* in the price of one firm's strong product encourages additional consumers to switch from one-stop to multi-stop shopping, thereby *increasing* the other firm's profit. As is usual with complements, the prices of strong products are subject to double marginalization problems. When contemplating an increase in the price of its strong product, firm i balances between the positive impact on its margin ρ_i and the adverse impact on multi-stop shopping, but ignores the negative effect of this reduction in multi-stop shopping activity on the other firm's profit. Firms would therefore benefit from a mutual moderation of the prices charged on these products, for example, through a bilateral price-cap agreement (See Rey and Tirole (2018)). Interestingly, although double marginalization is usually associated with excessively high price *levels*, here, it yields excessively distorted price *structures*: firms' total prices remain at cost but they engage in excessive cross-subsidization, compared with what would maximize their joint profit. Keeping total margins equal to zero, firms' joint profit when charging a margin ρ on both strong products is given by:

$$2\rho F(\delta - 2\rho),$$

and is maximal for some $\hat{\rho} < \rho^*$.[16]

At first glance, that shopping costs generate complementarity in firms' products might not come as a surprise. Indeed, although consumers have independent demands for goods A and B, as one might expect, one-stop shopping introduces a complementarity between the products offered

[15] Firms thus sell their weak products with the same negative margin $-\rho^* < 0$. Yet, a firm would not benefit from dropping its weak product (e.g., by charging a prohibitive price): it would no longer serve one-stop shoppers, from which it makes no loss.

[16] A standard revealed preference argument yields $\hat{\rho}F(\delta - 2\hat{\rho}) > \rho^* F(\delta - 2\rho^*) > \hat{\rho}F(\delta - \rho^* - \hat{\rho})$, implying $\hat{\rho} < \rho^*$.

within a firm: cutting the price of A_i, say, is likely to steer one-stop shoppers toward firm i, which in turn boosts the sales of the firm's other product, B_i. This form of complementarity is not specific to our setting and is well understood. More interestingly, however, multi-stop shopping here introduces a complementarity *across firms*, namely, between their strong products: cutting the price of one firm's strong product induces marginal consumers to switch from one-stop to multi-stop shopping, which boosts the sales of the other firm's strong product.[17]

□ **Discussion.** We now discuss a few robustness checks and variations of the baseline model.

- *Bundling.* As consumers have homogeneous valuations, there is no scope for tying and (pure or mixed) bundling. For instance, if one firm ties both products together physically, consumers are forced to engage in one-stop shopping, and price competition for one-stop shoppers leads to zero profit. Similar reasoning applies to pure bundling when products are costly, to such an extent that it does not pay to add one's favorite variety to a bundle. In principle, a firm may also engage in mixed bundling and offer three prices: one for its strong product, one for the weak product and one for the bundle. However, as one-stop shoppers only purchase the bundle, and multi-stop shoppers only buy the strong product, no consumer will ever pick the weak product on a stand-alone basis. Hence, only two prices matter here: the total price for the bundle and the stand-alone price for the strong product. As these prices can be implemented using the stand-alone prices for the two products, offering a bundled discount (in addition to these stand-alone prices) cannot generate any additional profit.
- *Multiple firms*. The analysis is unchanged when weak products are supplied by additional firms as well. For example, if weak products are also supplied at cost by competitive fringe firms, and regardless of whether these fringe firms each supply one or both of these products, then each firm $i = 1, 2$ would still undercut the fringe firms and offer its weak product at the same below-cost price. The same applies if each firm $i = 1, 2$ offers both weak products as well as its strong product. For example, if firm 1 can not only offer A_1 and B_1, but also produce the weaker variety A_2 in the same conditions as firm 2, then it would still sell A_1 and B_2 at the same prices as before, and either not offer A_2, or offer it at unattractive prices (e.g., at cost).
- *Bounded distribution of shopping costs.*The baseline model assumes a widespread dispersion of consumers' shopping costs, spanning the entire range from "pure multi-stop shoppers" (consumers with $s = 0$ always choose the best value offered for each product) to "pure one-stop shoppers" (consumers with $s \geq \delta$ never visit a second firm). We show in the online web Appendix B.1 that, even with less dispersed distributions of shopping cost, cross-subsidization still occurs as long as one-stop and multi-stop shopping patterns coexist. Competition for one-stop shoppers then drives total prices down to cost, but firms obtain a profit by selling their strong products to multi-stop shoppers; hence, they sell their weak products below cost.
- *Nonlinear pricing.* For the sake of exposition, we focus on unit demands, and so linear prices are efficient. If instead, consumers have an individual elastic demand of the form $q = d(p)$, where $d'(p) < 0$, linear prices are no longer efficient, and firms would have an incentive to offer nonlinear prices, such as two-part tariffs. For instance, to maximize bilateral gains from trade, firms could use cost-based two-part tariffs, with a constant marginal price reflecting the cost of production and a fixed fee designed to share the resulting surplus. Yet, the analysis carries over, applying the above analysis to the fixed fees. We show in the online web Appendix B.2 that marginal prices are equal to costs, and firms offer their overall baskets at cost, but firms subsidize the fees on their weak products. Interestingly, even if tariffs are individually efficient (in that they induce consumers to buy the efficient quantity, which maximizes the bilateral gains from the transactions), the equilibrium tariffs still feature double marginalization: keeping total fixed fees constant, fees charged on strong products exceed the level that would maximize industry profit.

[17] A similar complementarity for multi-stop shoppers arises when shopping patterns are driven by heterogeneous preferences rather than transaction cost differences; see Armstrong and Vickers (2010).

- *Online retailing.* To analyze the impact of online retailing, suppose that a fraction λ of "Internet-savvy" consumers see their shopping costs drop to zero. We show in the online web Appendix B.3 that, by modifying the distribution of shopping costs, the development of online sales is not only profitable, but moreover *increases* the prices of strong products. One-stop shoppers can still buy firms' baskets at cost, whereas multi-stop shoppers (including those buying online) face higher prices as the proportion of online customers increases.

3. Heterogeneous preferences

■ In the above analysis, cross-subsidization results from two key features: competition for one-stop shoppers drives total margins down to zero, and multi-stop shoppers purchase strong products (and only those ones). As a result, firms cross-subsidize their weak products, in order to make a profit from selling the strong products to multi-stop shoppers. In practice, however, consumers may have heterogeneous preferences over firms' offerings, and/or may be interested in only some of the products. This may relax competition for one-stop shoppers and may also induce some consumers to buy only the weak products. We now show that cross-subsidization still arises, however, as long as competition for one-stop shoppers remains sufficiently intense.

□ **Horizontal differentiation.** Multiproduct retailers such as supermarkets often offer differentiated brands (including their own private labels), and consumers may be quite heterogeneous in their valuations of these products. To capture this, we now assume that firms are horizontally differentiated, with consumers' preferences following a classic Hotelling pattern. Specifically, consumers are uniformly distributed along a Hotelling segment of unit length and indexed by their location $x \in [0, 1]$, and firms' offerings are located at the two ends of the line: that is, A_1 and B_1 are located at 0, say, whereas A_2 and B_2 are located at 1. Denoting by t the Hotelling differentiation parameter, a consumer located at a distance x from one variety of a product therefore incurs a cost tx when purchasing that variety, and $t(1-x)$ when purchasing the other variety. We also assume that the distribution of shopping costs is independent of consumers' locations.

The location x can be interpreted as consumers' relative preference for the two firms: one-stop shoppers located close to 0 (resp., 1) now favor firm 1 (resp., firm 2). Specifically, a one-stop shopper located at x obtains $w - 2tx - m_1 - s$ from patronizing firm 1 and $w - 2t(1-x) - m_2 - s$ from going instead to firm 2, where m_i denotes firm i's total margin on its basket. Thus, one-stop shoppers favor firm 1 if:

$$x < \hat{x} \equiv \frac{1}{2} - \frac{m_1 - m_2}{4t}.$$

Multi-stop shoppers still favor strong products, as in the baseline model. Thus, consumers with $x < \hat{x}$ favor multi-stop shopping over patronizing firm 1 if their shopping cost satisfies:

$$s < \lambda_1(x) \equiv \tau_1 - t + 2tx,$$

where $\tau_1 \equiv \delta + \mu_1 - \rho_2$. Likewise, consumers located at $x > \hat{x}$ prefer multi-stop shopping to patronizing firm 2 if:

$$s < \lambda_2(x) \equiv \tau_2 + t - 2tx,$$

where $\tau_2 \equiv \delta + \mu_2 - \rho_1$.

Thus, the demand for the bundles $A_1 - B_1$ and $A_2 - B_2$ can be expressed, respectively, as:

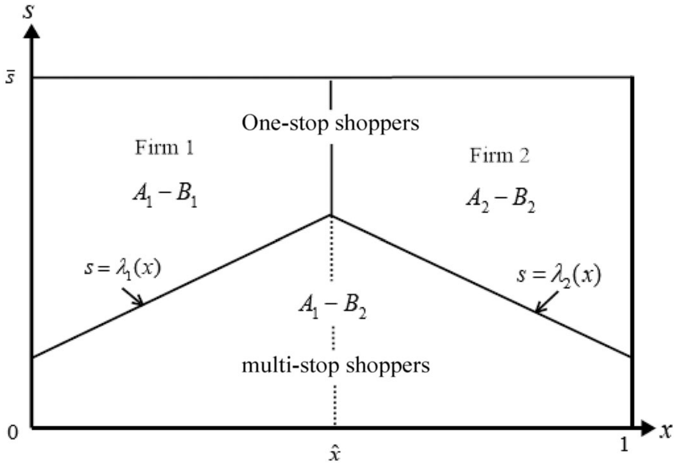
$$D_1 \equiv \int_0^{\hat{x}} [1 - F(\lambda_1(x))]dx, \;\; D_2 \equiv \int_{\hat{x}}^1 [1 - F(\lambda_2(x))]dx,$$

whereas the demand for multi-stop shopping of two strong products, $A_1 - B_2$, is given by:

$$D \equiv \int_0^{\hat{x}} F(\lambda_1(x))dx + \int_{\hat{x}}^1 F(\lambda_2(x))dx.$$

FIGURE 1

HETEROGENEOUS PREFERENCES



Then, firm 1's total profit can be written as:

$$\Pi_1 = m_1 D_1 + \rho_1 D = m_1(D_1 + D) - \mu_1 D. \tag{5}$$

For simplicity, we assume that the distribution of the shopping cost is bounded above by $\bar{s}$, which is, however, large enough to allow for both types of shopping patterns (one-stop and multi-stop). To ensure continuity as the differentiation parameter t tends to vanish, we also assume that the density $f(s)$ is continuously differentiable. We further suppose that the total value w is large enough to ensure full participation (all consumers buy both products). The demand is as then illustrated in Figure 1:

The heterogeneity of consumers' preferences over the two firms relaxes the intensity of competition for one-stop shoppers; as a result, in equilibrium, firms charge positive total margins: $\tilde{m}_1(t) = \tilde{m}_2(t) = \tilde{m}(t) > 0$. Yet, the following proposition shows that, as long as this competition remains sufficiently intense (i.e., as long as the differentiation parameter t is not too large), firms keep cross-subsidizing their products. We first show that this feature arises in any symmetric equilibrium with both consumption patterns. We then provide a sufficient condition (namely, that the density $f(s)$ is nonincreasing) that ensures the existence of such an equilibrium:

Proposition 3. Suppose that consumers' preferences follow the Hotelling pattern described above, and focus on symmetric equilibria in which both consumption patterns coexist, as depicted by Figure 1. There exist $\tilde{m}(t)$ and $\tilde{\mu}(t)$ such that, in equilibrium, firms charge a total margin $\tilde{m}(t)$ over their products and a margin $\tilde{\mu}(t)$ on their weak products; in addition:

(i) There exists $\bar{t} > 0$ such that, in the range $t \in (0, \bar{t})$, firms charge a positive total margin over their products (i.e., $\tilde{m}(t) > 0$) but keep selling their weak products below cost (i.e., $\tilde{\mu}(t) < 0$); in addition, both $\tilde{m}(t)$ and $\tilde{\mu}(t)$ increase with t; and
(ii) If the density $f(s)$ is nonincreasing, then there exists $\hat{t} > 0$ such that, in the range $t \in (0, \hat{t})$, there exists such an equilibrium.

Proof. See the online web Appendix C.1. ■

Proposition 3 shows that cross-subsidization can still occur when firms offer differentiated brands. However, its magnitude decreases as competition for one-stop shoppers becomes softer.

In the particular case where shopping costs are uniformly distributed, it can further be shown that the total margin $\tilde{m}(t)$ increases with t and the margin for weak products is given by:

$$\tilde{\mu}(t) = \frac{3\bar{s}t}{3\bar{s} + 2t - \delta} + \frac{t}{6} - \frac{\delta}{3},$$

which also increases with t and is null for some $\bar{t} > 0$.[18] Hence, cross-subsidization arises for $t < \bar{t}$, and disappears for $t > \bar{t}$. As competition for one-stop shoppers becomes less and less intense, firms charge them higher total margins, up to the point where they can charge high enough margins on their strong products to exploit multi-stop shoppers, without selling their weak products below cost.

□ **Stand-alone demands.** Other sources of consumer heterogeneity could further affect the analysis. For instance, some consumers may be interested in only one of the products rather than in the whole assortment, and among these, some may prefer the strong product of a firm but others may prefer its weak product. More generally, even when most consumers prefer one firm's variety of a good over the rival's variety, some consumers may nevertheless have a strong preference for the latter. Intuitively, firms will further engage in cross-subsidization when more consumers are interested in their "strong" products, and will instead reduce the level of cross-subsidization when more consumers are specifically interested in their "weak" products. Suppose, for example, that in addition to the multiproduct consumers with demand as described in the previous section, a small mass σ of consumers are only interested in the strong products, $A1$ and $B2$, and a mass ω of consumers are interested only in the weak products, $A2$ and $B1$. Firm i's profit is then given by:

$$\begin{aligned}\Pi_i &= m_i D_i + \rho_i D + \sigma \rho_i + \omega \mu_i \\ &= m_i(D_i + D + \sigma) - \mu_i(D + \sigma - \omega).\end{aligned}$$

As:

$$\frac{\partial^2 \Pi_i}{\partial \sigma \partial \mu_i} < 0 < \frac{\partial^2 \Pi_i}{\partial \omega \partial \mu_i},$$

a revealed preference argument shows that, other things being equal, an increase in the mass σ of customers interested in its strong product gives the firm an incentive to sell its weak product further below cost (i.e., to decrease the margin μ_i), whereas an increase in the mass ω of customers specifically interested in its weak product discourages cross-subsidization.

To further explore this, we next focus on the case where $\sigma = 0$ and the shopping cost s is uniformly distributed on $[0, \bar{s}]$. Also, to limit firms' market power on the weak products, $A2$ and $B1$, we assume that they are also offered at cost by a competitive fringe; hence, the presence of consumers only interested in these products may limit the scope for cross-subsidization but does not confer additional market power to the firms. We have:

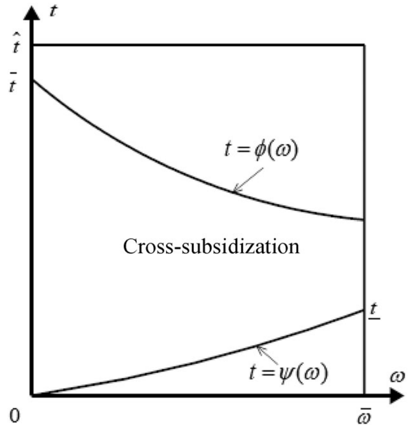
Proposition 4. Suppose that a unit-mass of consumers have preferences following the Hotelling pattern previously described, with shopping costs uniformly distributed between 0 and $\bar{s}$, and that, in addition, for each firm there is a small mass ω of consumers only interested in its weak product. There exists $\hat{t} > 0$, $\hat{\omega} > 0$, and $\psi(\omega)$ satisfying $\psi(0) = 0$ and $\psi'(\omega) > 0$, such that there exists a symmetric equilibrium in pure strategies for any $(\omega, t) \in [0, \hat{\omega}] \times [\psi(\omega), \hat{t}]$. Furthermore, there exists $\phi(\omega)$, satisfying $\phi'(\omega) < 0$ and $\hat{t} > \phi(\omega) > \psi(\hat{\omega})$ in the range $\omega \in [0, \hat{\omega}]$, such that, in this symmetric equilibrium, firms cross-subsidize their weak products whenever $\phi(\omega) > t > \psi(\omega)$.

Proof. See the online web Appendix C.2. ■

[18] Equilibrium existence is moreover guaranteed in that range (i.e., $\bar{t} < \hat{t}$) if shopping costs are sufficiently dispersed (e.g., $\bar{s} > 7\delta/2$); see the online web Appendix C.1.

FIGURE 2

STAND-ALONE DEMAND FOR WEAK PRODUCTS



These findings are illustrated in Figure 2. It can be checked that, as expected, the equilibrium margins $\tilde{m}(\omega, t)$ and $\tilde{\mu}(\omega, t)$ increase with t. Product differentiation softens competition for one-stop shoppers, which reduces the scope for cross-subsidization; the limit case $t = \phi(\omega)$, where firms stop cross-subsidizing their products, is defined by $\tilde{\mu}(\omega, \phi(\omega)) = 0$. Firms' profits also increase with product differentiation, thanks to reduced competition.

In addition, $\tilde{m}(\omega, t)$ and $\tilde{\mu}(\omega, t)$ also increase with ω. Single-product consumers' demand for the weak products reduces the scope of cross-subsidization, which softens competition for one-stop shoppers as well; as $\tilde{\mu}(\omega, t)$ increases in both t and ω, it follows that $\phi(\omega)$ decreases in ω. Firms' profits may, however, decrease as the demand for weak products increases, as the loss from serving these single-product consumers may more than offset the gain due to reduced competition.

Firms incur a loss from selling their weak products (and only those) at below-cost prices to single-product consumers, and they would therefore be tempted to drop these products if this loss were to exceed the gain from serving one-stop shoppers. This happens when ω is sufficiently large compared with t, namely, when $t < \psi(\omega)$.

4. Product choice

■ The above analysis relies on the assumption that firms have comparative advantages over different products. We now endogenize firms' product choices and show that, indeed, firms have an incentive to improve their positions on different products. We first extend the baseline setting by considering arbitrarily given positions in the two markets (the first subsection of Section 4). We then endogenize firms' product choice decisions (the second subsection of Section 4).

□ **Asymmetric comparative advantage.** Intuitively, when one firm benefits from a comparative advantage in *both* markets, then the other firm will not attract any consumer; hence, there is no multi-stop shopping, and cross-subsidization becomes a moot issue. The following proposition confirms this intuition and shows that, by contrast, multi-stop shopping and cross-subsidization keep arising as long as each firm enjoys a comparative advantage in one market.

Without loss of generality, we suppose that firm 1 benefits from a comparative advantage in market A, $\delta_1 > 0$, which exceeds firm 2 's comparative advantage in market B, $\delta_2 < \delta_1$. Note that we allow for $\delta_2 < 0$, in which case, firm 1 actually enjoys a comparative advantage in both markets.

In the absence of firm 2, firm 1 would sell both of its products as long as its individual margins do not exceed consumers' valuations. By charging m_1, it would attract all consumers with a shopping cost lower than $v_1 = w_1 - m_1$, where w_1 denotes the total surplus generated by firm 1's basket. Hence, it would choose the "monopoly" margin:

$$m_1^M \equiv \underset{m_1}{\operatorname{argmax}} \{m_1 F(w_1 - m_1)\},$$

which is uniquely defined under Assumptions A and B. We have:

Proposition 5. Suppose that firm 1 enjoys a weakly larger comparative advantage: $\delta_1 \geq \max\{\delta_2, 0\}$; under Assumptions A and B, there exists a unique trembling-hand perfect equilibrium, in which:

(i) Firm 2 sells its basket at cost but firm 1 attracts all one-stop shoppers and charges them a total margin m_1, reflecting its overall comparative advantage over the two products:

$$m_1^* = \min\left\{m_1^M, \delta_1 - \delta_2\right\};$$

(ii) If firm 2 does not enjoy a comparative advantage in the other market (i.e., $\delta_2 \leq 0$), then it attracts no consumer; hence, there is no multi-stop shopping, and cross-subsidization need not arise; and

(iii) If instead, firm 2 enjoys a comparative advantage in the other market (i.e., $0 < \delta_2 < \delta_1$), then consumers with a shopping cost:

$$s < s^* \equiv j^{-1}(\delta_2),$$

where $j(\cdot)$ is defined by (3), engage in multi-stop shopping (they visit both firms and buy their strong products), and cross-subsidization arises. Both firms sell their weak products below costs, with the same negative margin equal to $-h(s^*) < 0$.

Proof. See the online web Appendix D.1. ■

The outcome of competition for one-stop shoppers is intuitive: firm 1's basket offers a greater surplus; it wins the competition for one-stop shoppers and can charge them a total margin as high as its relative comparative advantage, $\delta_1 - \delta_2$. It does so when firm 2 exerts competitive pressure (i.e., $\delta_1 - \delta_2 < m_1^M$), otherwise, it charges the monopoly margin m_1^M.

That firm 2 keeps subsidizing its weak product is not surprising. As its overall basket is less attractive, competition for one-stop shoppers leads firm 2 to offer its basket at cost, as it enjoys market power over multi-stop shoppers. However, it charges a positive margin on its strong product, and must therefore sell the weak product below cost. To understand why firm 1 still subsidizes its weak product even though it now enjoys market power over one-stop shoppers as well, consider again the following thought experiment. Increase firm 1's margin on its strong product by a small amount and decrease the margin on its weak product by the same amount, so as to maintain the total margin m_1. This alteration of the price structure does not affect the profit made on one-stop shoppers (who pay the same total price for the basket) but increases the profit made on multi-stop shoppers (who pay a higher price for the strong product). In addition, this induces some marginal multi-stop shoppers to switch to one-stop shopping and buy firm 1's weak product as well (instead of buying only its strong product). It is therefore profitable for firm 1 to keep altering the price structure as long as it earns a nonnegative margin on its weak product; hence, in equilibrium, it sells its weak product below cost.

□ **Endogenous comparative advantage.** Our baseline model assumes that firms have comparative advantages over different products. We now show that such asymmetric comparative advantages arise endogenously when firms can invest in cost reduction or quality improvement. For the sake of exposition, we suppose that firms initially provide the same value for each product, and add a preliminary stage in which they can improve the value of its products. For tractability, we first focus on a simple setting in which firms can allocate a "value-improvement" endowment

Δ among the products A and B; that is, each firm can enhance the value of its products, subject to the constraint that the overall improvement cannot exceed Δ. For instance, firms may have to prioritize the projects of their R&D units so as to target quality-improving and/or cost-reducing innovations across their products. Supermarkets face similar choices for their private labels; in addition, they employ buying agents to negotiate with suppliers, and may concentrate their bargaining efforts so as to obtain better deals on specific products. At the end of this section, we discuss how the insights obtained in this simple setting extend to more general investment environments in which firms also choose their improvement capability Δ.

We thus consider the following extended game:

- Stage 1. Each firm $i = 1, 2$ chooses $(\Delta_{A_i}, \Delta_{B_i}) \in \mathcal{S} \equiv \{(\Delta_A, \Delta_B) \in \mathbb{R}^2_+ \mid \Delta_A + \Delta_B \leq \Delta\}$; these decisions are simultaneous; and
- Stage 2. Firms simultaneously set the prices for their products.

Firms' pricing decisions will obviously be driven in part by their own improvement decisions. Whether a firm's pricing decisions can also be contingent on the other firm's improvement decisions depends on the observability of these decisions. For example, quality improvements are more likely to be observed than cost reductions or lower input tariffs. We consider here both extreme situations, in which improvement decisions are either publicly observed or remain private at the end of the first stage. We assume, however, that consumers observe these decisions before making their purchasing decisions. This is consistent with the quality/cost dichotomy highlighted above and amounts to assuming that consumers can observe the quality of the products offered. In the case of reductions in costs or wholesale prices, the assumption is innocuous, as consumers' purchasing decisions do not depend on them.

We look for the trembling-hand perfect Nash equilibria of this two-stage game. The following proposition shows that firms have an incentive to invest in different products, which in turn gives rise to cross-subsidization:

Proposition 6. In the above two-stage game, and regardless of whether improvement decisions are public or private at the end of the first stage, there exists exactly two trembling-hand perfect Nash equilibria in pure strategies, in which: (i) in stage 1, firms enhance by Δ the value of their offerings in different markets; and (ii) in stage 2, they sell their baskets at costs but—thanks to cross-subsidization—obtain a positive profit by charging $\rho^* = h(s^*) > 0$ on their strong products, where $s^* = j^{-1}(\Delta)$.

In addition:

(i) If improvement decisions remain private at the end of the first stage, then there exists a symmetric mixed-strategy equilibrium in which firms invest Δ and charge ρ^* on either product with equal probability; and
(ii) If improvement decisions are publicly observed at the end of the first stage, then when $h(\cdot)$ is weakly concave, there is a symmetric mixed-strategy equilibrium in which firms invest Δ on either product with equal probability.

Proof. See the online web Appendix D.2. ■

To capture this intuition in its simplest form, consider a simple discrete-choice variant of the above game in which each firm must simply choose which product to target (i.e., $(\Delta_{A_i}, \Delta_{B_i}) \in \{(\Delta, 0), (0, \Delta)\}$). If both firms invest in the same market, then their offerings are not differentiated and head-to-head competition leads to zero profit for each firm. If instead they invest in different products, then they sell their baskets at cost but obtain a positive profit equal to $\pi^* = F(s^*)h(s^*)$, where $s^* = j^{-1}(\Delta)$. Hence, there are two pure-strategy equilibria, in which firm 1 invests in one product and firm 2 invests in the other product. Whether or not firms observe each other's improvement decisions at the end of the first stage does not affect these equilibria. If a firm expects its rival to invest entirely in a single product and to offer its basket at cost (implying that serving one-stop shoppers cannot bring any benefit), it has an incentive to invest in the other product in order to maximize the value offered to multi-shop shoppers and exploit their demand. The above proposition shows that the argument extends to continuous allocation decisions.

Interestingly, there also exists a mixed-strategy equilibrium in which firms invest in either product with equal probability. Half of the time, they end up with similar offerings, in which case, all products are supplied at cost. However, the rest of the time, each firm ends up with a strong and a weak product, and cross-subsidizes its weak product with the strong one. It follows that prices are also stochastic, and consistent with each firm offering random discounts or special offers on one product (either one). Consider, for example, the case of supermarkets negotiating a discount Δ off the regular input costs, c_A or c_B. Half of the time, every product $i = A, B$ is sold below the nondiscounted cost c_i by one firm (at price $c_i - \rho^*$), and above the discounted cost $c_i - \Delta$ by the other firm (at price $c_i - \Delta + \rho^*$); this induces multi-stop shoppers to mix-and-match in order to benefit from the lower price, $c - \Delta + \rho^*$, on both products.[19]

As mentioned above, we have also considered more general investment environments in which each firm $i = 1, 2$ can choose any improvements $\Delta_{A_i} \geq 0$ and $\Delta_{B_i} \geq 0$, at total cost $C(\Delta_{A_i} + \Delta_{B_i})$; see the online web Appendix D.3. Under mild regularity conditions ensuring the existence of an equilibrium in which both firms invest (and, for tractability, ensuring that the market is fully covered), the unique subgame (trembling-hand) perfect Nash equilibria in pure strategies are such that firms choose to invest in different products, which leads them to again sell their weaker products below cost. Interestingly, however, it is always the case that one firm invests more than the other in order to obtain market power over one-stop shoppers as well.

5. Resale-below-cost laws

■ In regulated industries, cross-subsidization has been a well-recognized issue in both theory and practice,[20] and has prompted regulators to impose structural or behavioral remedies.[21] In contrast, in competitive markets, the policy debate is more divided. Although below-cost pricing might be treated as predatory,[22] in many cases (including the Apple versus Amazon example), there is no such thing as a “predatory phase” followed by a “recoupment phase” (e.g., once rivals have been driven out of the market), which constitute key features of predation scenarios.[23] As mentioned in the Introduction, this has led many countries to adopt specific rules prohibiting or limiting below-cost pricing in retail markets. These rules, known as Resale-Below-Cost (RBC hereafter) laws, have been the subject of heated policy debates. In Ireland, for example, based on evidence that consumers pay more when grocery goods are subject to the prohibition of below-cost sales, in 2005, the Irish Competition Authority recommended terminating the RBC law.[24] However, the Irish Joint Committee on Enterprise and Small Business recommended keeping the

[19] The rest of the time, firms’ prices coincide for each product, and multi-stop shopping thus does not arise: all prices are at cost in case of public decisions, whereas cross-subsidization still arises in case of private decisions. In both cases, however, firms obtain the same expected profit, equal to $\pi^*(\Delta)/2$.

[20] The seminal article of Faulhaber (1975) rigorously defines the concept of cross-subsidy and introduces two tests for subsidy-free pricing, which have been widely applied in both regulation and antitrust enforcement. See Faulhaber (2005) for a recent survey.

[21] Such concerns led, for instance, to the breakup of AT&T and the imposition of lines of business restrictions on local telephone companies (*U.S. v. AT&T*, 1982). More recently, the European Commission required the German postal operator to stop cross-subsidizing its parcel services with the profit derived from its legal monopoly on letter services (*Deutsche Post*, 2001).

[22] See, for example, Bolton, Brodley, and Riordan (2000) and Eckert and West (2003) for detailed discussions of how predatory pricing tests should be designed. Rao and Klein (1992) and Berg and Weisman (1992) examine the treatment of cross-subsidization under US antitrust laws.

[23] In the United States, for instance, the feasibility of recoupment is necessary for a predation case since the Supreme Court decision in *Brooke Group Ltd. v. Brown & Williamson Tobacco Corp*.

[24] The Irish Competition Authority examined pricing trends under the Groceries Order (the RBC law introduced in Ireland in 1987). The authority found that prices for grocery items covered by the Order had been increasing, but prices

RBC law due to concerns about an increased concentration in grocery retailing and predatory pricing. The Irish example highlights the dilemma of antitrust authorities: RBC laws may prevent dominant retailers from engaging in predatory pricing against smaller or more fragile rivals, but in competitive markets, they may also lead to higher prices and thus harm consumers.

We now examine the impact of a ban on below-cost pricing in our baseline setting. We first note that such a ban raises equilibrium basket prices, which benefits firms at the expense of one-stop shoppers:

Proposition 7. When below-cost pricing is prohibited, in equilibrium, each firm obtains a profit at least equal to:

$$\bar{\pi} \equiv \max_{\rho} \rho F(\delta - \rho) > 2\pi^*.$$

It follows that, compared to the equilibrium that arises in the absence of a ban under Assumptions A and B:

(i) Firms more than double their profits; and
(ii) One-stop shoppers face higher prices for the firms' baskets.

Proof. See the online web Appendix E.4. ■

The intuition is simple. If the rival offers both of its products at cost, a firm cannot make a profit on one-stop shoppers, but can still make a profit by selling its strong product to multi-stop shoppers. Indeed, charging a margin $\rho < \delta$ induces consumers with shopping cost $s < \delta - \rho$ to buy both strong products, thus generating a profit $\rho F(\delta - \rho)$. By choosing the optimal margin:

$$\bar{\rho} \equiv \underset{\rho}{\operatorname{argmax}}\, \rho F(\delta - \rho), \tag{6}$$

the firm can thus secure $\bar{\pi}$. Hence, in any equilibrium, each firm earns a profit at least equal to $\bar{\pi}$. Furthermore, as the rival can no longer subsidize its weak product, each firm now more than doubles its profit: $\bar{\pi} = \max_{\rho} \rho F(\delta - \rho) > 2\rho^* F(\delta - 2\rho^*) = 2\pi^*$. Finally, equilibrium total margins are positive, as weak products cannot be sold below cost, and strong products are sold with a positive margin. One-stop shoppers thus face higher prices than in the absence of the ban.

Intuitively, banning below-cost pricing should lead the firms to offer their weak products at cost. Furthermore, as a firm can obtain at least $\bar{\pi}$ by charging $\bar{\rho}$ to multi-stop shoppers, it will never charge so low a margin that it would obtain less than $\bar{\pi}$, even if it were to attract all shoppers. That is, no firm will ever charge $\rho < \underline{\rho}$, where $\underline{\rho}$ is the lower solution to:

$$\underline{\rho} F(w - \underline{\rho}) = \bar{\pi}. \tag{7}$$

The next proposition shows that, even though there is no pure-strategy equilibrium when below-cost pricing is banned, there exists an equilibrium in which firms indeed sell their weak products at cost, and obtain an expected profit equal to $\bar{\pi}$ by randomizing the margins on their strong products between $\underline{\rho}$ and $\bar{\rho}$:

Proposition 8. If s is distributed with positive density over $\mathbb{R}_+$ (Assumption A), or over $[0, \bar{s}]$ with $\bar{s} > w$, then when below-cost pricing is prohibited:

(i) There exists no equilibrium in pure strategies; and
(ii) There exists a symmetric mixed-strategy equilibrium in which firms obtain an expected profit equal to $\bar{\pi}$ by selling weak products at cost and randomizing the margins on strong products over $[\underline{\rho}, \bar{\rho}]$.

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for grocery items not covered by the Order had been decreasing. It concluded that, on average, Irish families were paying 500 euros more per year because of the Order. See OECD (2007).

Proof. See the online web Appendix E.1. ■

As in the sales model of Varian (1980), firms face a dilemma: they are tempted to exploit "captive" customers (the uninformed consumers in Varian's model, and multi-stop shoppers here) but, at the same time, they want to compete for "price-sensitive" customers (the informed consumers in Varian's model, and one-stop shoppers here). To see why there is no pure-strategy equilibrium, note that competition for one-stop shoppers would again drive *total* basket prices down to cost. However, as below-cost pricing is banned, this would require selling *both* products at cost. Obviously, this cannot be an equilibrium, as a firm can make a profit on multi-stop shoppers by charging a small positive margin on its strong product.

The characterization of the mixed-strategy equilibrium is similar to that proposed by Varian (1980) and Baye, Kovenock, and de Vries (1992).[25] In this equilibrium, *ex post*, consumers with a shopping cost below $\tau^b(\rho_1, \rho_2) \equiv \delta - \max\{\rho_1, \rho_2\}$ favor multi-stop shopping and buy both firms' strong products, whereas consumers with a shopping cost in the range $\tau^b(\rho_1, \rho_2) < s < v^b(\rho_1, \rho_2) \equiv w - \min\{\rho_1, \rho_2\}$ are one-stop shoppers and buy from the firm that charges the lowest price for its basket.

Let us now examine the impact of a ban on consumers. We first note that marginal consumers are one-stop shoppers, as $v^b > \tau^b$. As banning below-cost pricing raises prices for one-stop shoppers, it follows that this reduces not only the number of one-stop shoppers, but also the total number of consumers, from $F(w)$ to $F(v^b(\rho_1, \rho_2))$. Furthermore, the multi-stop shopping cost threshold τ^b satisfies:

$$\tau^b(\rho_1, \rho_2) \geq \bar{\tau} \equiv \tau^b(\bar{\rho}, \bar{\rho}) = \delta - \bar{\rho} > s^*.$$

Hence, banning below-cost pricing *fosters* multi-stop shopping.

This does not mean that multi-stop shoppers face lower prices, however. In particular, the upper bound $\bar{\rho}$ exceeds the margin ρ^* that arises in the absence of the ban,[26] implying that multi-stop shoppers face higher prices with at least some probability. The next proposition shows that banning below-cost pricing actually harms multi-stop shoppers (as well as one-stop shoppers) when weak products offer relatively little value, that is, when w is close to δ:

Proposition 9. Suppose that s is distributed with positive density over $\mathbb{R}_+$ (Assumption A) or over $[0, \bar{s}]$ with $\bar{s} > w$. Keeping δ constant, for w close enough to δ:

(i) Every consumer's expected surplus is lower in the equilibrium characterized by Proposition 8 than in the equilibrium that arises in the absence of a ban; and
(ii) Total welfare can, however, be lower or higher, depending on the distribution of shopping costs. For instance, if $F(s) = (s/\bar{s})^k$, then there exists $\hat{k}(w, \delta) > 0$ such that banning below-cost pricing decreases (resp., increases) total welfare if $k < \hat{k}(w, \delta)$ (resp., $k > \hat{k}(w, \delta)$).

Proof. See the online web Appendix E.2. ■

The intuition is that, when weak products are "very" weak, there are relatively few one-stop shoppers. Firms can then raise the prices of their strong products, so as to exploit multi-stop shoppers, without being too concerned about losing one-stop shoppers. Indeed, in the limit case where $w = \delta$, the lower bound $\underline{\rho}$ of the equilibrium margin distribution converges to the upper bound $\bar{\rho}(> \rho^*)$, and thus multi-stop shoppers certainly face higher prices. By continuity, multi-stop shoppers face higher *expected* prices, as long as weak products are not too valuable.

[25] Using the analysis of the latter article, it can moreover be shown that, conditional on pricing weak products at cost, the (mixed-strategy) equilibrium (for the price of strong products) is unique.

[26] To see this, it suffices to note that, from the first-order conditions, ρ^* and $\bar{\rho}$ satisfy, respectively, $\rho = h(\delta - \rho^* - \rho)$ and $\rho = h(\delta - \rho)$, where $h(.)$ is an increasing function.

However, as a ban on below-cost pricing increases firms' profits, the impact on total welfare remains ambiguous, and depends, in particular, on the distribution of shopping costs.

Thus, in competitive markets, RBC laws increase firms' profits but hurt one-stop shoppers. When weak products offer relatively low value, multi-stop shoppers also face higher prices, in which case, banning below-cost pricing increases firms' profits at the expense of consumers. This finding gives support to the conclusion of the OECD (2007) report, which argues that RBC laws are likely to lead to higher prices and thus harm consumers. The reduction in consumer surplus may, moreover, exceed the increase in firms' profits and thus result in lower total welfare. However, when instead, weak products offer high value, RBC laws may have a positive impact on multi-stop shoppers.[27]

Remark: upstream margins. In the case of downstream firms (e.g., retailers), their comparative advantages may be mainly driven by differences in wholesale prices rather than in quality or cost. For instance, in the setting developed in Section 4, supermarkets may devote resources to negotiating better conditions from their suppliers, and have an incentive to target different products. Total welfare must also account for the profit of upstream suppliers, which may affect the social impact of RBC laws. For example, in the online web Appendix E.2, we consider a variant along these lines, in which firms initially face the same wholesale price for each product and negotiate a discount δ on one or the other product; "strong products" then correspond to those on which they negotiated the discount and "weak products" correspond to those on which they pay the regular wholesale price. To fix ideas, suppose, moreover, that strong products are supplied at cost (i.e., the discount corresponds to the supplier's entire margin). Suppliers thus only make a profit on the "weak" products, which retailers sell to one-stop shoppers (and only to those). By reducing the extent of one-stop shopping, RBC laws then hurt upstream suppliers as well, which further degrades the impact on total welfare.

In a setting where consumers are one-stop shoppers who underestimate (some of) their needs, Johnson (2017) finds that banning below-cost pricing has an unambiguously negative impact: it increases the price for potential loss leaders (those products for which consumers do not underestimate their needs) and harms consumers, despite decreasing the prices for the other products. In our setting, a ban on below-cost pricing also raises the price of potential loss leaders (namely, the weak products), but can either increase or decrease the (expected) price of the other products (the strong ones). Also, despite one-stop shoppers being worse-off under RBC laws, as in Johnson's article, we allow for multi-stop shoppers as well, and they can either be worse- or better-off. In spite of these discrepancies, Johnson's article and this article both call for the cautious use of below-cost pricing regulations in competitive markets; and where they are implemented, their impact should be carefully evaluated.

6. Conclusion

■ We have studied competition between multiproduct firms in a setting where firms enjoy comparative advantages over different goods or services, and customers have heterogeneous transaction costs. As a result, those with low costs tend to patronize multiple suppliers, whereas those with higher shopping costs are more prone to one-stop shopping. This gives rise to a form of co-opetition, as firms' baskets are substitutes for one-stop shoppers, but their strong products are complements for multi-stop shoppers. As a result, competition for one-stop shoppers drives total basket prices down to total cost but, in order to exploit their market power over multi-stop shoppers, firms price strong products above cost and weak products below cost. Furthermore, the complementarity of firms' strong products generates double marginalization problems, which here take the form of excessive cross-subsidization. Indeed, firms would benefit from mutual moderation, for example, by agreeing to put a cap on the prices of strong products. Such bilateral

[27] However, RBC laws reduce total expected consumer surplus when, for instance, the density of the distribution of shopping costs does not increase between s^* and δ; see the online web Appendix B.3.

agreements would benefit consumers (competition for one-stop shoppers would still allow them to buy the baskets at cost, but multi-stop shoppers would benefit from lower prices), and would also increase profits by boosting multi-stop shopping.

These insights highlight the role of the interaction across products in firms' own offerings, and the diversity in consumers' shopping patterns for the analysis of competition among multiproduct firms. Interestingly, until recently, the empirical literature on platform competition in media or healthcare industries, or on retail competition between supermarkets, have instead tended to either ignore multi-stop shopping or focus on a specific product category. The recent work by Thomassen et al. (2017), who account for the multiplicity of product categories and the heterogeneity of shopping patterns, constitutes a notable exception, and its findings confirms the importance of these features.

These insights can also shed some light on firms' incentives to invest in improving their offerings or to negotiate better conditions from their suppliers. When endogenizing product choices, we find that firms indeed have incentives to differentiate themselves by targeting different products.

The legal treatment of cross-subsidization in competitive markets has triggered much debate. We find that banning below-cost pricing substantially benefits firms—their profits more than double—at the expense of one-stop shoppers, and it can also reduce total consumer surplus and social welfare, depending on the value offered by weak products and the distribution of shopping patterns. Our analysis thus calls for a cautious use of resale-below-cost laws in competitive markets.

Appendix A: Proof of Proposition 1

Thanks to Lemma 1, the equilibrium characterization is fairly simple. As firms sell their baskets at cost, one-stop shopping gives consumers the "full" value w. Consumers may, however, prefer buying both strong products, A_1 from firm 1 and B_2 from firm 2; this involves an extra shopping cost s and yields a total value:

$$v_{12} \equiv u_1^A - p_1^A + u_2^B - p_2^B = w + \delta - \rho_1 - \rho_2,$$

where $\rho_1 \equiv p_1^A - c_1^A$ and $\rho_2 \equiv p_2^B - c_2^B$, respectively, denote firms 1 and 2's margins on their strong products. Consumers favor multi-stop shopping over one-stop shopping if the additional value from mixing-and-matching exceeds the extra shopping cost, that is, if

$$s \leq \tau \equiv v_{12} - w = \delta - \rho_1 - \rho_2.$$

Hence, consumers with a shopping cost $s < \tau$ engage in multi-stop shopping, whereas those with a shopping cost such that $\tau < s < w$ opt for one-stop shopping (and those with a shopping cost $s > w$ do not shop at all). As firms only derive a profit from selling their strong products to multi-stop shoppers, firm i's profit can be expressed as:

$$\pi_i(\rho_1, \rho_2) = \rho_i F(\tau) = \rho_i F(\delta - \rho_1 - \rho_2).$$

Furthermore, we know from Lemma 1 that there are some multi-stop shoppers who are active in equilibrium; hence, the margins ρ_1 and ρ_2 must satisfy $\rho_1 + \rho_2 < \delta$. If follows that these margins cannot be negative: any firm i offering that $\rho_i < 0$ would make a loss, which it could avoid by charging instead a nonnegative margin. Likewise, starting from a candidate equilibrium in which some firm i charges $\rho_i = 0$, that firm could profitably deviate by slightly raising its margin:

$$\left.\frac{\partial \pi_i}{\partial \rho_i}(\rho_1, \rho_2)\right|_{\rho_i = 0} = F(\tau) > 0.$$

Hence, in equilibrium, each firm i must charge a positive margin on its strong product: $\rho_i > 0$. As the basket is offered at cost, this implies that firm i sells its weak product *below cost*.

Appendix B: Proof of Proposition 2

Thanks to Lemma 1, the equilibrium is interior, and consumers whose shopping cost lies below $\tau = \delta - \rho_1 - \rho_2$ patronize both firms, whereas those whose shopping cost lies between τ and w patronize a single firm. As noted in the text, the monotonicity of $h(\cdot)$ ensures that the profit function $\pi_i(\rho_1, \rho_2)$ is strictly quasiconcave in ρ_i, and its aggregative game nature ensures that any candidate equilibrium is symmetric: $\rho_1 = \rho_2 = \rho$, which satisfies the first-order solution

$\rho = h(\delta - 2\rho)$. The monotonicity of $h(\cdot)$ further ensures that this first-order condition characterizes a unique candidate equilibrium, such that:

$$\rho^* = h(\tau^*),$$

where:

$$\tau^* = j^{-1}(\delta).$$

Note that, by construction, $\tau^* > 0$ (as $j(0) = 0 < \delta$) and thus: (i) $\rho^* = h(\tau^*) > 0$; and: (ii) $\rho^* < \delta/2$ (as $\delta - 2\rho^* = \tau^* > 0$).

There is thus a unique candidate equilibrium, in which both firms charge ρ^* on their strong products and a negative margin $\mu^* = -\rho^*$ on their weak products. We now show that firms cannot benefit from any deviation. Suppose, for example, that firm i deviates by charging ρ_i on its strong product and μ_i on its weak product. Obviously, it cannot make a profit from one-stop shoppers, as it would have to sell its basket (weakly) below cost to attract them. Furthermore, it cannot make a profit either by offering its weak product to multi-stop shoppers, as it would have to charge $\mu_i \leq \rho^* - \delta < 0$ to attract them. Thus, it can only make a profit from selling its strong product to multi-stop shoppers, and this profit is equal to $\rho_i F(\tau)$, where $\tau = \min\{\delta + \mu^* - \rho_i, \delta + \mu_i - \rho^*\}$; but then:

$$\rho_i F(\tau) \leq \rho_i F(\delta + \mu^* - \rho_i) = \rho_i F(\delta - \rho^* - \rho_i) \leq \pi^*,$$

where the inequality comes from the fact that the profit function $\rho_i F(\delta - \rho^* - \rho_i)$ is quasiconcave in ρ_i, from the monotonicity of $h(\cdot)$, and, by construction, maximal for $\rho_i = \rho^*$.

[Correction added on 22 July 2019, after first online publication: Appendix C has been moved to the Supporting Information section of the online article.]

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.