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Spatial pricing and the strategic choice of retail formats*

Toshitaka Gokan[†] Jacques-François Thisse[‡] Xiwei Zhu[§]

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Abstract

We develop a model in which offline and online transportation costs, online shopping disutility cost and consumer taste heterogeneity, and online and offline retailers' pricing policies interact to determine the equilibrium retail format that emerges from firms' and consumers' choices. This is done by combining spatial pricing and discrete choice theory within a unified game-theoretic framework. We study the industry equilibrium, as well as the corresponding consumer surplus and total welfare. Our results show that firms' choices of a retail format and consumers' decision to buy from an offline or online firm often depend on consumers' locations relative to firms'. Comparing aggregate consumer surpluses shows that consumers prefer online to alternative channels when they are sufficiently heterogeneous, but this need not be so when heterogeneity is weak. When consumers' tastes are heterogenous enough, the retail format maximizing total welfare depends on the value of the distaste costs of online purchase. Thus, the nature of products supplied by retailers is likely to affect the socially desirable retailing system through the degree of product differentiation.

Keywords — Offline retailing, online retailing, spatial price policies

JEL codes —L13; L81; R10.

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1 Introduction

E-commerce is one of the key features of the digital economy and could well gain the lion's share of retailing in a not distant future. In the United States, the share of e-commerce sales in total retail sales was 6.5% in 2014 but grew to reach 15.9% in 2023. In Japan, this share was equal to 4.4% in 2014 and reaches 9.4% in 2023. In China, this share grew from 10.6% in 2014 to 27.6% in 2023. In 2014, the e-commerce sales reached a share of 11.3% of all retail sales in the United Kingdom and reaches 26.7% in 2023.

Our goal is to develop a 'reduced form' model which accounts for offline and online transportation costs, online shopping disutility cost and consumer taste heterogeneity, and online and offline retailers' pricing policies. We then study how these variables and parameters interact to determine the equilibrium of the retail industry. This topic has attracted a lot of attention from researchers working in different fields. What makes our paper unique is the combination of spatial pricing studied in industrial organization and discrete choice theory within a unified game-theoretic framework that embeds ingredients from marketing.

Even though it is common to say that location no longer matters in e-commerce, the choice of a particular retail format is by nature a spatial problem. First, a firm selecting a retail format also chooses a *spatial price policy*. An offline retailer typically charges the same *mill price* to all its customers while a buyer faces a full price that reflects exactly her travel cost to the retailer. The issue is more complex for online firms because they can choose between different delivery and pricing strategies. Because e-retailers must ship commodities from a depot to spatially dispersed consumers, shopping vastly differs from shipping. This is why we find it critical to choose an approach in which shopping and shipping costs are distinct. Furthermore, Chintagunta *et al.* (2012) show that transaction costs specific to each channel play an important role in the choice between offline and online retailing. As a result, one should expect transportation costs, which account for a significant share of consumers' budget, to play a key role in consumers' decisions to buy from offline retailers and firms' decisions about adopting an online format. According to the Bureau of Labor Statistics, Americans spent on average, about 12.5% of their income on transportation. In China and the European Union, transportation accounts for 13.1% of consumer expenditure in 2021. As the frequency of trips for work and for shopping is similar, 23.6% versus 21.8% in the U.S. during the period 1995-2008, it is reasonable to guess that shopping costs represent a non-negligible share of consumers' budget (Couture *et al.*, 2018).

Firms that offer home delivery of products adopt of a wide range of pricing strategies. Basically, they are related to the way firms charge shipping costs to customers; examples include combined pricing, partitioned pricing or subscription pricing. Although the jury is still out to say what the best strategy is, a large share of consumers expects free shipping on their online purchases because it makes it easier to compare options, which fosters higher sales (Zhang and Sexton, 2001; Lederer, 2012; Etumnu, 2023). A defensible approach is thus to assume that e-retailers adopt a simple policy known as *uniform delivered pricing* when a firm charges the same delivered price, inclusive of shipping and handling costs, regardless of its customers' locations. We will discuss in the concluding section how our model can be used to tackle alternative, more general pricing strategies.

As retailers compete for spatially dispersed consumers through different spatial price policies, it seems natural to nest our problem within the framework of spatial competition theory (Bonfrer *et al.*, 2022). As highlighted by Brown (1989) long ago, Hotelling-like (1929) models have played a central role in retail location theory and are still widely used in the literature on retail formats. Examples include Balasubramanian (1998), Bouckaert (2000), Forman *et al.*

(2009), Yoo and Lee (2011), to mention a few.

Second, it is well known that discrete choice models provide efficient tools to study consumers' demand because they allow capturing in a simple and realistic manner heterogeneity in consumers' behavior (McFadden, 2001; Chintagunta and Nair, 2011; Dubé, 2019). To the best of our knowledge, these models have been less explored in the literature on competition between retail formats (see below for a brief discussion of a few contributions). Yet, we will see that the heterogeneity of consumer tastes is a key driver in the emergence of different retail formats under conditions that are otherwise identical across firms. Furthermore, the heterogeneity of consumers helps solve the problem of the existence of a price equilibrium, an issue which is still unsolved when consumers are homogeneous. Taste heterogeneity also implies that consumers are less sensitive to price, which concurs with the empirical evidence provided by Döpper *et al.* (2025) for the U.S.

In this paper, we have chosen to focus on a duopoly. Indeed, as shown by the literature, a duopoly is often sufficient to study several of the main issues associated with the emergence of various retailing systems. By marrying spatial pricing with random choice theory, we can determine how cost and pricing considerations interact with consumers' tastes and locations in the emergence of one of three possible combinations of retail formats, i.e., an offline duopoly, an online duopoly, and a mixed duopoly that involves the two different retail formats. Our framework allows one to study or revisit the following questions. (i) Does it pay off to go online? (ii) What is the equilibrium retail industry structure? (iii) Is one retail format more competitive than the other. (iv) What are the implications of the online business model for consumer and social welfare?

Competition between firms is modeled as a two-stage game. In the first stage, firms choose a retail format, either offline or online. In the second stage, they compete in prices, contingent on their chosen price policies. The market outcome is given by a subgame perfect Nash equilibrium. As usual, the game is solved by backward induction.

By borrowing concepts and ideas from different disciplines, we hope to contribute to a more unified body of literature on retail formats. Our main findings may be summarized as follows. First, firms' choices of a retail format and consumers' decision to buy from an offline or online firm often depend on firms' and consumers' locations. Here we want to stress that working with homogeneous consumers may give rise to results that cease to hold once it is recognized that consumers have different tastes, and vice versa. This point is important because many papers studying the emergence of retail formats assume that consumers are heterogeneous in locations, but few of them consider tastes as a second source of heterogeneity. What is more, different degrees of taste heterogeneity may lead to opposite results.

Second, consumers who purchase online are deprived from the advantages associated with buying from a physical store. This gives rise to what is called a distaste cost (Balasubramanian, 1998; Loginova, 2007). We show that *a conventional retailer finds it profitable to become an e-retailer when the distaste cost is sufficiently low.* This result may explain why expensive goods for which consumers have strong idiosyncratic preferences are still provided by conventional shops. By contrast, more standardized goods, such as books, CDs or inexpensive clothes, involve low distaste costs (Smith and Brynjolfsson, 2001). In this case, both firms choose to become e-retailers when consumer tastes are sufficiently heterogeneous. Under this condition, both firms make lower profits in an online duopoly than in an offline duopoly. In other words, firms face a prisoner's dilemma when they choose strategically their retail format.

Third, one of the main issues discussed in the literature is the expected procompetitive nature of online retailing generated by lower transaction costs (Brown and Goolsbee, 2002; Brynjolfsson *et al.*, 2003; Lieber and Syverson, 2012). Our emphasis on spatial pricing policies leads us to distinguish between two prices. The *producer price* of a conventional retailer is its mill price while the corresponding *consumer price* is the full price paid by consumers, which increases with the distance to the retailer. On the other hand, when the firm is an e-retailer, the producer and consumer prices are constant across locations and equal up to the distaste cost. Having said that, we will show that *a shift to the e-channel by a conventional retailer always induces its rival to lower its producer price*. In this sense, it is fair to say that e-commerce fosters competition. By contrast, no clear-cut result emerges about the impact on consumer prices.

Fourth, the tenets of e-commerce hold that it reduces market friction, unleashes competition and makes consumers better-off. Here too, our analysis is more nuance in that *consumers' best retail format depends on where consumers are located relative to retailers*. As a result, it seems futile to look for general answers regarding the desirability of the online channel. Nevertheless, comparing total welfare shows that the online channel performs better than the alternative channel when consumers are sufficiently heterogeneous, but this need not be so when heterogeneity is weak. Consequently, by affecting consumers' attitudes toward product differentiation, the nature of the goods supplied by retailers is likely to affect the socially desirable retail system. To illustrate, a channel may be better for a luxury good, but not for a standard homogeneous good.

Finally, shopping and shipping costs have different impacts on the market outcome. For example, in the mixed duopoly, shopping costs borne by consumers and shipping costs incurred by e-retailers affect differently the two retailers. Profits made by the offline retailer decrease with shopping costs, but increase with shipping costs, whereas the opposite holds for the e-retailer. On the other hand, taste heterogeneity has an unambiguous impact on prices because it relaxes competition. More specifically, *when consumers are more heterogeneous, both types of firms charge higher producer prices*, which agrees with well-established results in industrial organization (Tirole, 1988).

Related literature. There is a plethora of contributions in spatial competition theory which belong to economics, marketing or operations research, which cannot be discussed here (see Drezner and Eiselt, 2024, for a recent, though incomplete, survey). We refer to Gauri *et al.* (2021) and Ratchford *et al.* (2022) for two detailed overviews of the now vast literature on competition between different retail formats. Here, we will only discuss papers closely related to ours.

The idea that consumers are heterogeneous along several dimensions is not new. Yoo and Lee (2011) and Colombo and Matsushima (2020) assume that spatially dispersed consumers are heterogeneous in the disutility they incur for using an Internet channel. This second heterogeneity is captured by a distance to a reference point. By facilitating consumers' search, e-commerce was expected to strongly reduce price dispersion. Brynjolfsson and Smith (2000) observe that price dispersion still prevails among e-retailers. Smith and Brynjolfsson (2001) then use the multinomial logit to rationalize customers' behavior who do not always buy the cheapest homogeneous good, such as books or CDs. Bernstein *et al.* (2008) also use the multinomial logit and consider different markets involving only brick-and-mortar retailers, physical retailers and retailers which combine off- and online sales, and retailers selling through both channels. They find that combining the two channels is a dominant strategy for all retailers. This is reminiscent of our result that suggest that the industry equilibrium involves only online-firms when consumers are sufficiently heterogeneous. However, their setting includes no transportation costs. We will discuss other relevant contributions in the main text. We will also see that our modeling strategy is consistent with a good deal of empirical evidence.

As a final note, we want to stress the difference between our paper and the existing literature. We compare different formats for a given number of firms while most papers consider the entry of online firms in a market characterized by a given number of conventional retailers. As entry typically intensifies competition, it is hard to distinguish between the effects caused by competition between different retailing formats and those associated with a higher degree of competition. By contrast, in our setting, a change in the market outcome is caused only the choice of formats made by firms.

The road map for the rest of the paper is as follows. The model is presented in Section 2 and its working is illustrated in Section 3 by considering the simple case of two conventional retailers. In Section 4, we study a mixed duopoly that involves offline and online firms. We first determine the equilibrium prices and then, the conditions under which a conventional retailer chooses to become an e-retailer. Section 5 identifies conditions for the two firms to be e-retailers. Being equipped to compare different retail formats, Section 6 casts doubt on the idea that online firms are not necessarily more competitive than offline firms, while Section 7 compares consumer surplus under different retail formats. We conclude in Section 8 by discussing several extensions.

2 The model and preliminary results

The market features a population of unit size and two firms, denoted 1 and 2, that produce a good differentiated. Consumers buy the same quantity of this good, which is normalized to 1. Firms' marginal costs are the same and normalized to 0. Each consumer knows the variety supplied by each firm. In what follows, we first describe the baseline model that we will use to study different retail formats. We then show that this model of probabilistic choice generates aggregate demands identical to those obtained from a deterministic setting with horizontal product differentiation. Let p_i be the price paid by a consumer when she patronizes firm i.

When consumers are about to make a choice, they must evaluate and compare various characteristics whose utility is likely to change due to idiosyncratic and external factors such as the context and environment in which the choice is made. Firms cannot observe all the variables affecting consumers at each moment a choice is made. Consumer behavior is then described by *choice probabilities*, which are obtained by maximizing a random utility. The alternative with the greatest realization is the one chosen (McFadden, 1986; Anderson *et al.*, 1992; Chintagunta and Nair, 2011).

Assume that individuals consume a given quantity of the differentiated good, which is normalized to one. The random indirect utility of a consumer who chooses variety i is given by $V_i = Y - p_i + \varepsilon_i$ where Y is her income. Since we consider a duopoly, we use the simplest discrete choice model in which $\varepsilon \equiv \varepsilon_2 - \varepsilon_1$ is uniformly distributed over $[-L, L]$ with a density $1/2L$. In other words, consumers' heterogeneity is modeled by the *linear probability model*.

The probability that a consumer chooses variety $i = 1, 2$, which is also firm i's expected demand at prices p_1 and

p_2, is given by

$$q_1(p_1,p_2) = \Pr(V_1 \geq V_2) = \begin{cases} 0 & \text{if } p_1 - p_2 \geq L \\ \frac{L-p_1+p_2}{2L}, & \text{if } -L < p_1 - p_2 < L \\ 1 & \text{if } -L \geq p_1 - p_2 \end{cases}, \tag{1}$$

$$q_2(p_1,p_2) = 1 - q_1(p_1,p_2). \tag{2}$$

Clearly, $q_1 > q_2$ if and only if $p_1 < p_2$. The parameter L measures the intensity of preference for diversity: the expected demand for a variety sold at a higher (resp., lower) price increases (resp., decreases) with L. More specifically, as L becomes larger, consumers care more about diversity in consumption and less about prices. The own and cross-partial derivatives of the choice probabilities with respect to the prices are such that increasing the price for a product reduces its own demand but increases its rival's demands. Therefore, the linear probability model captures the classical substitution effect between retailers.

It is worth noting that (1)-(2) are identical to the demands generated by a linear characteristics space where two varieties are located at $z_1 = -L/2 \in \mathbf{R}$ and $z_2 = L/2 \in \mathbf{R}$, while consumers are uniformly distributed with a unit density over the interval $[-1/2, 1/2] \subset \mathbf{R}$ (Anderson *et al.,* 1992, Proposition 4.7). In other words, consumer heterogeneity and product differentiation are the two sides of the same coin.

Firm i's (expected) profits are given by $\Pi_i(p_1,p_2) = p_i q_i(p_1,p_2)$. Applying the first order conditions yields the equilibrium prices $p_1^* = p_2^* = L > 0$. These prices increase with consumer heterogeneity ($L \uparrow$) because price competition becomes softer. On the other hand, when $L \to 0$, we fall back on the Bertrand outcome, that is, firms price at marginal cost, here 0.

We add a second type of differentiation to the linear probability model by assuming that firms 1 and 2 are located at the endpoints $x_1 = 0$ and $x_2 = 1$ of Main Street, while consumers are uniformly distributed along the interval $[0, 1]$ with a unit density. Therefore, a consumer is characterized by (i) her address $x \in [0,1]$ in the geographical space and (ii) her address $z \in [-1/2, 1/2]$ in the characteristics space.

Let $t > 0$ be the unit shopping cost. Assuming that firms are conventional retailers, the full price $p_i(x)$ paid by a consumer at x is equal to the mill price p_i set by the retailer plus the cost $t\,|x - x_i|$ of travelling to this retailer, which is linear in the distance between the consumer and store i. In this context, the random indirect utility of a consumer at x who chooses variety i is given by $V_i(x) = Y - p_i(x) + \varepsilon_i$.

3 Competition between two brick-and-mortar stores

Assume that the two firms are conventional retailers. In this case, consumers travel to the physical stores and the full prices are given by firms' mill prices plus the corresponding travel costs to the shops: $p_1(x) = p_1 + tx$ and $p_2(x) = p_2 + t(1-x)$. The quantities that a consumer located at x buys from firms 1 and 2 are, respectively, given by

$$q_1(p_1,p_2;x) = \Pr(V_1(x)\geq V_2(x)) = \begin{cases} 0 & \text{if } x \geq x_{\max} \\ \frac{L-p_1-tx+p_2+t(1-x)}{2L}, & \text{if } x_{\min} < x < x_{\max} \\ 1 & \text{if } \quad x \leq x_{\min} \end{cases}, \tag{3}$$

$$q_2(p_1,p_2;x) = \Pr(V_2(x)\geq V_1(x)) = \begin{cases} 1 & \text{if } x \geq x_{\max} \\ \frac{L+p_1+tx-p_2-t(1-x)}{2L}, & \text{if } x_{\min} < x < x_{\max} \\ 0 & \text{if } \quad x \leq x_{\min} \end{cases},$$

where

$$x_{\min} \equiv \max\left\{0, \frac{-p_1+p_2+t-L}{2t}\right\}, \qquad x_{\max} \equiv \min\left\{\frac{-p_1+p_2+t+L}{2t}, 1\right\} = 1 - x_{\min} \tag{4}$$

are the consumers indifferent between varieties.

Two cases may arise. In the first one, we have $x_{\min} > 0$ and $x_{\max} < 1$. In other words, there is *partial market coverage* because firms do not compete for all consumers. Using (4) shows that this condition holds when $L < t$. In the second case, we have $x_{\min} = 0$ and $x_{\max} = 1$, which means that firms now compete for all consumers: there is *full market coverage*. This arises when $L \geq t$.

In the first case, market demands are given by

$$q_1(p_1,p_2) \equiv \int_0^{x_{\min}} dx + \int_{x_{\min}}^{x_{\max}} \frac{-p_1-tx+p_2+t(1-x)+L}{2L}dx = \frac{t-p_1+p_2}{2t},$$
$$q_2(p_1,p_2) \equiv \int_{x_{\min}}^{x_{\max}} \frac{L+p_1+tx-p_2-t(1-x)}{2L}dx + \int_{x_{\max}}^{1} dx = \frac{t+p_1-p_2}{2t}.$$

Firms' profits are given by $\Pi_{1m} = p_1 q_1(p_1,p_2)$ and $\Pi_{2m} = p_2 q_2(p_1,p_2)$, which are both concave in their respective price. Applying the first-order conditions yields the equilibrium prices:

$$p_{1m}^* = p_{2m}^* = t > L. \tag{5}$$

As total demand is equally split between the two firms, equilibrium profits are given by

$$\Pi_{1m}^* = \Pi_{2m}^* = \frac{t}{2}. \tag{6}$$

It is straightforward to check that $x_{\min} = (t-L)/2t > 0$ and $x_{\max} = (t+L)/2t < 1$. Hence, consumers located in $[0,(t-L)/2t)$ patronize firm 1 only while those located in $((t+L)/2t, 1]$ visit and buy only from firm 2. Put differently, firm 1 (resp., firm 2) is the sole firm that supplies the market segment $[0,(t-L)/2t)$ (resp., $((t+L)/2t,1]$). The two firms compete over the area of contention given by $[(t-L)/2t,(t+L)/2t]$. This area expands as the degree of consumer heterogeneity increases ($L\uparrow$), whereas it shrinks as the shopping cost rises ($t\uparrow$). As a result, t and L are not substitutes. Furthermore, over the interval $[(t-L)/2t,(t+L)/2t]$ the probability of purchasing from firm 1 decreases as the distance x increases.

Finally, even though only firm 1 supplies the consumers in $[0,x_{\min})$, this firm does not behave like a monopolist because firm 2 still strives to serve these consumers. Therefore, the price p_1^* has the nature of a limit price. The same holds for firm 2 in $(x_{\max},1]$.

In sum, the common equilibrium price remains the same provided that the degree of consumer heterogeneity is lower than the degree of geographical differentiation, that is, $t > L$. Observe that the results obtained in the first case are identical to those obtained in a standard Hotelling model where $L = 0$.

Considering the second case ($L \geq t$), it is readily verified that firms' demands become

$$\begin{aligned} q_1(p_1, p_2) &= \int_0^1 \frac{L - p_1 - tx + p_2 + t(1-x)}{2L} dx = \frac{L - p_1 + p_2}{2L}, \\ q_2(p_1, p_2) &= \int_0^1 \frac{L + p_1 + tx - p_2 - t(1-x)}{2L} dx = \frac{L + p_1 - p_2}{2L}. \end{aligned}$$

The equilibrium prices and profits are now given by

$$p_{1m}^* = p_{2m}^* = L \geq t. \tag{7}$$

Hence, firms' demands are equal to 1/2, while the equilibrium profits are now given by

$$\Pi_{1m}^* = \Pi_{2m}^* = \frac{L}{2}. \tag{8}$$

Summarizing, we have:

Proposition 1. *Assume a market with two brick-and-mortar stores. If $t > L$, there exists a unique price equilibrium given by $p_{1m}^* = p_{2m}^* = t$. If $L \geq t$, there exists a unique price equilibrium given by $p_{1m}^* = p_{2m}^* = L$.*

Thus, geographical differentiation, consumer heterogeneity, or both relax price competition and allow firms to earn positive profits. Proposition 1 shows that profits and market prices depend on which attribute in consumer preferences is dominant. When $t > L$, raising t allows firms to charge higher prices because there is more spatial differentiation between the two retailers. Likewise, when $L \geq t$, consumers are willing to pay a higher price when L increases because varieties are more differentiated. In both cases, price competition is relaxed through more differentiation (Tirole, 1988).

If $L \geq t$, the equilibrium spatial distribution of consumption is given by

$$q_1^*(x) \equiv q_1(p_1^*, p_2^*; x) = \frac{p_2^* + t(1-2x)}{2L},$$

which decreases as the distance to firm 1 rises. Similarly, $q_2^*(x) = 1 - q_1^*(x)$ increases with x. Hence, spatial proximity matters to determine firms' sales.

4 Competition between offline and online firms

In this section, we consider a *mixed* duopoly in which firm 1 is offline and firm 2 online which charges a uniform delivered price P. As argued by Smith and Brynjolfsson (2001), consumers are sensitive to shipping fees and delivery times. For online firms, the choice of a delivery strategy is therefore a key issue. This has led online firms to implement sophisticated logistic strategies that allow them to serve at low cost geographically dispersed customers by using a fleet of trucks that each delivers the good to several customers. But doing this requires solving an NP-hard optimization problem which aims to determine the least-cost delivery routes that start and end at the same location. This problem, called the vehicle routing problem, has been extensively studied in operations research and management science (Laporte, 2009; Koç *et al.*, 2020). On the other hand, due to traffic congestion and a high opportunity cost of time, people's travel costs within cities remain substantial (Redding and Turner, 2015). Further, Chintagunta *et al.* (2012) find that shopping online is cheaper than travelling to an offline retailer. Therefore, we find it reasonable to differentiate the shopping cost borne by consumers from the shipping cost enticed by e-retailers.

Since the vehicle routing problem is NP-hard, it seems hopeless to consider a game-theoretic model which would account for the strategic determination of a solution to this problem within each e-retailer's profit-maximization problem (Ahmadi-Javi *et al.*, 2018). To deal with this issue in an analytically tractable way, we assume that the e-retailer undertakes one return trip by customer and bears a shipping cost T which is significantly lower than the shopping cost, $T << t$. As the e-retailer pays the shipping cost, it never chooses a delivered price P smaller than T. Parameters t and T measure the cost of geographical differentiation in different retail contexts. Lower case letters, (p, t) are used for the conventional retailer and capital letters (P, T) for the e-retailer.

Consumers who buy from an e-retailer save travel costs but bear a *distaste cost*. This cost includes the deprivation of the various advantages provided by the physical inspection of goods, the delay in receiving the product, the difficulty in returning products, and the after-sales services supplied by a conventional store. All of this generate a utility loss, which is expressed as a monetary cost. Smith and Brynjolfsson (2001) find that this cost is positive even for homogeneous goods like books. We capture the distaste cost by assuming that consumers at x make purchase decisions based on the consumer prices $p_1(x) = p + tx$ and $p_2 = \gamma P$ where $\gamma > 1$. In other words, the utility loss incurred on the occasion of an online purchase is modeled by an iceberg transportation cost whose value is equal to $(\gamma - 1)P$. The fact that in multi-channel retailers online and offline prices are identical about 72% of the time seems to confirm that distaste costs are not negligible (Cavallo, 2017).

In the literature, this cost is supposed to be additive, $P + m$ (Balasubramanian, 1998; Cao *et al.*, 2016; Guo and Lai, 2017). We choose instead a multiplicative cost because the distaste cost is likely to be higher when consumers buy a luxury and expensive product, such as cloths produced by prestigious fashion houses, leather goods, jewelry, and watches, than when they acquire more standardized products like books or CDs. One expects the distaste cost to be negligible if the product bought from an online seller has previously been purchased at a brick-and-mortar store. For simplicity, we assume that γ is the same across consumers. More generally, the parameters t, T and γ may be viewed as different proxies for the various transaction costs borne by consumers who choose a specific channel (Chintagunta *et al.*, 2012).

Throughout the paper, we assume that $t > \gamma T$. This inequality seems empirically more relevant because (i) online firms have access to efficient logistic technologies that allow them to supply customers at lower costs ($T \downarrow$), (ii) shopping costs did not decrease as much as shipping costs because the opportunity cost of time grew ($t \uparrow$), and (iii) advanced information technologies allow consumers to better assess the quality of online products ($\gamma \downarrow$). We show in Appendix that assuming $t = T$ and $\gamma = 1$ leads to results that often seem unreasonable.

4.1 Equilibrium in a mixed retailing market

The demands of a consumer at x for varieties 1 and 2 are, respectively, given by

$$q(p,P;x) = \begin{cases} 0 & \text{if } x \geq x_{\max} \\ \frac{L-p-tx+\gamma P}{2L}, & \text{if } x_{\min} < x < x_{\max} \\ 1 & \text{if } \quad x \leq x_{\min} \end{cases},$$

$$Q(p,P;x) = \begin{cases} 1 & \text{if } x \geq x_{\max} \\ \frac{L+p+tx-\gamma P}{2L}, & \text{if } x_{\min} < x < x_{\max} \\ 0 & \text{if } \quad x \leq x_{\min} \end{cases}.$$

where

$$x_{\min} \equiv \max\left\{0, \frac{-p+\gamma P - L}{t}\right\}, \qquad x_{\max} \equiv \min\left\{\frac{-p+\gamma P + L}{t}, 1\right\}. \tag{9}$$

As in the case of two conventional retailers, we consider partial market coverage in which $x_{\min} > 0$ and $x_{\max} < 1$ and full market coverage where $x_{\min} = 0$ and $x_{\max} = 1$. The asymmetry between the two types of retailers allows for two more situations, that is, $x_{\min} = 0$ and $x_{\max} < 1$ and $x_{\min} > 0$ and $x_{\max} = 1$. Analyzing these two additional cases does not add much to our results.

Partial market coverage. Consider first the case where $x_{\min} > 0$ and $x_{\max} < 1$. Then, we have

$$\Pi_m = p\frac{-p+\gamma P}{t}, \qquad \Pi_U = \int_{x_{\min}}^{x_{\max}} Q(p,P;x)(P - T(1-x))dx + \int_{x_{\max}}^{1} (P - T(1-x))dx, \tag{10}$$

where $T(1-x)Q$ is the cost of shipping quantity Q to consumers at x. Note that our definition of Π_U supposes that each customer is supplied by firm 2 through a specific shipment. By assuming that the shipping rate T can be arbitrarily low, and is always smaller than the shopping rate t, we retain enough analytical flexibility while avoiding appealing to complicated logistic strategies. Recall that in the real-world e-retailers typically use sophisticated delivery strategies such as the vehicle routing problem discussed in the introduction.

Differentiating twice the profit functions (10) with respect to their own price shows that both functions are concave. Furthermore, differentiating Π_m with respect to p yields $p^*(P) = \gamma P/2$. Next, differentiating π_U with respect to P, plugging $p^*(P) = \gamma P/2$ and solving for P, we obtain the unique candidate price equilibrium:

$$p^* = \frac{t^2 + \gamma T t}{3t + \gamma T} > 0, \qquad P^* = \frac{2t^2 + 2\gamma T t}{3\gamma t + \gamma^2 T} > 0. \tag{11}$$

It remains to check the following three conditions (i) $x_{\min}(p^*, P^*) > 0$, (ii) $x_{\max}(p^*, P^*) < 1$ and (iii) $P^* - T(1 - x_{\min}) > 0$, which guarantees that $\pi_U(p^*, P^*) > 0$.

(i) + (ii) Then, by plugging p^* and P^* in $x_{\min}$ and $x_{\max}$, it is readily verified that the first two desired inequalities hold if and only if the following condition is satisfied:

$$L < \frac{t+\gamma T}{3t+\gamma T}t < \frac{t}{2}. \tag{12}$$

(iii) $P - T(1 - x_{\min}) > 0$ if and only if

$$L < \frac{2t^2}{(3t+\gamma T)\gamma T}t \tag{13}$$

holds. Since $t > \gamma T$, (12) is the more binding condition for (p^*, P^*) to be a price equilibrium, while (12) and (13) are identical when $t = \gamma T$.

Note that (12) implies that $L < t/2$, that is, consumers cannot be too heterogeneous in tastes for partial market coverage to arise. Furthermore, differentiating (12) with respect to t or T shows that decreasing transportation costs reduce the likelihood of partial market coverage.

Importantly, using (12) to compare (7) and (11) shows that $p^* < p_{1m}^*$. In other words, *the presence of an e-retailer intensifies competition and places downward pricing pressure on the conventional retailer.*

To sum up, we have shown the following proposition.

Proposition 2. *Assume $t > \gamma T$. In a mixed duopoly with partial market coverage, there exists a unique price equilibrium given by* (11) *if and only if* (12) *holds. Furthermore, when its competitor shifts to the e-channel, the conventional retailer decreases its mill price.*

In other words, like in Proposition 1, L cannot be too large for the market to be partially covered. As L decreases but remains positive, the two market segments supplied by a single firm expands. In the limit, when $L \to 0$, $x_{\min} = x_{\max} = (t + \gamma T)/(3t + \gamma T)$ and consumers buy from a single firm. Note this boundary between the two market areas is smaller than 1/2 because $t > \gamma T$.

Finally, equilibrium profits are obtained by plugging (11) into (10):

$$\Pi_m^* = t\frac{(t+\gamma T)^2}{(3t+\gamma T)^2}, \qquad \Pi_U^* = \frac{12t^4(2t+\gamma T) - L^2\gamma T(3t+\gamma T)^2}{6t^2\gamma(3t+\gamma T)^2}, \tag{14}$$

so that Π_U^* is always positive under the condition (12), that is, when partial coverage prevails at the market equilibrium.

Full market coverage. We now turn to the case where $x_{\min} = 0$ and $x_{\max} = 1$, meaning that consumers at each location are supplied by both firms. For this, the condition

$$t - L < \gamma P^* - p^* < L$$

must hold. This interval is not empty if and only if $L > t/2$, that is, consumers must be sufficiently heterogeneous for all consumers to buy from both firms.

The demands of consumers at x are as follows:

$$q(p, P; x) = \frac{L - p - tx + \gamma P}{2L}, \qquad Q(p, P; x) = \frac{L + p + tx - \gamma P}{2L}. \tag{15}$$

Profits are thus defined as follows:

$$\begin{aligned}
\Pi_m &= p\int_0^1 q(p, P; x)dx = p\left(\frac{1}{2} + \frac{\gamma P - p}{2L} - \frac{t}{4L}\right), \\
\Pi_U &= \int_0^1 Q(p, P; x)(P - T(1-x))dx = \left(P - \frac{T}{2}\right)\left(\frac{1}{2} + \frac{p - \gamma P}{2L} + \frac{t}{4L}\right) + \frac{tT}{24L}.
\end{aligned}$$

Since both functions are concave in their own price, applying the first-order conditions yield the candidate equilibrium prices of the off- and online shops:

$$p^* = L - \frac{t - \gamma T}{6}, \qquad P^* = \frac{L}{\gamma} + \frac{t + 2\gamma T}{6\gamma} > 0. \tag{16}$$

For the prices (16) to be a Nash equilibrium of the game between the offline and online retailers, the following two conditions must be satisfied:

$$p^* > 0 \Leftrightarrow 6L > t - \gamma T, \tag{17}$$

and

$$P^* > T \Leftrightarrow 6L > 4\gamma T - t. \tag{18}$$

Furthermore, the condition for the two firms to serve the whole market at the prices (16) is given by

$$-L < -p^* - tx + \gamma P^* < L.$$

Substituting $x = 0$ and $x = 1$ in (15) leads to the inequalities

$$-p^* + \gamma P^* < L \Leftrightarrow 6L > 2t + \gamma T, \tag{19}$$

and

$$-L < -p^* - t + \gamma P^* \Leftrightarrow 6L > 4t - \gamma T. \tag{20}$$

The four inequalities (17)-(20) are satisfied if L is sufficiently large, that is, consumers are heterogeneous enough. The next lemma makes this statement more precise.

Lemma 1. *If $t > \gamma T$, then the most demanding condition is given by*

$$L > \frac{4t - \gamma T}{6} > \frac{t}{2}. \tag{21}$$

Indeed, we have:

$$\begin{aligned} \text{(i) } 6L &> t - \gamma T \text{ is implied by (iv)} \\ \text{(ii) } 6L &> 4\gamma T - t \text{ is implied by (iv)} \\ \text{(iii) } 6L &> 2t + \gamma T \text{ is implied by (iv)} \\ \text{(iv) } 6L &> 4t - \gamma T. \end{aligned}$$

Note that (21) always holds when $L > t$. In other words, when taste heterogeneity matters more than travelling, equilibrium prices depend on L in Proposition 3, but they do not in Proposition 2 because $t > L$. Next, conditions (12) and (21) do not overlap.

Summarizing yields the following proposition.

Proposition 3. *Assume $t > \gamma T$. The mixed duopoly implies full market coverage and the unique price equilibrium given by* (16) *if and only* (21) *holds. Furthermore, the presence of an e-retailer incentivizes the physical retailer to reduce its mill price* ($p^* < p^*_{1m}$).

As shown by (16) higher shopping costs ($t \uparrow$) lead the conventional retailer to decrease its price because its demand is reduced. By contrast, higher shipping costs ($T \uparrow$) lead the e-retailer to raise its delivered price because its transportation cost rises. Shopping and shipping costs thus have different impacts on market prices, confirming once more that the two retail formats differ in nature. Furthermore, both equilibrium prices increase when consumers have more heterogeneous tastes.

Note also that a higher distaste cost γ allows the conventional retailer to raise its price because the e-retailer becomes less competitive. Consequently, the e-retailer must lower its price P. Therefore, *the transaction costs T and γ have different impacts on the online firm.* In addition, the pass-through is incomplete in both retail formats: the conventional retailer decreases its price by 1/6 of the shopping cost increase while the e-retailer absorbs 2/3 of its shipping costs.

Since $t > \gamma T$, the price gap $p_1^* - p^* > 0$ widens as shopping costs increase or shipping costs decrease. For example, a higher density of population is likely to permit better access to conventional retailers in larger cities than in rural areas. This in turn should foster the gradual disappearance of conventional retailing in small cities and rural areas, which will boost the development of e-commerce in such regions. This concurs with Fan *et al.* (2018) who find that the average welfare gains from e-commerce are 1.11% for Chinese cities in the largest population quintile but 2.01% for those in the lowest quintile.

Substituting the equilibrium prices (16) into firms' profits yields

$$\Pi_m^* = \frac{1}{72L}\left(6L + \gamma T - t\right)^2, \qquad \Pi_U^* = \frac{1}{72\gamma L}\left(6L + t - \gamma T\right)^2 + \frac{tT}{24L}. \tag{22}$$

Observe that the conventional retailer's profits decrease with shopping costs ($t \uparrow$), but increase with shipping costs ($T \uparrow$), whereas the opposite holds for the e-retailer. Next, a higher distaste cost ($\gamma \uparrow$) is always detrimental to the online retailer but is beneficial to the offline retailer. In sum, by relaxing competition, a retailer's higher transaction cost is always detrimental to this retailer, which agrees with Chintagunta *et al.* (2012). By contrast, its competitor always earns larger profits. Last, more heterogeneous consumers always allow both firms to make higher profits because competition is relaxed.

As the distance from $x = 0$ increases, the full price of the conventional retailer ($p^* + tx$) increases while that of the online retailer remains constant (γP^*). The former is smaller than the latter if and only if $x < \tilde{x} \equiv 1/3 + \gamma T/6t$. Beyond this location, the e-retailer prices at a lower level than its competitor. At the equilibrium prices (16), the quantities sold by each type of firm are as follows:

$$q^*(x) = \frac{6(L - tx) + \gamma T + 2t}{12L}, \qquad Q^*(x) = \frac{6(L + tx) - \gamma T - 2t}{12L}, \tag{23}$$

which shows that $q^*(x)$ decreases with x while $Q^*(x)$ increases with x. In other words, the consumption of a variety decreases as the distance to its supplier rises (Lieber and Syverson, 2012). Next, when t and T are negligible, $q^*(x) \approx Q^*(x)$ holds because the spatial differentiation effect is negligible too.

Dolfen *et al.* (2013) observe that the main share of the gains generated by e-commerce in the U.S. stems from substituting to retailers available online but not locally. This concurs with (23) which shows that a more efficient shipping strategy ($T \downarrow$) implies that consumers will buy more from the online channel. By contrast, when consumers have better access to a conventional retailer ($t \downarrow$), they substitute away from the e-retailer.

Furthermore, *the online firm's sales are larger than those of the offline firm:*

$$0 < \int_0^1 q^*(x)dx = \frac{6L - t + \gamma T}{12L} < \frac{1}{2} < \int_0^1 Q^*(x)dx = \frac{6L + t - \gamma T}{12L}. \tag{24}$$

Thus, even though the conventional retailer lowers its price when its competitor goes online, its sales are reduced. Thus, both firm 1's sales and mill price are decreased when firm 2 becomes an online retailer. As a result, *a firm's decision to shift from offline to online is detrimental to the firm that remains offline.* On the other hand, profits made by firm 2 when it becomes an e-retailer need not be larger than the profits earned when it is a conventional retailer. We will see below when firm 2 finds it profitable to adopt the online channel.

Though e-commerce favors trade toward remote locations, the e-retailer does not drive the conventional retailer out of business. Indeed, $q^*(0) > 0$ while Π_m^* is always positive (see (14) and (22)). Recall here our assumption that both firms operate under the same marginal cost. If it operates under a higher marginal cost, the offline firm could be forced to exit the market because its mill price cannot fall below its marginal cost.

So far, we have assumed that all consumers face the same expenditure when they order from an online firm. Yet, in remote, rural regions, consumers may face logistical and cultural obstacles to the adoption of e-commerce, which allows conventional retailers to survive (Couture *et al.*, 2021). Formally, this idea may be captured by assuming that consumers in, say, region $[0, a]$ bear a higher cost γ than those in $(a, 1]$. Because the full price of the online firm becomes higher in $[0, a]$, the conventional retailer may be able to retain more customers.

4.2 Is it profitable for an offline retailer to become an online retailer?

In the foregoing, we assumed that firm 2 was an e-retailer while firm 1 remained a physical retailer. It is, however, legitimate to ask whether firm 2 finds it profitable to become an e-retailer? In other words, does profit maximization incentivizes firm 2 to shift from the conventional channel to the online channel, and if so under which conditions? Again, two cases may arise.

Partial market coverage. To answer the above question, we must compare firm 2's profits in the two retailing channels: $\Pi_{2m}^*$and Π_U^*, which require $t > L$ since (12) holds under $t > L$.

When making its decision, firm 2 understands that firm 1 will price differently according to the channel selected by firm 2. Using (6) and (14) shows that firm 2's profit difference under the two channels is equal to

$$\Pi_{2m}^* - \Pi_U^* = G(L, \gamma) = \frac{t}{2} - \frac{2t^2\,(2t + \gamma T)}{\gamma\,(3t + \gamma T)^2} + \frac{L^2 T}{6t^2}.$$

Differentiating G with respect to γ shows that this function is increasing. Since $G(L, 1) > 0$ for all $L < t$, firm 2 always chooses to remain a conventional retailer.

Hence, we have:

Proposition 4. *Assume $t > \gamma T$. In a mixed duopoly with partial market coverage* (i.e. (12) holds)*, the offline retailer always chooses to remain offline.*

In other words, ignoring heterogeneity would imply the absence of the online channel.

Full market coverage. Using (8) and (22), it is readily verified that

$$\Pi_{2m}^* - \Pi_U^* = H(L, \gamma) \equiv \frac{L}{2} - \frac{1}{72\gamma L}\,(6L + t - \gamma T)^2 - \frac{tT}{24L}. \tag{25}$$

The function $H(L, \gamma)$ is defined over $(t, \infty)\times\,(1, t/T)$. Differentiating H with respect to both γ and L shows that $H(L, \gamma)$ increases with each of these parameters. Since $H(L, 1) < 0$ and $H(L, t/T) = [12L^2(t - T) - Tt^2]/(24Lt)$, the equation $H(L,\gamma)=0$ has a unique solution $\bar{\gamma}(L)$ that belongs to $(1, t/T]$ if and only if $H(t, t/T) = (12t - 13T)/24 > 0$, which implies $H(L, t/T) > 0$. It is straightforward that $H(t, t/T) > 0$ if and only if $t > 13T/12$, which means that the distaste cost cannot account for more than 8.33% of the equilibrium price P_2^*.

Finally, the implicit function theorem implies that $\bar{\gamma}(L)$ decreases when L increases. This is because price competition between two off-line retailers is less intense.

To sum up, we have:

Proposition 5. *Assume $t > \gamma T$. In a mixed duopoly with full market coverage, when $t < 13T/12$ and $t < L$ firm 2 always chooses to become an e-retailer. If $L > t > 13T/12$ there exists a unique value $\bar{\gamma}(L) \in (1, t/T)$ such that firm 2 chooses to become an e-retailer when $\gamma < \bar{\gamma}(L)$ whereas firm 2 remains a conventional retailer when $\gamma > \bar{\gamma}(L)$.*

Thus, firm 2 shifts to the e-channel under different conditions. First, this firm always chooses to become an e-retailer when shopping costs are low. Since $\gamma T < t$, shipping and distaste costs are low too. Firm 2 then chooses to sell more by changing its format (see (24)). This concurs with Datta and Sudhir (2013) who show that *retailers choose to differentiate themselves in formats when the spatial differentiation effect is weak.*

Second, when shopping costs take intermediate values ($t > 13T/12$), firm 2 chooses to become an e-retailer when the distaste cost is sufficiently low ($\gamma < \bar{\gamma}$). This may explain why luxury and expensive goods, such as fashion clothes, jewelry, and watches, for which consumers have strong idiosyncratic preferences are still provided by conventional shops. By contrast, more standardized goods, such as books, CDs, appliances or inexpensive clothes, involve low distaste costs. It is no surprise, therefore, that Amazon started by selling such products. Furthermore, the adoption of new information technologies that allow for a better perception of goods by consumers are likely to favor e-retailing at the expense of brick-and-mortar stores.

Third, since the cut-off $\bar{\gamma}$ varies with the degree of taste heterogeneity, Propositions 3 and 4 show that *a market involving identical firms may be organized according to different retail formats.* In sum, when the spatial differentiation effect and consumer heterogeneity are weak, at least one firm shifts to the e-channel.

Last, $\Pi_U^* > \Pi_{2m}^*$ holds when $t = T$ and $\gamma = 1$.

5 Competition between e-retailers

In this section, we consider the case in which both firms are e-retailers. Let P_i be the delivered price chosen by firm i and γP_i the corresponding full price paid by consumers. Since $p_i = \gamma P_i$ is independent of x, the demand functions are given (1) and (2). Consequently, there is always full market coverage, so that the profit functions are given by

$$\begin{aligned} \Pi_{1U} &= \int_0^1 (P_1 - Tx)\frac{L - \gamma P_1 + \gamma P_2}{2L} dx = \frac{1}{2L}\left(P_1 - \frac{T}{2}\right)(L + \gamma P_2 - \gamma P_1), \\ \Pi_{2U} &= \frac{1}{2L}\left(P_2 - \frac{T}{2}\right)(L + \gamma P_1 - \gamma P_2), \end{aligned}$$

where each profit function is concave in its own price. Applying the first-order conditions yields the common candidate equilibrium prices:

$$P_1^* = P_2^* = \frac{L}{\gamma} + \frac{T}{2}. \tag{26}$$

For these prices to be an equilibrium, the following condition is necessary and sufficient: P_i^* is larger than T, which holds if and only if $2L > \gamma T$, which holds if $L > t/2$. These prices imply that the pass-through of shipping cost is positive but smaller than 1, whereas the equilibrium uniform price decreases with the distaste cost. This confirms the idea that both shipping and distaste costs differ in nature.

Furthermore, like in Section 4, the e-retailer, here firm 2, must decrease its delivered price, $P_2^* < P^*$, when firm 1 shifts to the e-channel.

The equilibrium profits are then given by

$$\Pi_{1U}^* = \Pi_{2U}^* = \frac{1}{2}\int_0^1 (P_1^* - Tx)dx = \frac{L}{2\gamma}, \tag{27}$$

which decrease with the distaste cost but increase with consumer heterogeneity. Thus, distaste costs play here a role like shopping costs in the conventional duopoly.

Proposition 6. *Assume $L > \gamma T/2$. If the market features two online firms, then there exists a unique price equilibrium given by* (26)*. Furthermore, when the conventional retailer shifts to the e-format, the pre-existing online store must lower its delivered price.*

This proposition shows that L cannot be too small for a price equilibrium to exist in an online duopoly. This should not come as a surprise as uniform pricing has the nature of an aggressive pricing strategy that leads to the non-existence of an equilibrium in pure strategies when consumers are differentiated along the sole spatial dimension (Kats and Thisse, 1993).

Can both firms choose to become e-retailers? Since the online retailer supplies the whole market, we consider only full market coverage. In this case, firm 1 chooses to become an e-retailer if

$$\Pi_1^* = \frac{1}{72L}(6L + \gamma T - t)^2 < \Pi_{1U}^* = \frac{L}{2\gamma}, \tag{28}$$

where profits are defined as above for $L > t/2 > \gamma T/2$ holds. It is readily verified that (28) holds if and only if

$$\frac{t}{2} < L < \frac{\gamma}{\gamma - \sqrt{\gamma}} \cdot \frac{t - \gamma T}{6}, \tag{29}$$

which is never satisfied when L is large.

Furthermore, since $\Pi_1^* < \Pi_{1U}^*$ when $\gamma = 1$, while the left-hand side (right-hand side) of (28) increases and converges to ∞ (decreases and converges to 0) when $\gamma \to \infty$, there exists a unique value $\hat{\gamma} > 1$ such that (28) holds for all $\gamma < \hat{\gamma}$. Since $\Pi_1^* > \Pi_{1U}^*$ when $\gamma = t/T$, it must be that $\hat{\gamma}$ is smaller than t/T.

Last, when both t and T are negligible, the conventional retailer never shifts to the e-format because it would have to bear the distaste cost. However, if this cost is ineligible too, the conventional retailer is almost indifferent between the two formats.

The following proposition comprises a summary.

Proposition 7. *Assume that firm* 2 *is an e-retailer. If* (29) *holds, then $\hat{\gamma} \in (1, t/T)$ exists such that firm* 1 *chooses to become an e-retailer if and only if $\gamma < \hat{\gamma}$. Otherwise, firm* 1 *remains a conventional retailer.*

We are now equipped to determine the equilibrium structure of the industry. First, Proposition 6 shows that firm 2 adopts an online channel if $\gamma < \bar{\gamma}$. In the resulting mixed duopoly, firm 1 chooses in turn to become an online retailer when $\gamma < \hat{\gamma}$. Thus, the equilibrium structure of the industry involves two online firms if $1 < \gamma < \min\{\bar{\gamma}, \hat{\gamma}\}$. When $\gamma > \min\{\bar{\gamma}, \hat{\gamma}\}$, at least one firm does not shift to the online channel.

Comparing (8) and (27) shows that conventional stores always make higher profits ($L/2$) than as e-retailers ($L/2\gamma$). Consequently, we have the following proposition.

Proposition 8. *Assume that* (29) *holds. Firms* 1 *and* 2 *choose to be e-retailers if and only if the distaste cost is sufficiently low* ($1 < \gamma < \min\{\bar{\gamma}, \hat{\gamma}\}$). *Furthermore, firms earn lower profits than in an offline duopoly.*

This proposition concurs with Bernstein *et al.* (2008) who show that firms may get trapped into a prisoner's dilemma when they choose between bricks-and-mortar and click-and-mortar. Like us, their setting involves heterogeneous consumers but, unlike us, it does not include transportation costs.

6 Is e-commerce more competitive than conventional retailing?

We have seen that a retailer must decrease its mill or delivered price when its rival chooses to become an e-retailer. We now study the impact of e-retailing shift on consumer prices, that is, the full prices paid by consumers. To compare all possible retail formats, we consider the case of full market coverage.

(i) We first compare prices in the offline and mixed duopolies when firm 1 is a conventional retailer. It follows from (16) that $p^* + tx < p_1^* + tx = L + tx$. Hence, the full prices paid to the offline retailer are lower in the mixed duopoly than in the conventional duopoly.

As for firm 2, we must compare $p_2^* + t(1-x)$ and γP^*. The marginal consumer is at the location where the two full prices are equal:

$$p_2^* + t(1-\bar{x}) = \gamma P^* \Leftrightarrow \bar{x} = \frac{5}{6} - \frac{\gamma T}{3t}.$$

Thus, we have $\gamma P^* < p_2^* + t(1-x)$ for $x < \bar{x}$. Put differently, when firm 2 is an e-retailer, consumers located in $[0, \bar{x})$ pay a lower full price than when firm 2 is a conventional retailer, which impels firm 1 to reduce its own price from p_1^* to p^*. By contrast, consumers located in $(\bar{x}, 1]$ pay a higher full price when firm 2 is an e-retailer. This is because an e-retailer balances the profits made by selling to distant customers and those made from selling to the close customers when it chooses its delivered price. As $\bar{x}$ is larger than $1/2$, more than half consumers are better-off when firm 2 is an e-retailer. Nevertheless, the remaining consumers are worse-off. Therefore, firm 2's decision to become an e-retailer has opposite impacts on consumers, so that *we cannot conclude that one format is globally more competitive than the other from the consumers' point of view.* Furthermore, it follows from (21) that the online firm cannot drive the offline firm out of business, even when $\gamma \approx 1$ or $T \approx 0$. In other words, product differentiation protects the conventional retailer.

(ii) We now turn our attention to the offline and online duopolies. Considering firm 1, the marginal consumer is located at $\bar{x}_1$, which solves

$$p_1^* + t\bar{x}_1 = \gamma P_1^* \Leftrightarrow \bar{x}_1 = \frac{\gamma T}{2t} < \frac{1}{2}.$$

Hence, consumers located to the left of $\bar{x}_1$ pay a lower full price when firm 1 is an offline retailer whereas those located to the right of $\bar{x}_1$ bear a lower price when firm 1 is an e-retailer.

As for firm 2, we have

$$p_2^* + t(1-\bar{x}_2) = \gamma P_2^* \Leftrightarrow \bar{x}_2 = \frac{2t - \gamma T}{2t} > \frac{1}{2},$$

where $\bar{x}_1 < \bar{x}_2$. Hence, consumers located to the left of $\bar{x}_2$ pay a higher full price when firm 2 is a conventional retailer whereas those located to the right of $\bar{x}_2$ bear a higher price when firm 2 is an e-retailer.

Therefore, three cases may arise. Consumers locate in $[0, \bar{x}_1)$ pay a lower full price when firm 1 is a conventional retailer, but a higher full price when this firm is an e-retailer. The same holds for consumers located in $(\bar{x}_2, 1]$ when they buy from firm 2. By contrast, consumers located in $[\bar{x}_1, \bar{x}_2]$ always bear a lower full price when both firms are e-retailers.

(iii) It remains to discuss the case of mixed and online duopolies when firm 2 is an e-retailer. Starting with firm 1, we find

$$p^* + t\hat{x} = \gamma P_1^* \Leftrightarrow \hat{x} = \frac{t + 2\gamma T}{6t} < \frac{1}{2},$$

which means that consumers located in $(\hat{x}, 1]$ prefer firm 1 to be an e-retailer. Regarding firm 2, we must compare γP^* and γP_2^*:

$$\gamma P^* - \gamma P_2^* = \frac{t - \gamma T}{6} > 0.$$

In other words, all consumers pay a lower price to firm 2 in an online duopoly. Therefore, consumers located to the right of $\hat{x}$ always pay lower prices in an online duopoly. However, consumer in $[0, \hat{x})$ are better-off when firm 1 is a conventional retailer. Once more, consumers are split between those who prefer a mixed duopoly and those who prefer an online duopoly.

Straightforward calculations show that the different marginal consumers may be ranked as follows:

$$0 < \bar{x}_1 < \hat{x} < 1/2 < \bar{x} < \bar{x}_2 < 1.$$

Using the above price comparisons for the different retail formats, we may conclude as follows:

$0 < x < \bar{x}_1$	Mixed $\succ$ Offline $\succ$ Online
$\bar{x}_1 < x < \hat{x}$	Mixed $\succ$ Online $\succ$ Offline
$\hat{x} < x < \bar{x}$	Online $\succ$ Mixed $\succ$ Offline
$\bar{x} < x < \bar{x}_2$	Online $\succ$ Offline $\succ$ Mixed
$\bar{x}_2 < x < 1$	Offline $\succ$ Online $\succ$ Mixed

By lowering the cost of distribution and by making search easier for consumers, online retailing is expected to intensify price competition. Our findings cast doubt on this claim and show that *the most competitive retail format depends on the location of consumers*. Even the ranking of formats may change with consumers' locations, while there is always a market segment over which each retail format yields the lowest full prices, thus confirming the idea that spatial proximity still matters in consumers' choices.

Furthermore, which retail format is the most competitive depends on the parameters t and γ that characterize consumers' attitudes, as well as the parameter T that describes the delivery strategy of e-retailers. In addition, the conventional duopoly is the most competitive format for a minority of consumers located in the area $(\bar{x}_2, 1]$, which implies that the presence of an online firm allows more than half consumers to benefit from lower prices. Note also that the mixed duopoly is the most competitive over a consumer segment wider than that for which the conventional duopoly dominates.

We may thus conclude as follows.

Proposition 9. *The presence of an online retailer leads to lower consumer prices for a majority of consumers, but not for all of them.*

The above results are in line with the common wisdom that the entry of online firms fosters competition, although the empirical evidence is somewhat inconclusive (Yoo and Lee, 2011; Goldfarb and Tucker, 2019).

7 Do consumers prefer offline or online retailing?

7.1 Consumer surplus

Are consumers better-off when firms shift to e-retailing, or do they prefer to keep brick-and-mortar stores? To answer this question, we use a measure of consumers' welfare in a setting where consumers are differentiated by preferences and locations.

One advantage of discrete choice models is that they lead to social welfare functions. Using Theorems 3.3 and 3.4 of Anderson *et al.* (1992) implies that the linear probability model describes a population of heterogeneous consumers who can be represented by a single consumer whose indirect utility is given by

$$V(Y,\mathbf{p}) = Y + H(\mathbf{p}) \equiv \begin{cases} Y + \frac{-2L(p_1+p_2)+(p_1-p_2)^2}{4L} & \text{if } q_1(p_1,p_2)+q_2(p_1,p_2)=1 \\ -\infty & \text{otherwise.} \end{cases} \quad . \tag{30}$$

Using Roy' identity yields the demand functions (1) and (2):

$$-\frac{\partial H}{\partial p_i} = -\frac{\partial}{\partial p_i}\left[\frac{-2L(p_1+p_2)+(p_1-p_2)^2}{4L}\right] = \frac{L-p_i+p_j}{2L}, \qquad i,j=1,2 \text{ and } i \neq j.$$

In this framework, $V(Y,p(x))$ measures the indirect utility of consumers located at x. To study individual welfare, we evaluate the indirect utility (30) at the full prices paid by consumers.

We focus on the case of full market coverage to permit comparisons between retail formats ($L \geq t$). Since individual preferences are quasi-linear, the expression

$$S = \int_0^1 V(Y,\mathbf{p}(x))dx.$$

measures total consumer surplus.

We first consider the case of the offline duopoly. Plugging the equilibrium prices (7) in (30), we obtain the indirect utility in the offline duopoly:

$$V_m(x) = Y - L - \frac{2Lt - t^2(1-2x)^2}{4L},$$

which is convex in x and symmetric about $x = 1/2$. That is, consumers are better-off when they are located near one of the two physical retailers.

Since individual preferences are quasi-linear, the consumer surplus may be defined by the sum of individual indirect utilities:

$$S_m = \int_0^1 V_m(x)dx = Y - L - \frac{t}{2} + \frac{t^2}{12L}. \tag{31}$$

Consider now the online duopoly. Since both firms charge the same delivered price, the indirect utility is given by

$$V_U = Y - L - \frac{\gamma T}{2}, \tag{32}$$

which is constant across locations. In other words, consumers share the same utility regardless of their locations.

Since $V(Y, \gamma P_1^*, \gamma P_2^*)$ is independent of x, we have

$$S_U = Y - L - \frac{\gamma T}{2}. \tag{33}$$

Last, plugging (16) in (30) yields the indirect utility in the mixed duopoly:

$$V_M(x) = Y - \frac{4L + \gamma T + 2tx}{4} + \frac{(2t + \gamma T - 6tx)^2}{144L}.$$

It follows from Proposition 3 that consumers are better-off as they are located closer to the conventional retailer because its full price decreases while the full price of the online retailer remains constant.

Summing individual indirect utilities leads to

$$S_M = \int_0^1 V_M(x)dx = Y - L - \frac{t + \gamma T}{4} + \frac{(2t - \gamma T)^2 + 2\gamma T t}{144L}. \tag{34}$$

It is readily verified that, in the three formats, consumers at x are always worse-off when transportation costs increase ($t \uparrow$ or $T \uparrow$) and when consumers are more heterogenous ($L \uparrow$).

7.2 Comparing retailing formats

Offline versus online formats. The utility differential is defined as follows:

$$f(x) \equiv V_m(x) - V_U = \frac{t^2 (2x - 1)^2 - 2L (t - \gamma T)}{4L},$$

which is convex, symmetric, minimized at $x = 1/2$ and maximized at $x = 0$ and $x = 1$. Determining the signs of $f(0)$ and $f(1/2)$ is thus sufficient to find the sign of $f(x)$.

Evaluating $f(x)$ at $x = 0$ and $x = 1/2$ yields the following expressions:

$$f(0) = \frac{t^2 - 2L (t - \gamma T)}{4L}, \qquad f(1/2) = -\frac{t - \gamma T}{2} < f(0).$$

Therefore, we have: (i) if $f(0) < 0$, then all consumers prefer an online duopoly and (ii) if $f(0) > 0$, then $f(x) = 0$ has one root between 0 and 1/2 and a second root between 1/2 and 1. In other words, if $t^2 - 2L (t - \gamma T) > 0$, consumers around the market center prefer an online duopoly because the full price is flat, whereas those close to the market endpoints prefer an offline duopoly because they are close to a conventional retailer. On the other hand, if the consumers at x are sufficiently heterogeneous in taste (i.e., $t^2 - 2L (t - \gamma T) < 0$), all consumers prefer online retailers. This difference in results shows how important it is to consider heterogeneous consumers to determine the consumer performance of a retail format.

Aggregating individual preferences and comparing S_m and S_U show that $S_m - S_U$ and $t^2 - 6L (t - \gamma T)$ have the same sign. More specifically, three cases may arise: (i) if $6L(t - \gamma T) < t^2$, consumers close to the market center prefer an online duopoly but consumer surplus is higher in a mixed duopoly; (ii) if $2L(t-\gamma T) < t^2 < 6L(t-\gamma T)$, consumers near the endpoint of the market prefer the mixed duopoly but the consumer surplus is higher in an online duopoly; and (iii) if $t^2 < 2L(t-\gamma T)$, every consumer is better-off in the online duopoly.

Mixed versus online formats. In this case, the utility differential is given by

$$g(x) \equiv V_M(x) - V_U = \frac{\gamma^2 T^2 + 4t^2 (3x-1)^2 + 4\gamma T(9L+t) - 12tx(6L+\gamma T)}{144L},$$

which decreases with x by (21). Determining the signs of $g(0)$ and $g(1)$ is thus sufficient to find the sign of $g(x)$.

Setting $x = 0$ and $x = 1$ in the above expression yields:

$$g(0) = \frac{(2t+\gamma T)^2 + 36\gamma LT}{144L} > g(1) = \frac{(4t-\gamma T)^2 - 36L(2t-\gamma T)}{144L}.$$

Since $g(0) > 0$ and $g(1) < 0$ by (21), there exists a unique solution $\tilde{x}$ to $g(x) = 0$. Hence, the population is split between two groups of consumers who have opposite preferences. More specifically, those close to the left-endpoint of Main Street prefer the mixed format because of their proximity to the physical retailer. On the contrary, those established near the right-endpoint prefer the online format which is more competitive. As $g(x)$ is shifted downward as L increases, $\tilde{x}$ moves to the left, meaning that fewer consumers prefer the mixed duopoly when the population becomes more heterogeneous.

Comparing S_M and S_U, we obtain

$$S_M - S_U = \frac{(2t-\gamma T)^2 + 2\gamma Tt - 36L(t-\gamma T)}{144L},$$

which is negative when L is large enough. In other words, a strongly heterogeneous population prefers an online duopoly to a mixed duopoly.

Mixed versus offline formats. The utility differential is now given by

$$h(x) \equiv V_M(x) - V_m(x) = -\frac{3t^2}{4L}x^2 - \frac{6L+\gamma T-10t}{12L}tx + \frac{36L(2t-\gamma T) - (4t-\gamma T)(8t+\gamma T)}{144L}.$$

By definition, $h(x)$ is the difference between V_M, which is a decreasing function of x, and V_m, which is a convex and symmetric function about $x = 1/2$ with $h(1/2) > 0$. In addition, $h(x)$ is concave. Differentiating $h(x)$ with respect to x and solving for x yield its maximizer:

$$x^* = -\frac{1}{18t}(6L - 10t + \gamma T),$$

which is negative if and only if

$$L > L_{\min} \equiv \frac{10t-\gamma T}{6} > 0. \tag{35}$$

Therefore, two cases may arise. In the former, $x^* < 0$, so that $h(x)$ is decreasing over $[0,1]$. In the latter, $x^* > 0$ implies that $h(x)$ increases over $[0, x^*)$ and decreases over $(x^*, 1]$.

Consider the first case. Since $h(1) < 0$ and $h(1/2) > 0$, the intermediate value theorem implies that $x' \in (1/2, 1)$ exists such that $h(x) > 0$ for $x < x'$ and negative otherwise. In other words, consumers located close to firm 1 prefer conventional retailing, whereas those established close to firm 2 prefer mixed retailing.

Consider now the second case. Since $h(x^*)$ increases with L over $(t, L_{\min})$, we have $h(x^*) > 0$ for all $L < L_{\min}$ because $h(x^*)|_{L=t} > 0$. Furthermore, we have $h(0)|_{L=t} > 0$ while $h(0)$ increases with L. Therefore, $x'' \in (x^*, 1)$ exists such that $h(x)$ is positive on $[0, x'')$ and negative on $(x'', 1]$.

Combining both cases, we may conclude that consumers are split in two groups, those close to firm 1 prefer purchasing from the conventional retailer, while those close to firm 2 prefer to buy online.

Regarding consumer surplus, we get

$$S_M - S_m = \frac{t - \gamma T}{4} - \frac{(2t + \gamma T)(4t - \gamma T)}{144L},$$

which increases with L and becomes positive for a sufficiently large values of L. Put differently, the aggregate population prefers a mixed retail format to an offline format when consumers are heterogeneous enough.

7.3 Summary

Wrapping up the above findings provides new evidence on the impact of various retail formats on consumer surplus.

First, *when consumers are sufficiently heterogeneous, they prefer an online duopoly to an offline or to a mixed duopoly*. This need not hold when consumers are weakly heterogeneous. Furthermore, comparing offline and mixed duopolies shows that the population is split between two groups of consumers who have opposite preferences. However, the aggregate population prefers the mixed format when consumers are sufficiently heterogeneous. In addition, these choices may be reversed when consumers are weakly heterogeneous, thus showing once more that considering heterogeneous individuals is critical when assessing the desirability of different retail formats.

Second, consumers' most-preferred retail format depends on where consumers are located relative to retailers, which agrees with Forman *et al.* (2009). Third, raising transportation costs reduces consumer surplus in each duopoly type. A higher degree of heterogeneity has a similar impact. The reason is the same in both cases: retailers charge higher prices.

8 What is the most efficient retail format?

We can answer the above question by summing consumer surplus and firms' profits associated with each retailing format.

8.1 Total welfare

Using (8) and (31), we obtain total welfare in the offline duopoly:

$$W_m = S_m + \Pi^*_{1m} + \Pi^*_{2m} = Y - t/2 + t^2/12L.$$

Similarly, it follows from (27) and (33) that total welfare in the online duopoly is given by

$$W_U = S_U + \Pi^*_{1U} + \Pi^*_{2U} = Y - \frac{\gamma - 1}{\gamma} L - \frac{\gamma T}{2}.$$

The expression for total welfare is much more involved in the mixed duopoly than in the above two cases. Using (32) and (22), we obtain

$$W_M = S_M + \Pi_m^* + \Pi_U^* = Y - \frac{\gamma - 1}{2\gamma}L - \frac{5t + \gamma T}{12} + \frac{t - \gamma T}{6\gamma} + \frac{(t - \gamma T)^2 + 2Tt + t^2}{48L} + \frac{(t - \gamma T)^2}{72\gamma L}.$$

Differentiating W_i for $i = m, U, M$ shows that in each retailing format higher transportation costs. Furthermore, total welfare in the mixed and online duopolies decreases with the distaste costs. As expected, the three costs associated with the two retailing formats always lead to a welfare drop.

8.2 The socially optimal retailing format

Offline versus online formats. Simple algebra shows that

$$W_m - W_U = \frac{12L^2(\gamma - 1) + t^2\gamma - 6L\gamma(t - \gamma T)}{12L\gamma}.$$

It is readily verified that $W_m - W_U$ increases with γ. Substituting $\gamma = t/T > 1$ shows that $W_m - W_U$ is positive. Setting $\gamma = 1$ implies that $W_m - W_U$ is positive if and only if $t^2 - 6L(t - T) > 0$, which amounts to

$$L < L_1 \equiv \frac{t^2}{6\,(t - T)}, \tag{36}$$

The interval (t, L_1) is non-empty if and only if

$$T < t < \frac{6}{5}T. \tag{37}$$

When both (36) and (37) hold, $t^2 - 6L(t - T)$ is always positive, which means that the offline duopoly generates a higher total welfare than the online duopoly. Otherwise, when one of these two conditions does not hold, $t^2 - 6L(t - T)$ is negative. The intermediate value theorem then implies that $\gamma_1 > 1$ exists such that $W_U > W_m$ if and only if $\gamma < \gamma_1$.

Mixed versus online formats. It is readily obtained

$$W_M - W_U = \frac{w}{144L\gamma}$$

where

$$w \equiv 72L^2(\gamma - 1) - 12L\,(5\gamma - 2)\,(t - T\gamma) + 2t^2 + 6t^2\gamma + 2t\gamma T - 6t\gamma^2 T + 2\gamma^2 T^2 + 3\gamma^3 T^2.$$

It is easy to see that w increases with γ and is positive at $\gamma = t/T$. Setting $\gamma = 1$ implies that $W_M - W_U$ is positive if and only if

$$L < L_2 \equiv \frac{8t^2 - 4tT + 5T^2}{36\,(t - T)}. \tag{38}$$

The interval (t, L_2) is non-empty if and only if

$$1 < t/T < \frac{3\sqrt{11} + 8}{14} \approx 1.282. \tag{39}$$

In this case, total welfare in a mixed duopoly is larger than in an online duopoly. When (38) or (39) does not hold, the intermediate value theorem implies that $\gamma_2 > 1$ exists such that $W_U > W_M$ if and only if $\gamma < \gamma_2$. Otherwise, the mixed duopoly generates a higher total welfare than the online duopoly.

Mixed versus offline formats. Simple calculations lead to the expression:

$$W_m - W_M = \frac{72(\gamma-1)L^2 - 12\,(\gamma+2)\,(t-\gamma T)\,L + 2t\,(3\gamma-1)\,(t+\gamma T) - (3\gamma+2)\,\gamma^2T^2}{144L\gamma}.$$

Differentiating this expression shows that $W_m - W_M$ increases with γ. Further, it is positive at $\gamma = t/T > 1$. Setting $\gamma = 1$ implies that $W_m - W_M$ is positive if and only if

$$L < L_3 \equiv \frac{4t^2 + 4tT - 5T^2}{36(t-T)}. \tag{40}$$

The interval (t, L_3) is non-empty if and only if

$$1 < t/T < \frac{5+\sqrt{15}}{8} \approx 1.109. \tag{41}$$

In this case, total welfare in a conventional duopoly is larger than in the mixed duopoly.

When (40) or (41) does not hold, the intermediate value theorem implies that $\gamma_3 > 1$ exists such that $W_M > W_m$ if and only if $\gamma < \gamma_3$. Stated differently, if consumers have a strong preference for variety ($L \uparrow$), or if e-retailers have access to an efficient delivery logistics ($t/T \uparrow$), the mixed duopoly is the better retailing configuration when the distaste cost is sufficiently low.

Summarizing, we obtain:

Proposition 10. *Assume that either consumers are heterogenous or e-retailers have access to an efficient delivery system. Then, if the distaste cost γ is sufficiently small, total welfare is maximized at the online duopoly. If γ is large enough, the conventional duopoly maximizes total welfare.*

When γ takes intermediate values, the best format depends on how large is t/T and on the degree L of consumer heterogeneity.

9 Concluding remarks

We have developed a simple spatial-discrete choice model of competition between offline and online firms. Because our setting relies on standard assumption made in industrial organization and marketing, it suffices to show that general results are unlikely to arise in more ambitious models. More specifically, our paper first shows that the relative performance of the offline and online formats crucially depends on the locations of consumers relative to the retailers. At first sight, this might come as a surprise as e-commerce is often perceived as a retail format in which space and distance no longer matter. Our paper shows that this view is too contrived for at least two reasons. First, the location of conventional retailers remains a crucial determinants of consumers' shopping attitudes. Second, delivering goods to geographically dispersed consumers requires the design of sophisticated transportation strategies that depend on the geographical distribution of consumers. This should be sufficient to highlight the spatial nature of retail competition in the digital economy.

We have chosen a very simple pricing policy for the e-retailers. We acknowledge that partitioned pricing and subscribing pricing, among others, are equally very important. Our setting can be extended to deal with such policies. The unit interval can be partitioned into a small number of zones in which the e-retailer sets a base price π_i and a shipping fee ϕ_i for each zone i (Burman and Biswas, 2007). As $\pi_i + \phi_i = \gamma P_i$, choosing a base price and a shipping fee is equivalent to selecting a uniform delivered price P_i specific to each zone. As the number of zones increases, this pricing policy converges to what is called spatial discriminatory pricing (Thisse and Vives, 1988; Guo and Lai, 2022). Likewise, an e-retailer that sells several goods can charge a fixed membership fee to its customers while shipping goods for free (Balakrishnan *et al.*, 2024). Last, when a firm adopts a multi-channel strategy, its set of customers is split between those located in its vicinity (they visit the store) and the remote consumers (they order online). The location of the consumer indifferent between the two channels depends on the price chosen by the other firm.

For simplicity, we have assumed that the two retailers face the same marginal cost. Here too, the model can be extended to deal with heterogeneous firms operating under different costs that may vary with their format. For example, if firm $i = 1, 2$ faces a marginal cost $c_i > 0$ in the setting considered in Section 3, the equilibrium prices become $p_1^* = t + 2c_1/3 + c_2/3$ and $p_2^* = t + c_1/3 + 2c_2/3$, which remain simple to handle.

Our paper has highlighted the role of consumer heterogeneity for the market outcome. Admittedly, we have achieved that by using the linear probability model, which is consistent with linear demands in a duopoly like Hotelling's. Unfortunately, this discrete choice model cannot be extended to oligopolistic settings (Armstrong and Vickers, 2015). A natural candidate is the multinomial logit. However, we must keep in mind that working with this model is analytically more cumbersome. Chambers *et al.* (2025) have recently proposed an extension of discrete choice models that could solve this problem. Clearly, more research is called for here .

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Appendix

Setting $t = T$ and $\gamma = 1$ in the equilibrium prices in the case of full market coverage yields the following results

1. Offline duopoly. (i) Prices: $p_{1m}^* = p_{2m}^* = L$. (ii) Profits: $\Pi_{1m}^* = \Pi_{2m}^* = L/2$. (iii) CS: $S_m = Y - L - t/2 + t^2/12L$. (iv) Welfare: $W_m = Y - t/2 + t^2/12L$.

2. Mixed duopoly. (i) Prices: $p^* = L$ and $P^* = L + t/2$. (ii) Profits: $\Pi_m^* = L/2$ and $\Pi_U^* = L/2 + t^2/24L$. (iii) CS: $S_M = Y - L - t/2 + t^2/48L$. (iv) Welfare: $W_M = Y - t/2 + t^2/16L$.

3. Online duopoly. (i) Prices: $P_1^* = P_2^* = L + t/2$. (ii) Profits: $\Pi_{1U}^* = \Pi_{2U}^* = L/2$. (iii) CS: $S_U = Y - L - t/2$. (iv) Welfare: $W_U = Y - t/2$.

4. Comparison. To sum up, (i) the producer price of an offline firm does not decrease when its competitor shifts to the online channel; (ii) firm 1 earns the same profits regardless of its own format and the format chosen by its competitor; (iii) ranking channels in terms of consumer surplus and total welfare yields $S_m > S_M > S_U$ and $W_m > W_M > W_U$. These three predictions strike us as unplausible, thus highlighting the need to work with different transportation costs in the offline and online channels.