UNIVERSIDAD CARLOS III DE MADRID working papers

Working Paper 01-67
Economics Series 22
December 2001

Departamento de Economía
Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
Fax (34) 91 624 98 75

# ELECTRONIC COMMERCE, CONSUMER SEARCH AND RETAILING COST REDUCTION *

Cristina Mazón[1] and Pedro Pereira[2]

***Abstract***

This paper explains three things in a unified way. First, how e-commerce can generate price equilibria, where physical shops either compete with virtual shops for consumers with Internet access, or alternatively, sell only to consumers with no Internet access. Second, how these price equilibria might involve price dispersion on-line. Third, why prices may be higher on-line. For this purpose we develop a model where e-commerce: reduces consumers' search costs, involves trade-offs for consumers, and reduces retailing costs.

***Keywords:*** *Electronic-Commerce, Search, Cost Reduction, Retailing.*

***JEL Classification:*** *D43, D83, L13, L81, M31, O31, O33*

[1] Universidad Complutense de Madrid, Facultad de Ciencias Económicas y Empresariales, Departamento de Fundamentos del Análisis Económico II, Campus de Somosaguas, 28223 Madrid, Spain; E.mail: cmazon@ccee.ucm.es; phone: 91-394.2918; fax: 91-394.2591

[2] Universidad Carlos III de Madrid, Departamento de Economía, c/ Madrid, 126, 28903 Getafe, Madrid, Spain; E.mail: ppereira@eco.uc3m.es; phone: 91-624-9753; fax: 91-624-9875; e-mail: cmazon@ccee.ucm.es; phone: 91-394-2918; fax 91-394-2591

# 1 Introduction

The Internet allowed the creation of a new retailing technology: ***electronic commerce*** (e-commerce)[1]. E-commerce has similarities with catalogue retailing. Without a physical shop, it offers products that cannot be physically inspected or immediately delivered, and are paid for usually with a credit card. But e-commerce also has unique attributes. The Internet allows to cheaply store, search, and disseminate information; is available anywhere, anytime, for anyone who can accede to it; allows interactivity; provides perceptual experiences superior to those of a catalogue, but inferior to those of physical inspection; and serves as a transactions and physical distribution medium for digital goods[2]. Due to this last aspect, conceivably, it will be in markets for digital goods that e-commerce will have a bigger impact, as the recent evolution of markets for stocks, mortgages, or life insurance suggests (Bakos et al. (2000), Brown & Goolsbee (2000)).

The short history of e-commerce suggests three observations. First, physical shops responded to e-commerce, sometimes by lowering their prices to compete with virtual shops for consumers with Internet access; other times they did not lower their prices, and concentrated on selling only to consumers with no Internet access. In stockbrokerage retailing, Charles Schwab lowered the off-line fee from $65 to $30 to match the on-line fee (*New York Times*, August 16, 1999), which suggests the first price regime. And in book retailing, in 1999, Barnes & Noble and Borders matched within hours an Amazon 50% discount on best sellers on their virtual, but not on their physical shops (*New York Times*, May 18, 1999). This suggests that firms with both physical and virtual shops competed for consumers with Internet access on their virtual shops, but not on their physical shops, i.e., the second price regime. What explains these price regimes? Second, there is price dispersion on-line. Brynjolfsson & Smith (2001a) find that for books, firms with both physical and virtual shops charge on their virtual shops 8.7% more than firms that only have virtual shops, and that on-line the price range is 33% of the average price[3]. If supposedly, the Web gives consumers

[1] Transacting products based on the processing and transmission of digitized data over the network of computers that use the transmission control protocol/Internet protocol, TCP/IP.

[2] Goods that can be expressed as zeros and ones.

[3] All empirical studies find price dispersion on-line. For example, Baye, Morgan & Scholten (2001) find price dispersion for consumer electronics, Brynjolfsson & Smith (2000b), Clay, Krishnan, Wolff & Fernandes (1999), Clay, Krishnan & Wolff (2001) and Smith (2001) also report price dispersion on-line for books; Carlton & Chevalier (2001) find price dispersion for fragrances, DVD players, and side-by-side refrigerators; Clemons, Hann & Hitt (1999) find that after controlling for ticket quality, prices on-line vary as much as 18%; Lee (2000) reports price dispersion on-line for over-the-counter medications; and Pan, Ratchford & Shankar (2001) find large price dispersion on-line, even after controlling for the vendors' characteristics, for books, DVDs, computers, computer software and consumer electronics. Brynjolfsson & Smith (2000a), find that for books, established firms with both physical and virtual shops charge on their virtual shops 8.7% more than newly created purely virtual firms. Friberg, Gansland & Sandström (2000) and Tang, Lu & Ho (2000), find similar evidence.

access to perfect information, what explains price dispersion on-line? Third, prices are typically lower on-line. Brynjolfsson & Smith (2001a) find that book prices average 9-16% less on virtual shops than on physical shops[4]. Are lower prices intrinsic to e-commerce?

We believe these three things are related, and develop a static, partial equilibrium search model, for a functionally identical product, that explains them in a unified way. The model has three important aspects: e-commerce reduces consumers' search costs, involves trade-offs for consumers, and reduces retailing costs. E-commerce reduces consumers' search costs, because on the Web consumers can visit at a low cost virtual shops and learn prices[5], or can use ***shopbots***, software programs that automatically search for price information[6]. E-commerce involves trade-offs for consumers, because buying from a virtual shop does not require a shopping trip, but requires waiting for delivery. E-commerce reduces retailing costs, compared to physical shops, because virtual shops allow savings on ***property costs***, i.e., leases and acquisition of shop and warehouse space, on ***labor costs***, i.e., personnel to attend shops, and on ***inventory costs***, i.e., inventories for showcasing or immediate delivery[7].

In our model, firms decide whether to open virtual shops and set prices, and consumers search for prices. There are two consumer types: new consumers have Internet access, old consumers do not, or do not consider using the Internet an option. New consumers canvass prices through the Web, and then decide if they buy from a virtual or a physical shop. There are two firms: the old firm has a physical shop, the new firm does not. Either firm can open a virtual shop. Virtual shops have lower marginal production costs than physical shops.

Since search and waiting for delivery are costly, new consumers accept prices above the minimum charged in the market. This gives firms market power.

The virtual shops' pricing behavior is simple. Virtual shops have the lowest cost and charge the lowest price. Thus, they are not constrained by consumer search, and charge their monopoly price.

---

4 Friberg, Ganslandt & Sandström (2000) find that prices for books and CDs are on average 15% lower on-line in Sweden; and Bakos et al (2000) find that full service brokers charge higher commission than on-line brokers, which are hard to justify with price improvements.

5 *Yahoo Internet Life*, August 19 1999, reports that it took 32 minutes to find a hotel in New York using "the old way", while only 6 minutes using "the net way".

6 E.g., ClickTheButton, DealPilot , www.previewtravel.com for airfares, and www.microsurf.com for mortgages.

7 On the Web, a banking transaction costs $.1, compared with $.27 at an ATM or $.52 over the phone, and processing an airline ticket costs $1, compared with $8 through a travel agent (*The Economist*, June 26, 1999). USA retailers with no physical presence in a state do not collect local sales taxes, 6%. Clearly these cost reductions will vary across classes of goods. They are plausible for digital goods.

The physical shop's pricing behavior depends of whether the old firm has a virtual shop, and on whether the new firm is in the market. Because new consumers have access to lower cost shops, and if waiting for delivery is not too costly, they only accept buying from a physical shop for a lower price than old consumers. When only the new firm opens a virtual shop, if the physical shop charges a lower price acceptable to both consumer types, it earns a lower per consumer profit, if it charges a higher price acceptable only to old consumers, it earns a higher per consumer profit. Thus, the physical shop trades-off ***volume of sales*** and ***per consumer profit***; sometimes it chooses to sell to both old and new consumers, and other times it chooses to sell only to old consumers. When both firms open virtual shops, the old firm faces an additional ***channel conflict*** effect, besides the volume of sales and per consumer profit effects. If its physical shop charges a lower price acceptable to both consumer types, half of the new consumers it sells to would otherwise buy from the old firm's virtual shop, where per consumer profit is higher. This causes the old firm to have its physical shop charge a lower price to attract new consumers, only if the virtual shops' cost reduction is small; otherwise it prefers to sell to new consumers only from its virtual shop. We argue that these price equilibria are different from others in search theory, where firms face consumers with different reservation prices.

Since digital goods are more convenient to buy on-line, physical shops may have to charge lower prices than virtual shops to sell them to new consumers.

The model generates price dispersion on-line in two alternative ways: first, if the virtual shops of the new and old firms have different costs, and second, if consumers trust differently the new and old firms.

Our model has three novel features on the context of the search literature. First, firms can sell through two alternative distribution channels. Second, it captures some of the consumers' and firms' trade-offs regarding e-commerce. And third, the production and the search cost distributions are endogenous, in the sense that they depend on the firms' investment choices.

Our assumptions about the consumers' choices on how to search for prices, and how to buy, are admittedly restrictive. We think they are justifiable as a first approach, since they allows us to glean some intuition about the trade-offs for firms and consumers associated with e-commerce, while keeping the model simple. In addition, as we argue in footnotes 9 and 10, some consumers in some markets behave similarly. However, we discuss ways of relaxing, in further research, some of the model's more restrictive assumptions.

Section 2 presents the basic model, where reservation prices are exogenous, and section 3 characterizes its equilibria. Section 4 presents the model with endogenous reservation prices. Section 5 discusses price equilibria for digital goods. Section 6 allows the new and old firm to operate the new technology at different costs. Section 7 discusses trust. Section 8 discusses self-cannibalization and channel conflict. Section 9 discusses some directions for further research. Section 10 discusses related literature. Proofs are in the Appendix.

# 2 The Basic Model

In this section we formalize the firms' opening of a virtual shop and pricing decisions, given consumers' reservation prices, as a 2 stage game. In section 4 we will insert this ***Basic*** model in a larger game that includes a third stage, where reservation prices are determined.

## (a) The Setting

Consider a retail market for a functionally identical search good, which opens for 1 period.

There are 2 alternative ***retailing technologies***: a ***New***, virtual shop based technology, and an ***Old***, physical shop based technology[8]. A ***Virtual Shop*** has a Web site, where consumers can observe prices and buy, and its logistics is based on the Web. A ***Physical Shop*** has a physical location, where consumers can observe prices and buy, and its logistics is based on the physical world. A physical shop may have a Web site, but only to post prices[9]. A firm is ***Old*** if it has a physical shop, opened before the game, and ***New*** if it does not.

The game has 2 stages. In stage 1 firms choose whether to open virtual shops. In stage 2 firms choose prices. Then consumers buy, delivery takes place, agents receive their payoffs, and the market closes.

Subscript $j$ refers to firms and we index a new and an old firm by: $n, o$. Subscripts $t$ refers to shops and we index a new firm's virtual shop, an old firm's virtual shop, and a physical shop by: $vn, vo, p$.

---

[8] Technologies that make products available for use or consumption. This concept is related to that of a ***distribution channel*** (see Kotler (1994)).

[9] Bailey (1998) and Brynjolfsson & Smith (1999) found that, e.g., Cody's and Powell's Books, posted prices on the Web, but only sold at their physical locations.

## (b) Consumers

There is a unit measure continuum of risk neutral consumers of 2 types. ***New*** consumers, a proportion $\lambda \in (0,1]$, have Internet access; ***Old*** consumers do not. At price $p$ a consumer demands $D(p)$, where $D(.)$ is a differentiable, decreasing, bounded function, with a bounded inverse.

Consumers do not know the prices of individual shops, and can only learn them by visiting the shops. Old consumers visit the physical shop's physical location, and if offered a price no higher than $s$, where $D(s) \equiv 0$, buy and receive the product. When there are no virtual shops, new consumers behave similarly. Otherwise new consumers canvass prices through the Web[10]. They have the list of Web sites, obtained, e.g., from a search engine, but do not know to which type of shop the directions correspond. Each new consumer picks randomly which Web site to visit, from the set he has not sampled yet. The new consumers' reservation price for a type $t$ shop is $r_t$. When new consumers visit a new (old) firm's virtual shop, if offered a price no higher than $r_{vn}$ ($r_{vo}$), they buy, and wait for delivery; when they visit a physical shop's Web site, if offered a price no higher than $r_p$, they go to the shop's physical location, buy, and receive the product; otherwise they reject the offer and search again. As an alternative to sequential search (some) new consumers could use shopbots. In section 9 we discuss further this issue. Visiting a Web site or a physical shop's physical location, and waiting for delivery of the product bought from a virtual shop, involve costs, which we will ignore until section 4.

## (c) Firms

There are 2 risk neutral firms: a new and an old firm. If the new firm decides not to open a virtual shop, it exits the game with a $0$ payoff. Opening a virtual shop involves a set-up cost, $K \in (0,+\infty)$. The probability with which firm $j$ opens a virtual shop is $a_j$; let $a = (a_n, a_o)$. At the end of stage 1 all players observe $a$. If at least 1 virtual shop opens, the physical shop creates its own Web site, where it posts its price. We assume it is impractical for a physical shop to have more than 1 web site.

---

[10] In 1999, 25% of the consumers in the market for a new car, used the Internet, many only to obtain price information about physical shop dealers (J.D. Power and Associates, 1999, cited by Morton, Zettelmeyer & Risso (2000)). Barnes & Noble's web site attracts "two kinds of shoppers, (...). The first group prints out the information on books from the site and then drives to the store for purchases. The second group makes purchases on-line", (*International Herald Tribune*, December 18, 1998).

Marginal production costs are constant for both shop types. The marginal cost of shop $t$ is $c_t$. Let $c_p$ Î $\left(0,s\right)$ and $c_{vn} = c_{vo} = c_p - D_c =: c_v$, where $D_c$ Î $\left(0,c_p\right]$ is the ***production cost reduction*** induced by the new technology. All players know $\left(c_p, c_v\right)$.

The old firm can charge different prices at its 2 shops[11]. Shop $t$'s price and per consumer profit are $p_t$ and $p(p_t;c_t) := \left(p_t - c_t\right)D(p_t)$; $p(.)$ is strictly quasi-concave in $p$. Let $\hat{p}_t := argmax_p\, p(p;c_t)$. Even for the maximum cost reduction the physical shop can charge $\hat{p}_v$ without losses, i.e., $c_p < \hat{p}_v$ for $D_c = c_p$. Shop $t$'s expected consumer share and expected profit are: $f_t(p_t)$ and $P(p_t;c_t) := p(p_t;c_t)f_t(p_t)$. The new and old firm's net expected profits are: $V^n := \left[P(p_{vn};c_v) - K\right]a_n$ and $V^o := P(p_p;c_p) + \left[P(p_{vo};c_v) - K\right]a_o$. Firm $j$'s net profit when in stage 1 firms play $\left(a_n, a_o\right)$, and after both firms and consumers play optimally is $V^j_{a_n a_o}$.

We assume that $r_p < \hat{p}_p$, which rules out uninteresting cases, where although virtual shops exist, the physical shop is able to sell to new consumers at $\hat{p}_p$, its monopoly price. When the old firm is indifferent between its physical shop selling to both consumer types and selling only to old consumers, it chooses the latter.

A firm's stage 1 ***strategy***, is a rule that for every firm type, says with which probability a firm should open a virtual shop. A firm's stage 2 ***strategy***, is a rule that for each history and shop type, says which price a shop should charge. A firm's ***payoff*** is expected profit, net of the investment expenditure.

## (d) Equilibrium

A subgame perfect Nash ***Equilibrium*** is: an opening and a pricing rule, for each shop and firm type, $\left\{\left(a^*_j, p^*_t\right) j = n, o;\ t = vn, vo, p\right\}$, such that:

**(E.1)** Given any $r_t$ and $a$, firms choose $p^*_t$ to solve problems: $max_{p_{vn}}\ V^n$ and $max_{\{p_{vo},\, p_p\}}\ V^o$;

**(E.2)** Given any $r_t$, and $p^*_t$, firms choose $a^*_j$ to solve problem: $max_{a_j} V^j$.

---

[11] Barnesandnoble.com charges different prices than Barnes and Noble's physical shops.

# 3 Equilibrium of the Basic Model

In this section we construct the basic model's equilibrium by working backwards. First, given reservation prices and the profile of opening of virtual shops decisions, we derive the equilibrium prices. Virtual shops charge their monopoly price. The physical shop charges sometimes the new consumers' reservation price, other times its monopoly price. Second, given reservation prices and equilibrium prices, we derive the firms' equilibrium opening of virtual shop's rule. Either firm sometimes opens a virtual shop, sometimes does not. There are 6 types of equilibria, depending on whether firms choose to open a virtual shop, and whether the physical shop sells to all or only to old consumers.

## 3.1 Stage 2: The Price Game

In this sub-section we characterize equilibrium prices.

The number of shops that charge a price acceptable to new consumers, i.e., $p_t \le r_t$, $t = vn, vo, p$, is $a$, and the number of shops that charge a price acceptable to new consumers when firms play $(a_n, a_o)$ in stage 1 is $a^{a_n a_o}$. If virtual shop $t$ charges a price higher than $r_t$, it makes no sales; if it charges a price no higher than $r_t$, its expected consumer share is $l / a$.[12] Thus, for $0 < a$:

$$\phi_t(p;\rho_t) = \begin{cases} 0 & \Leftarrow \rho_t < p \\ \lambda/\alpha & \Leftarrow p \le \rho_t \end{cases} \qquad t = vn, vo$$

If the physical shop charges a price higher than $s$, it makes no sales; if it charges a price higher than $r_p$, but no higher than $s$, it sells to old consumers, $1 - l$; if it charges a price no higher than the $r_p$, its expected consumer share is $l / a + 1 - l$. Thus, for $0 < a$:

$$\phi_p(p;\rho_p) = \begin{cases} 0 & \Leftarrow s < p \\ 1-\lambda & \Leftarrow \rho_p < p \le s \\ \lambda/\alpha + 1 - \lambda & \Leftarrow p \le \rho_p \end{cases}$$

We assume also that $r_t$ is strictly higher than the lowest of the prices consumers can find if they search:

**(H)** $\min\{p_{t'}\} < \rho_t \qquad t' \ne t$

[12] Because there is a continuum of new consumers, and each new consumer picks randomly which Web site to visit, from the set he has not sampled yet.

This assumption rules out equilibria, which are not subgame perfect in the larger model, if search and waiting for delivery are costly. It follows that costly search and impatience give firms market power, since they lead new consumers to accept prices above the minimum charged in the market[13]. From **(H)**, $0 < a$ .

When neither firm opens a virtual shop, $a = (0,0)$, the industry is a monopoly, and $a^{00} = 1$.

Consider the case where only the new firm opens a virtual shop, $a = (1,0)$. The supply side consists of the physical shop, and the new firm's virtual shop. For $a = (1,0)$, the value of $r_p$ for which the old firm is indifferent between its physical shop selling to both consumer types at $p_p = r_p$, and selling only to old consumers at $p_p = \widehat{p}_p$, given that the new firm's price is acceptable to new consumers, is $p^s_{10}$, i.e., $p(p^s_{10}(l); c_p)[l/2 + 1 - l] \equiv p(\widehat{p}_p; c_p)(1 - l)$.

**Proposition 1:** If $a = (1,0)$, then: **(i)** $p^*_{vn} = \widehat{p}_v$ ; **(ii)**

$$p^*_p = \begin{cases} \rho_p & \Leftarrow \quad p^s_{10}(\lambda) < \rho_p \\ \widehat{p}_p & \Leftarrow \quad \rho_p \le p^s_{10}(\lambda) \end{cases}$$

where $p^s_{10}(.)$ is decreasing, and $p^s_{10}(1) = c_p$. §

Since the new firm's virtual shop charges the lowest price in the market, and given **(H)**, it is never constrained by consumer search and always charges $\widehat{p}_v$. The physical shop also benefits from the market power generated by costly search, and from being the only shop old consumers can buy from, by charging a higher price than the new firm's virtual shop. However, it is constrained by consumer search, if it is beneficial to sell to both consumer types[14]. If $r_p$ is high, i.e., $p^s_{10}(l) < r_p$, or alternatively, if $l$ is large, i.e., $l > \widehat{l}(r_p) := (p^s_{10})^{-1}(r_p)$, the old firm wants to sell to both consumers types, so reduces its price below $\widehat{p}_p$ and charges $r_p$. If $r_p$ is low, i.e.,

---

[13] ***Market power*** is the ability to raise price above marginal cost.

[14] And the threat of a second search by new consumers is credible, i.e., $r_p < \widehat{p}_p$ .

$r_p < p^s_{10}(l)$, the old firm wants to sell only to old consumers and charges $\hat{p}_p$.[15] The higher is the proportion of new consumers, the more willing is the physical shop to lower its price to sell to them. From **Proposition 1**:

$$\alpha^{10} = \begin{cases} 2 \Leftarrow p^s_{10}(\lambda) < \rho_p \\ 1 \Leftarrow \rho_p \leq p^s_{10}(\lambda) \end{cases}$$

When the old firm does not open a virtual shop and charges $r_p$ instead of $\hat{p}_p$, it sells to $l/2$ new consumers, earning an additional $p(r_p;c_p)(l/2)$, the ***Volume of Sales*** effect, but loses $-[p(\hat{p}_p;c_p)-p(r_p;c_p)]$ per old consumer, and a total of $-[p(\hat{p}_p;c_p)-p(r_p;c_p)](1-l)$, the ***per Consumer Profit*** effect. Thus, the physical shop trades-off volume of sales and per consumer profit[16].

When the physical shop charges $r_p$, new consumers search only once[17]; otherwise new consumers may search twice, until they find the virtual shop.

When only the new firm opens a virtual shop there can be 2 types of price equilibria. In both the virtual shop charges $\hat{p}_v$. The physical shop at a ***Competing*** equilibrium charges $r_p$, and at a ***Segmentation*** equilibrium charges $\hat{p}_p$. The ***Competing*** equilibrium occurs when $(r_p, l)$ are large, and the ***Segmentation*** equilibrium occurs when $(r_p, l)$ are small.

Now consider the case where both firms open virtual shops, $a = (1,1)$. The supply side consists of a physical shop and 2 virtual shops. For $a = (1,1)$, the level of $r_p$ for which the old firm is indifferent between its physical shop selling to both consumer types at $p_p = r_p$, and selling only to old consumers at $p_p = \hat{p}_p$, given that both virtual shops' prices are acceptable to new consumers, is $p^s_{11}$, i.e., $p(\hat{p}_v;c_v)(l/3)+p(p^s_{11}(l,D_c);c_p)[l/3+1-l] \equiv$

---

[15] When $r_p < p^*_p$ the physical shop could shut its Web site.

[16] The physical shop could price discriminate between new and old consumers, by, e.g., offering coupons at its Web site. It might, however, be reluctant to do so, because when informed about them, old consumers could perceive these price differences as unfair. See Sinha (2000) for a discussion of this issue.

[17] The option to search serves only as a credible, out of equilibrium threat, constraining the old firm's price decisions.

$p(\hat{p}_v; c_v)(l/2) + p(\hat{p}_p; c_p)(1 - l)$. We assume that for $D_c = c_p$, $2 < p(\hat{p}_v; c_v)/p(\hat{p}_p; c_p)$, which can be interpreted as the ***Large Cost Reduction Opportunities*** case. The value of $D_c$ for which $p(\hat{p}_v; c_v)/p(\hat{p}_p; c_p) \equiv 2$, is $D_c^c$.[18]

**Proposition 2:** If $a = (1, 1)$, then: **(i)** $p_{vn}^* = p_{vo}^* = \hat{p}_v$; **(ii)**

$$p_p^* = \begin{cases} \hat{p}_p & \text{for } \Delta_c \in [\Delta_c^c, c_p] \\ \begin{cases} \rho_p \Leftarrow p_{11}^s(\lambda, \Delta_c) < \rho_p \\ \hat{p}_p \Leftarrow \rho_p \le p_{11}^s(\lambda, \Delta_c) \end{cases} & \text{for } \Delta_c \in (0, \Delta_c^c) \end{cases}$$

where $p_{11}^s(.)$ is decreasing in $l$, increasing in $D_c$, $p_{10}^s(l) < p_{11}^s(l, D_c)$, and $p_{11}^s(l, D_c) \in (c_p, \hat{p}_p)$. §

Note that $p_{vn}^* = p_{vo}^* = \hat{p}_v$ is an expression of Diamond's (1971) paradox[19]. From **Proposition 2**:

$$\alpha^{11} = \begin{cases} 2 & \text{for } \Delta_c \in [\Delta_c^c, c_p] \\ \begin{cases} 3 \Leftarrow p_{11}^s(\lambda, \Delta_c) < \rho_p \\ 2 \Leftarrow \rho_p \le p_{11}^s(\lambda, \Delta_c) \end{cases} & \text{for } \Delta_c \in (0, \Delta_c^c) \end{cases}$$

When the old firm opens a virtual shop, it faces another effect, besides the ***Volume of Sales*** effect, $p(r_p; c_p)(l/6)$, and the ***per Consumer Profit*** effect, $-[p(\hat{p}_p; c_p) - p(r_p; c_p)](1 - l)$. If its physical shop charges $r_p$ instead of $\hat{p}_p$, half of the new consumers it sells to, $l/6$, would otherwise buy from its own virtual shop, causing a loss of $-[p(\hat{p}_v; c_v) - p(r_p; c_p)](l/6)$. This ***Channel Conflict*** effect causes the old firm to only want to reduce its physical shop's price below $\hat{p}_p$ to attract new consumers, if cost reduction is small, i.e., $D_c \le D_c^c$. Otherwise, the old firm prefers to sell to new consumers only from its virtual shop. And when the old firm's physical shop does reduce its price to attract new consumers, it does so for higher reservation price values than when it does not open a virtual shop, $p_{10}^s < p_{11}^s$.

When all consumers have Internet access, $l = 1$, $p_{11}^s(1, D_c) < \hat{p}_p$. Thus, if cost reduction is small and the reservation price is high, $p_{11}^s < r_p$, the old firm still sells from the physical shop, since this allows it to have a share of

---

[18] Price $\hat{p}_v$ depends on $c_v$, and thus on $D_c$. If $2 < p(\hat{p}_v; c_v)/p(\hat{p}_p; c_p)$, $D_c^c \le c_p$, whereas if $p(\hat{p}_v; c_v)/p(\hat{p}_p; c_p) \le 2$, $D_c^c = c_p$.

[19] Low cost shops charge their monopoly price, regardless of how low the search cost is, and how many shops there are. See Davis & Holt (1996) for experimental evidence.

new consumer of $2l/3$ instead of $l/2$. If, however, cost reduction is large and the reservation price is low, $r_p \leq p^s_{11}$, the physical shop chooses to have zero sales, which could be interpreted as ***Shutting Down***[20].

When both firms open virtual shops there is a ***Competing*** and a ***Segmentation*** equilibrium. A ***Competing*** equilibrium, exists when $D_c$ is small and $(r_p, l)$ are large, and a ***Segmentation*** equilibrium exists when either $D_c$ takes intermediate values and $(r_p, l)$ are small, or when $D_c$ is large.

The price equilibria of case $a = (1,1)$ are different from other search theory equilibria where firms must choose whether to sell only to high reservation price consumers, or to sell also to low reservation price consumers (e.g., Braverman (1980), Burdett & Judd (1983), Rob (1985), Salop & Stiglitz (1977), Varian (89), Wilde & Schwartz (1979)), because the old firm's problem is not just whether to sell to low reservation price consumers, but also how to sell to them, since it can do so either through its virtual or its physical shop.

Finally, consider the case where only the old firm opens a virtual shop, $a = (0, 1)$. The supply side consists of the old firm's physical and virtual shops.

**Proposition 3:** If $a = (0, 1)$, then: **(i)** $p^*_{vo} = \hat{p}_v$; **(ii)** $p^*_p = \hat{p}_p$. §

Now since the old firm is alone in the industry, it has no incentive to reduce its physical shop's price below $\hat{p}_p$. Any new consumer its physical shop might attract is stolen from its virtual shop, where per consumer profit is no smaller. And, if all consumers have Internet access, $l = 1$, again the physical shop has zero sales. From **Proposition 3**: $a^{01} = 1$.

When only the old firm opens a virtual shop there is a ***Segmentation*** equilibrium.

**Table 1** summarizes the price equilibria's main features.

**[Insert table 1 here]**

## 3.2 Stage 1: The Opening of Virtual Shops Game

In this sub-section we characterize the equilibrium opening rule and establish existence of equilibrium.

---

[20] Egghead, a software firm, started as a physical shop firm, then opened a virtual shop, and eventually closed its chain of physical shops. It decided that since it sells "zeros and ones" it has no need for a physical presence.

The next proposition, characterizes without proof, the firms' optimal strategy for stage 1.

**Proposition 4:**

$$a_n^* = \begin{cases} 0 & \Leftarrow \ a_o V_{11}^n + (1-a_o)V_{10}^n > 0 \\ [0,1] & \Leftarrow \ a_o V_{11}^n + (1-a_o)V_{10}^n = 0 \\ 1 & \Leftarrow \ a_o V_{11}^n + (1-a_o)V_{10}^n < 0 \end{cases} \qquad a_o^* = \begin{cases} 0 & \Leftarrow \ a_n\left(V_{11}^o - V_{10}^o\right) + (1-a_n)\left(V_{10}^o - V_{00}^o\right) > 0 \\ [0,1] & \Leftarrow \ a_n\left(V_{11}^o - V_{10}^o\right) + (1-a_n)\left(V_{10}^o - V_{00}^o\right) = 0 \\ 1 & \Leftarrow \ a_n\left(V_{11}^o - V_{10}^o\right) + (1-a_n)\left(V_{10}^o - V_{00}^o\right) < 0 \end{cases}$$

§

Firms should open a virtual shop if its expected incremental profit is positive.

The next proposition establishes the existence of equilibrium. Given the range of values we consider, virtually any profile of decisions to open a virtual shop can be an equilibrium.

**Proposition 5:** Equilibrium exists. §

# 4 Endogenous Reservation Prices

In this section we add to the model, a third stage where reservation prices are determined, given consumers' search and waiting costs. The game consists of 3 stages. The first 2 unfold as in **Section 2**'s model. In stage 3 consumers make their search and purchase decisions; then delivery takes place, agents receive their payoffs, and the market closes.

To complete the model we introduce the following costs. Visiting the physical shop involves cost, $s \in (0,+\infty)$, which includes the opportunity cost of the time spent, and associated expenses like driving. Visiting a Web site involves cost, $s - D_s$, which includes the opportunity cost of the time spent, and associated expenses like phone calls and Internet fees, and where, $D_s \in (0,s)$, is the ***search cost reduction*** induced by the new technology. Waiting for delivery of a product bought from a virtual shop involves cost, $d$, that results from deferring consumption. Searching Web sites is instantaneous, a consumer may observe any number of prices, and may at any time accept any offer received to date. Let $S(p) := \int_p^{\infty} D(t)dt$. The surplus of a consumer that buys from a type $t$ shop at price $p_t$, is $S(p_t) - u_t$, where $u_t = s$ if $t = p$, and $u_t = d$ if $t = vn, vo$. Let $DS := S(\hat{p}_v) - S(\hat{p}_p)$.

Old consumers, and new consumers when $a = (0,0)$, visit the physical shop, and if offered a price $p \leq s$ buy and receive the product, getting a surplus of $S(p) - s$. When $a \neq (0,0)$, new consumers first visit a Web site chosen at random: **(H)**.[21] Then, they decide if they accept the best offer at hand and terminate search; or if they reject it, retaining the option to recall it later, and visit one of the other shop's Web sites. If new consumers have visited all shops, they accept the offer with the highest surplus.

A consumer's ***information set*** just after his $k$-th search step, consists of all previously observed prices. A consumer's stage 3 ***strategy***, $z$, is a stopping rule that for any sequence of observations, says if search should stop or continue. A consumer's ***payoff*** is the expected consumer surplus, net of the search expenditure.

A subgame perfect Nash ***Equilibrium*** is: a stopping rule for new consumers, and an opening and a pricing rule, for each shop and firm type, $\left\{\left(a_j^*, p_t^*, z^*\right) j = n, o; t = vn, vo, p\right\}$, such that:

**(E.0)** Given any $a$ and $p_t$, new consumers choose $z^*$ to maximize net expected surplus;

**(E.1)** Given any $a$, and $z^*$, firms choose $p_t^*$ to solve problems: $max_{p_{vn}} V^n$ and $max_{\{p_{vo},\, p_p\}} V^o$;

**(E.2)** Given $z^*$ and $p_t^*$, firms choose $a_j^*$ to solve problem: $max_{a_j} V^j$.

Next we characterize the new consumers equilibrium search behavior for $a \neq (0,0)$.

When $a = (1,0), (0,1)$, new consumers' search may involve 3 steps. In step 3, consumers know both prices, and the optimal strategy is to accept $p_t$, if $S(p_t) - u_t \geq S(p_{t'}) - u_{t'}$. In step 2, a consumer who was offered $p_t$ at the shop he choose to visit at random in step 1, gains $\left[S(p_{t'}) - u_{t'} - S(p_t) + u_t\right]$ by searching. Search is optimal if and only if $s - D_s < \left[S(p_{t'}) - u_{t'} - S(p_t) + u_t\right]$. Let $r_t^{a_n a_o}$ equate the marginal search cost, $s - D_s$, to the marginal benefit, when firms play $(a_n, a_o)$ in stages 1:

$$\left[S(p_{t'}) - u_{t'} - S(\rho_t^{a_n a_o}) + u_t\right] = \sigma - \Delta_\sigma \qquad t' \neq t \tag{1}$$

[21] This first step is usually absent in the search literature since it is assumed that consumers get their first price observation for free.

The new consumers' optimal search rule is to accept offer $p_t$ and terminate search, if $p_t \le r_t^{a_n a_o}$, and reject offer $p_t$ and proceed to step 3, if $p_t > r_t^{a_n a_o}$.[22] It is straightforward to show that the maximum price for which new consumers accept the physical shop's offer in step 3, is strictly smaller than $r_p^{10}$. Thus the physical shop cannot charge a price higher than $r_p^{10}$, expecting that it will be rejected in step 2, but accepted in step 3. If $p_{vn}^* = p_{vo}^*$, $r_{vn}^{10} = r_{vo}^{01}$.

**Lemma: (i)** If $D_s < d$, then $p_t < r_p^{a_n a_o}$, $t = vn, vo$. **(ii)** If $d < 2s - D_s$, then $p_p < r_t^{a_n a_o}$, $t = vn, vo$. **(iii)** If $d < DS + D_s$, then $r_p^{a_n a_o} < \hat{p}_p$. **§**

Thus **(H)** follows if search and waiting for delivery are costly. And since new consumers have access to lower cost shops, if waiting for delivery is not too costly, new consumers only accept buying from the physical shop for a lower price than old consumers: $r_p < \hat{p}_p$. From now on let $d \in \left(D_s, D_s + min\left\{DS, 2\left(s - D_s\right)\right\}\right)$.

When $a = (1,1)$, new consumers' search may consist of 4 steps. Steps 3 and 4 are similar to steps 2 and 3 of the previous 2 cases. In step 2, there are 2 Web sites to sample. Let $S(p_{t''}) - u_{t''} < S(p_{t'}) - u_{t'}$. If $S(p_t) - u_t < S(p_{t''}) - u_{t''}$, a new consumer who is offered $p_t$, gains $\left[S(p_{t'}) - u_{t'} - S(p_t) + u_t\right]$ by sampling shop $t'$, and gains $\left[S(p_{t''}) - u_{t''} - S(p_t) + u_t\right]$ by sampling shop $t''$. If $S(p_{t''}) - u_{t''} \le S(p_t) - u_t < S(p_{t'}) - u_{t'}$, new consumers' expect to gain $\left[S(p_{t'}) - u_{t'} - S(p_t) + u_t\right]/2$ by searching, since they reject shop $t''$'s offer. The optimal search rule is to hold reservation price $r_t^{11}$, which equates the marginal benefit to the marginal cost:

$$\begin{cases} \frac{1}{2}\left[S(p_{t'}) - u_{t'} - S(\rho_t^{11}) + u_t\right] + \frac{1}{2}\left[S(p_{t''}) - u_{t''} - S(\rho_t^{11}) + u_t\right] = \sigma - \Delta_\sigma & \Leftarrow \quad S(r_t^{11}) - u_t < S(p_{t''}) - u_{t''} \\ \frac{1}{2}\left[S(p_{t'}) - u_{t'} - S(\rho_t^{11}) + u_t\right] = \sigma - \Delta_\sigma & \Leftarrow \quad S(p_{t''}) - u_{t''} \le S(r_t^{11}) - u_t < S(p_{t'}) - u_{t'} \end{cases} \tag{2}$$

[22] See Reinganum (1979) or Benabou (1993).

As before, it is straightforward to show that the maximum price for which new consumers accept the physical shop's offer, is smaller in step $t$ than in step $t+1$, $t = 2,3$. If $p^*_{vn} = p^*_{vo}$, $r^{11}_{vn} = r^{11}_{vo}$. The **Lemma** holds, and if $s < \left(S(\hat{p}_p) + D_s\right)/2$, in equilibrium consumers always have a strictly positive net surplus.

Equilibrium prices are as in **Section 3** and **Proposition 5** holds.

# 5 Digital Goods

In this section we discuss the price equilibria for digital goods. We argue that for this case, virtual shops' prices may be higher than the physical shop's price.

We assumed that buying from a virtual shop has the inconvenience of requiring waiting for delivery. However, for digital goods, with enough bandwidth, the cost of waiting is small, possibly zero.

Consider **Section 4**'s model. Let $d = 0$.

From (1), $r_p^{a_n a_o} < p_t$, $t = vn, vo$, and the physical shop must charge a lower price than virtual shops to sell to new consumers. This is intuitive. Functionally identical goods sold through different retailing technologies, acquire different attributes. E-commerce reduces prices because it reduces costs, and may force the physical shop to charge a lower price. If in addition consumers value negatively e-commerce's attributes, relative to those of other retailing technologies, consumers will only buy on-line if compensated by lower prices, which pushes prices further down. If however, consumers value positively e-commerce's attributes, they will pay for the convenience of buying on-line, and the net effect can be such that prices are higher on-line than off-line.

# 6 Firm Asymmetry

In this section, we discuss how a possible asymmetry between the new and old firm with respect to the new technology, affects the price equilibrium.

We assumed that the new and old firm is equally capable of achieving the new technology's cost reduction. However, if virtual shops require new forms of organization that take advantage of the new technology's low cost of information processing and transmission, if integrating virtual and physical shop retailing is hard, and if old firms' employees resist the new technology because it devalues their skills, the new firm might achieve larger retailing cost reductions than the old firm. On the other hand, if the old firm has superior logistical expertise, or is able to bargain better deals from suppliers, due to volume of sales and past relationship[23], and if virtual and physical shops can share their logistical systems, the old firm might achieve a larger retailing cost reduction.

Consider **Section 2**'s model. Let $c_{vo} = c_p - (1-e)D_c$; parameter $e \in (1 - c_p/D_c, 1]$, measures the cost difference between the old and new firms, relative to the new technology. For $(e, D_c) = (0, D_c^c)$, let $p(\widehat{p}_{vo}; c_{vo})/p(\widehat{p}_p; c_p) = 2$; for $(e, D_c) = (1 - c_p/D_c, c_p)$, let $2 < p(\widehat{p}_{vo}; c_{vo})/p(\widehat{p}_p; c_p)$; and $p(\widehat{p}_{vo}; c_{vo})/p(\widehat{p}_p; c_p) \equiv 2$, defines $\bar{e}(D_c)$. Let $G^s := \{(e, D_c) \in (1 - c_p/D_c, 1] \times (0, c_p] : p(\widehat{p}_{vo}; c_{vo})/p(\widehat{p}_p; c_p) \leq 2\}$ and $G^l := \{(e, D_c) \in (1 - c_p/D_c, 1] \times (0, c_p] : p(\widehat{p}_{vo}; c_{vo})/p(\widehat{p}_p; c_p) > 2\}$. Denote the level of $r_p$ for which the old firm is indifferent between its physical shop selling to both consumer types, and selling only to old consumers, by $\breve{p}_{11}^s(.)$. Let $r_v := r_{vn}^{11} = r_{vo}^{11}$.

The firms' pricing behavior remains unchanged, except for $a = (1,1)$. **(H)** implies $min\{\widehat{p}_{vn}, \widehat{p}_{vo}\} < r_v$.

**Proposition 6:** If $a = (1,1)$, then: **(i)** $p_t^* = min\{r_v, \widehat{p}_t\}$, $t = vn, vo$; **(ii)**

$$p_p^* = \begin{cases} \widehat{p}_p & for\ \Gamma^l \\ \begin{cases} \rho_p \Leftarrow \breve{p}_{11}^s(\varepsilon, \Delta_c) < \rho_p \\ \widehat{p}_p \Leftarrow \rho_p \leq \breve{p}_{11}^s(\varepsilon, \Delta_c) \end{cases} & for\ \Gamma^s \end{cases}$$

where, $\breve{p}_{11}^s(.)$ is decreasing in $e$, $\bar{e}(.)$ is increasing, $G^s = [0,1] \times [0, D_c^c] \cup [\bar{e}(D_c), 1] \times (D_c^c, c_p)$, and $G^l = [0, \bar{e}(D_c)) \times (D_c^c, c)$. §

Assumption **(H)** implies $min\{\widehat{p}_{vn}, \widehat{p}_{vo}\} < r_v$. If $r_v < max\{\widehat{p}_{vn}, \widehat{p}_{vo}\}$, there is price dispersion on-line.

# 7 Trust

In this section we discuss the implications of trust for price equilibria on-line.

We assumed that consumers trusted the new and old firm equally. However, consumers might have more trust in the old firm because it has a longer presence in the market. If this is the case, then the utility loss from buying

[23] KB Toys, the second largest specialty toy retailer and its virtual shop, "enjoys enormous market power, enabling it to negotiate advantageous prices and terms with toy

from the new firm's virtual shop will be larger than from buying from old firm's virtual shop, because it not only involves deferring consumption, but also because consumers have less trust in the new firm.

Consider **Section 4**'s model. Buying from virtual shop $t$ involves a utility $d_t$, $t = vn, vo$, with $d_{vo} < d_{vn}$.

From (2), if $d_{vo} + s - D_s < d_{vn}$, then $p^*_{vn} = r^{11}_{vn} < p^*_{vo} = \widehat{p}_v$, and there will be price dispersion on-line. This is intuitive. If consumers trust less the new firm than the old firm, they will only buy from the new firm's virtual shop if compensated by a lower price, or equivalently, the old firm's virtual shop can take advantage of the consumers' trust to charge a premium.

# 8 Self-Cannibalization and Channel Conflict

It has been argued that an old firm may be reluctant to use e-commerce for fear of its virtual shop, with supposedly a lower per consumer profit, stealing business from its physical shop, i.e., ***Self-Cannibalization***[24]. In this section we discuss under which conditions self-cannibalization way occur[25].

We start by discussing how opening a virtual shop impacts the old firms' profits. The impact of opening a virtual shop on the old firm's profit can be decomposed in 3 effects. The ***Cost Reduction*** effect, is the increase in the old firm's profit from selling to new consumers through its virtual shop at a lower cost, instead of its physical shop, $\left[p\left(min\left\{r_{vo}, \widehat{p}_{vo}\right\}; c_{vo}\right) - p\left(p^*_p; c_p\right)\right]\left(l/m_c\right)$, where $l/m_c$ is the proportion of new consumers that buys from the old firm's virtual shop, but that would buy from the physical shop if the old firm did not open a virtual shop. The ***Market Penetration*** effect, is the increase in the old firm's profit, due to the rise in its new consumers' share, from opening a virtual shop when the new firm also does, $p\left(min\left\{r_{vo}, \widehat{p}_{vo}\right\}; c_{vo}\right)\left(l/m_p\right)$, where $l/m_p$ is the proportion of new consumers that buy from the old firm's virtual shop, but that would buy from the new firm's virtual shop if the old firm did not open a virtual shop. The ***Price Discrimination*** effect, is the increase in the old firm's profit from switching from a ***Competing*** to a ***Segmentation*** equilibrium, $\left[p\left(\widehat{p}_p; c_p\right) - p\left(r_p; c_p\right)\right]\left(1 - l\right)$.

manufacturers" (Gulati & Garino 2000)

24 Toys"R"Us invested $80 million to launch a virtual division, but Robert Mogg, the man in charge, resigned, claiming that the firm was afraid of competing with its own physical shops (*El País*, September 5, 1999). Alba et al. (1997): "E-commerce offers an advantage to retailers that have low penetration (...). On the other hand, companies with high penetration might experience significant self-cannibalization of its in-shop sales, making e-commerce less attractive".

25 We discuss self-cannibalization of new consumers. This involves no loss of generality, because although $l$ is exogenous, $l$ $Î\left(0,1\right]$.

Self-cannibalization is part of the ***Cost Reduction*** effect. With cost asymmetry, if $0 < e$, the ***Cost Reduction*** effect can be negative, if $r_{vo}$ is low and $c_{vo}$ high, justifying the fear of ***Self-Cannibalization***. If, however, the virtual shop has lower costs than the physical shop, and has market power, the intra-firm transfer of new consumers is profitable[26]. In addition, if the old firm opens a virtual shop it can increase its share of new consumers, the ***Market Penetration*** effect, and price discriminate between new and old consumers, the ***Price Discrimination*** effect, both of which are also profitable. Thus, self-cannibalization requires that the virtual shop of the old firm has either high costs, or low market power, or both.

# 9 Further Research

In this section we discuss ways of relaxing, in further research, the assumptions that new consumers search sequentially, that old consumers have no Internet access, and that new consumers must canvass prices through the Web.

First we discuss search through shopbots. Consider the model of **Section 2**, but now let there be 2 types of new consumers. ***Shoppers*** search through shopbots; and ***Non-Shoppers***, search sequentially. We assume shopbots give consumers perfect price information, i.e., for shoppers $D_s = s$.[27] Preliminary analysis suggests the following. For $a = (0,0)(0,1)$, price equilibria remain unchanged. For $a = (1,0)$ there is a ***Competing*** and a ***Segmentation*** equilibrium for some parameters values, and for other parameter values, there is an additional equilibrium that resembles that of a Bertrand duopoly with cost asymmetry[28]. For $a = (1,1)$, virtual shops play mixed strategies, as in Varian (80)-Rosenthal (80)-Stahl (89),[29] and the physical shop plays a pure strategy qualitatively similar to that of **Section 3**. Thus, the firms' trade-offs, between selling only to high reservation price consumers, or selling to high and to low reservation price consumers, or between using only 1 retail technology, or using both, apparently remain

---

[26] Baseball Express, claims that its Web site stole sales from its catalogue, but that selling on the Web is more profitable (*New York Times*, September, 2, 1999).

[27] Shopbots give consumers a sample of between 20 to 40 prices at a low fixed search cost. Thus, although they do not give consumers perfect information, or necessarily identify the lowest price, contrary to popular belief, shopbots can be approximated by a ***newspaper search technology*** (Braverman (1980), Salop & Stiglitz (1977), Wilde & Schwartz (1979)), i.e., perfect information at a fixed cost. Here we ignore the fixed cost since we take the proportion of shoppers as given.

[28] That is, a duopoly where firms face a downward sloping demand curve, have different constant marginal costs, and choose prices.

[29] See Baye & Morgan (2001) and Iyer & Pazgal (2000) for alternative ways of generating price dispersion on-line.

qualitatively the same. However, there is an expository cost. Aside from the equilibria being more complex, there are 2 pairs of reservation prices, 1 for each type of new consumer.

Second we discuss allowing all consumers to choose where to buy and where to search for prices. Consider the model of **Section 2**, but now all consumers can choose which retailing technology to use, and let there be 3 types of consumers: ***New***, ***Old***, and ***Switchers***. ***Old*** consumers have a high waiting cost and cannot use (or are not aware of) shopbots. ***New*** consumers have a low waiting cost, and can use shopbots. ***Switchers*** have an intermediate waiting cost, and cannot use shopbots. For the appropriate choice of parameter values, ***Old*** consumers will choose to buy from a physical shop, ***New*** consumers will choose to buy from a virtual shop, and will search through shopbots, and ***Switchers*** sometimes will chose to buy on-line and search sequentially, and other times will choose to buy off-line. Again, seemingly there will be equilibria that resemble qualitatively ***Competing*** and a ***Segmentation*** equilibria The expository cost is also obvious. Note that without this sort of consumer heterogeneity, the ***Competing*** equilibrium will be non-generic.

Given that either of these 2 extensions are important, but have an expository cost, it might be necessary to simplify other aspects of the model. It is however unclear which.

# 10 Related Literature

This section inserts the paper on the literature. Our paper relates to 3 literature branches. First, to the e-commerce marketing literature: Alba, Lynch, Weitz, Janiszewski, Lutz, Sawyer & Wood (1997), Bakos (1997), Lal & Sarvary (1998), Peterson, Balasubramanian, & Bronnenberg, (1997), Zettelmeyer (1997). Bakos (1997) presents a model of circular product differentiation, where consumers search for prices and product characteristics. All consumers have Internet access. If search costs for price and product information are separated, and if e-commerce lowers the former, prices decrease; if it lowers the latter, prices can increase.

Second, our paper relates to the literature that analyzes competition between alternative retailing technologies: Balasubramanian (1998), Bouckaert (2000), Friberg, Ganslandt & Sandstrom (2000), Legros & Stahl (2000), and Michael (1994). Balasubramanian (1998) and Bouckaert (2000) use a model of circular product differentiation to analyze competition between catalogue and physical shop retailing. Physical shops are located on the circumference, and catalogue firms at the center of the circle. The presence of a catalogue firm lowers prices, and the number of physical shops in the market.

Third, our paper relates to the advertising and markets for information literatures: Baye & Morgan (2001a), Caillaud & Jullien (2000), Ellison & Ellison (2001), Iyer & Pazgal (2000), and Kephart & Greenwald (1999). Baye & Morgan (2001a) examine the interaction between markets for information and the product market they serve. They show that the product market can exhibits price dispersion, even if consumers are fully informed. Kephart & Greenwald (1999) investigate the impact of shopbots on markets. Shopbots allow users to choose the number of searches, and make search cost depend only weakly on the number of searches, i.e., nonlinear, leading to a more extensive search.

In 2 companion papers (Mazón & Pereira 2001a, 2001b) we discuss the firms' incentives to invest in e-commerce, and welfare effects of the adoption of e-commerce.

# Appendix

In the appendix we prove the **Lemma** and **Propositions** contained in the main text, and 1 auxiliary result, **Lemma A**.

**Lemma A:** If $\alpha \neq (0,0)$, then: **(i)** for $p' \in (\rho_t, +\infty)$

$$p_t^* = \begin{cases} \min\{\rho_t, \widehat{p}_v\} & \Leftarrow \quad c_t \leq \rho_t \\ p' & \Leftarrow \quad \rho_t < c_t \end{cases} \qquad t = vn,\ vo$$

**(ii)** for $p'' \in (\rho_p, +\infty)$

$$p_p^* = \begin{cases} \rho_p \text{ or } \widehat{p}_p & \Leftarrow \quad c_p \leq \rho_p \\ p'' & \Leftarrow \quad \rho_p < c_p \end{cases}$$

**(iii)** $p_{vn}^* = p_{vo}^* < p_p^*$.

**Proof: (i)** First we establish the result for $p_{vn}^*$, and for $p_{vo}^*$ when $\rho_p < p_p^*$. We proceed in 2 steps. In step 1 we show that $p_t^* = \min\{\rho_t, \widehat{p}_v\}$ for $c_v \leq \rho_t$. Let $\widehat{p}_v < \rho_t$. Suppose $p_t^* \neq \widehat{p}_v$. If $p_t^* < \widehat{p}_v$, there is a $\varepsilon > 0$ sufficiently small such that $p_t^* + \varepsilon < \rho_t$. Thus, if a shop deviates and charges $p_t^* + \varepsilon$, it loses no customers, and by strict quasi-concavity of the per consumer profit, profit rises. Thus, $\widehat{p}_v \leq p_t^*$. If $\widehat{p}_v < p_t^*$, by definition of $\widehat{p}_v$, if a shop deviates and charges $p_t^* = \widehat{p}_v$, it increases its profit. Thus, $p_t^* \leq \widehat{p}_v$, and therefore, $p_t^* = \widehat{p}_v$. Now let $\rho_t \leq \widehat{p}_v$. Suppose $p_t^* \neq \rho_t$. Shops can make a non-negative profit so they never charge $\rho_t < p_t^*$. And, if they charge $p_t^* < \rho_t$, they could, as before, increase profit by rising price to $\rho_t$. It follows that $p_t^* = \rho_t$ for $\rho_t \leq \widehat{p}_v$, and therefore $p_t^* = \min\{\rho_t, \widehat{p}_v\}$ for $c_v \leq \rho_t$.

In step 2 we show that $p_t^* = p' \in (\rho_t, +\infty)$ for $\rho_t < c_v$. If a shop charges $p' \in (\rho_t, +\infty)$ it has a zero profit; otherwise it has a negative profit.

Now we establish the result for $p^*_{vo}$ when $p^*_p \le r_p$. The previous argument applies, since old firm's virtual shop only affects $f_p(.)$, if it charges $r_{vo} < p_{vo}$ instead of $p_{vo} \le r_{vo}$, which is never optimal since $\pi(p_{vo}; c_v)(\lambda/3) + \pi(p_p; c_p)[\lambda/3 + 1 - \lambda] - \pi(p_p; c_p)[\lambda/2 + 1 - \lambda] < 0$.

**(ii)** Recall that by assumption $r_p < \hat{p}_p$. Case $r_p < c_p$ is similar to **(i)**. So Let $c_p \le r_p$. We proceed in 2 steps. In step 1 we observe that by the same arguments as in **(i)**, $r_p \le p^*_p \le \hat{p}_p$.

In step 2 we show that either $p^*_p = r_p$ or $p^*_p = \hat{p}_p$. Suppose $p^*_p = p \in (r_p, \hat{p}_p)$. The physical shop's profit is $\pi(p; c_p)(1-\lambda)$. If a firm deviates and charges $p^*_p = \hat{p}_p$, it will loose no customers, and by strict quasi-concavity of the per consumer profit, profit rises.

**(iii)** Suppose $p^*_p \le p^*_t$, $t = vn, vo$. Let $p^*_p < c_p$. By **(ii)** $r_p < p^*_p \le p_t$, which violates **(H.2)**. Let $c_p \le p^*_p$. Consider $p^*_p = p^*_t$. By **(i)** and **(ii)**, $r_p = p^*_p \le p^*_t = \min\{r_t, \hat{p}_v\}$, which violates **(H.2)**. Thus, $p^*_t < p^*_p$. §

**Proposition 1:** For $(r_p, \lambda) \in [c_p, \hat{p}_p] \times (0, 1]$, $\psi^o(r_p, \lambda) := \pi(r_p; c_p)[\lambda/2 + 1 - \lambda] - \pi(\hat{p}_p; c_p)(1-\lambda)$ and $\psi^o(p^s_o(\lambda); \lambda) \equiv 0$.

**(i)** Follows from **(H.2)** and **Lemma A: (iii)** and **(i)**.

**(ii)** We proceed in 3 steps. In step 1 we establish the existence of $p^s_o$. Since $\forall \lambda$, $\psi^o(c_p; \lambda) < 0 < \psi^o(\hat{p}_p; \lambda)$, and $\psi^o(.)$ monotonic in $r_p$, it follows from the intermediate value theorem that, $\forall \lambda \in (0,1), \exists^1 p^s_o \in (c_p, \hat{p}_p)$. The implicit function theorem implies that $p^s_o = p^s_o(\lambda)$ with $p^s_o(.)$ decreasing.

In step 2 we establish $p^*_p$. Follows from **Lemma A: (ii)**, and the definition of $p^s_o$.

In step 3 we establish $p^s_o(1) = c_p$. Follows from $\psi^o(c_p; 1) = 0$. §

**Proposition 2:** For $(r_p, \lambda, D_c) \in [c_p, \hat{p}_p] \times (0,1] \times (0, c_p]$, $\psi^m(r_p; \lambda, D_c) := \pi(\hat{p}_v; c_v)(\lambda/3) + \pi(r_p; c_p)[\lambda/3 + 1 - \lambda] - \pi(\hat{p}_v; c_v)(\lambda/2) - \pi(\hat{p}_p; c_p)(1-\lambda)$ and $\psi^m(p^s_m(\lambda, D_c); \lambda, D_c) \equiv 0$.

**(i)** As in **Proposition 1: (i)**.

**(ii)** We proceed in 7 steps. In step 1 we show that $\forall D_c \in (0, D^c_c]$: $\pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p) \le 2$ and $\forall D_c \in (D^c_c, c_p)$: $\pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p) > 2$. Since $\pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p)$ is increasing in $D_c$, for $D_c = 0$ $\pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p) < 2$, and for $D_c = c_p$ $2 < \pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p)$, it follows from the intermediate value theorem that $\exists^1 D^c_c \in (0, c]$: $\pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p) \equiv 2$. The result follows from the monotonicity of $\pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p)$.

In step 2 we observe that $\psi^m(.)$ is strictly increasing in $r_p$, $\forall (\lambda, D_c)$ $\psi^m(c_p; \lambda, D_c) < 0$ and $\psi^m(\hat{p}_p; \lambda, D_c) = -\lambda\pi(p^*_p; c_p)\{[\pi(\hat{p}_v; c_v)/\pi(\hat{p}_p; c_p)] - 2\}/6$.

In step 3 we establish the existence of $p^s_m$, $\forall D_c \in (0, D^c_c]$. Given steps 1 and 2, it follows from the intermediate value theorem that $\forall (\lambda, D_c) \exists^1 p^s_m \in [c_p, \hat{p}_p]$. The implicit function theorem implies that $p^s_m = p^s_m(\lambda, D_c)$, and $p^s_m(.)$ is strictly decreasing in $\lambda$, and strictly increasing in $D_c$.

In step 4 we show that $p^*_p = \hat{p}_p$, $\forall D_c \in (D^c_c, c_p]$. Follows from steps 1 and 2.

In step 5 we show that $p^s_o \le p^s_m$. Note that $\psi^m = \psi^o - A$, $A := \lambda[\pi(\hat{p}_v; c_v) + \pi(r_p; c_p)]/6$. Let $\psi := \psi^o - hA$, $h \in [0,1]$. For $h = 0$ $\psi = \psi^o$, and that for $h = 1$ $\psi = \psi^m$. The result follows from $\partial\psi/\partial h < 0$.

In step 6 we establish $p^*_p$. Follows from **Lemma A: (iii)**, step 4 the definition of $p^s_m$.

In step 7 we establish $p^s_m(1,\Delta_c) < \hat{p}_p$. Follows from $0 < y^m(\hat{p}_p;1,\Delta_c),\ \forall \Delta_c \in (0, \Delta^c_c]$. §

**Proposition 3:** Follows from **(H.2)**, the definition of new and old consumers, $p(\hat{p}_p, c_p) < p(\hat{p}_v, c_v)$, and the old firm being the only firm. §

**Proposition 5:** Follows from Kakutani's fixed theorem, since firms' best response correspondences, presented in **Proposition 4**, $a_j^* = A_j(a_{j'}; r_p, l, \Delta_c, K)$, $A_j : [0,1] \times [\hat{p}_v, +\infty) \times (0,1] \times (0, c_p] \times (0,+\infty) \to [0,1]$ are upper-hemi continuous in $a_{j'}$. §

**Lemma:** Let $f^p(p;d,\Delta_s) := S(p_t) - d - S(p) + \Delta_s$; $f^p(.)$ is increasing in $p$ and $f^p(r_p;d,\Delta_s) \equiv 0$. Let $f^v(p;d,\Delta_s,s) := S(p_p) - S(p) + d - 2s + \Delta_s$; $f^v(.)$ is increasing in $p$ and $f^v(r_t;d,\Delta_s,s) \equiv 0$.
**(i)** If $\Delta_s < d$, $f^p(p_t;d,\Delta_s) = -d + \Delta_s < 0$. Thus, $0 \le f^p(p;d,\Delta_s)$ only if $p_t < p$, and thus $p_t < r_p$. **(ii)** As in **(i)** using $f^v(.)$. **(iii)** If $d < \Delta S + \Delta_s$, $0 < f^p(\hat{p}_p;d,\Delta_s) = \Delta S - d + \Delta_s$. Thus $0 \le f^p(p;d,\Delta_s)$ only if $p < \hat{p}_p$, and thus $r_p < \hat{p}_p$. §

**Proposition 6:** Identical to the proof of **Proposition 2** using the definitions of $G^l$, $G^s$, and $\breve{p}^s_{11}(.)$. §

## Table 1: Summary of Model's Price Equilibria

| a | | $\mathbf{p_p^*}$ | Share vn | Share vo | Share p | Equilibrium |
|---|---|---|---|---|---|---|
| $(1,0)$ | $p_{10}^s < r_p$ | $r_p$ | $l/2$ | – | $l/2 + 1 - l$ | *Competing* |
| $(1,0)$ | $r_p \le p_{10}^s$ | $\widehat{p}_p$ | $l$ | – | $1 - l$ | *Segmentation* |
| $(0,1)$ | – | $\widehat{p}_p$ | – | $l$ | $1 - l$ | *Segmentation* |
| $(1,1)$ | $D_c \le D_c^c$, $p_{11}^s < r_p$ | $r_p$ | $l/3$ | $l/3$ | $l/3 + 1 - l$ | *Competing* |
| $(1,1)$ | $D_c \le D_c^c$, $r_p \le p_{11}^s$ | $\widehat{p}_p$ | $l/2$ | $l/2$ | $1 - l$ | *Segmentation* |
| $(1,1)$ | $D_c^c < D_c$ | $\widehat{p}_p$ | $l/2$ | $l/2$ | $1 - l$ | *Segmentation* |

# References

**Alba**, **J**., **Lynch**, **J**., **Weitz**, **B**., **Janiszewski**, **C**., **Lutz**, **R**., **Sawyer**, **A**. & **Wood**, **S**., 1997, “Interactive Home Shopping: Consumer, Retailer, and Manufacturer Incentives to Participate in Electronic Marketplaces”, *Journal of Marketing*, **61**, 38-53

**Bailey**, **J**., 1998, “Electronic Commerce: Prices and Consumer Issues for Three Products: Books, Compact Discs, and Software”, OCDE/GD(98)4

**Balasubramanian**, **S**., 1998, “Mail versus Mall: A Strategic Analysis of Competition between Direct Marketers and Conventional Retailers”, *Marketing Science*, **17**, 181-95

**Bakos**, **J**., 1997, “Reducing Buyer Search Costs: Implications for Electronic Marketplaces”, *Management Science*, **43**, 1676-1692

**Bakos**, **Y**., **Lucas**, **H**., **Oh**, **W**., **Simon**, **G**., **Viswanathan**, **S**. & **Weber**, **B**., 2000, “The Impact of Electronic Commerce on the Retail Brokerage Industry”, *Stern School*

**Baye**, **M**., **Morgan**, **J**., & **Scholten**, **P**., 2001, “Price Dispersion in the Small and in the Large”, *American Economic Review*, **91 (3)**, 454-474

**Baye**, **M**. & **Morgan**, **J**., 2001, “Information Gatekeepers and Competitiveness of Homogeneous Product Markets”, *American Economic Review*, **91 (3)**, 454-474

**Benabou, R**., 1993, “Search, Market Equilibrium, Bilateral Heterogeneity and Repeat Purchases”, *Journal of Economic Theory*, **60**, 140-63

**Bouckaert**, **J**., 1999, “Monopolistic Competition with a Mail Order Business”, *Economics Letters*, **66**, 303-10

**Braverman**, **A**., 1980, “Consumer Search and Alternative Market Equilibria”, *Review of Economic Studies*, **47**, 487-502

**Brown**, **J**. & **Goolsbee**, 2000, “Does the Internet Make Markets More Competitive? Evidence from the Life Insurance Industry”, *University of Chicago*

**Brynjolfsson, E.** & **Smith, M.,** (2000a), “Frictionless Commerce? A Comparison of Internet and Conventional Retailers”, *Management Science*, **46(4)**, 563-585

**Brynjolfsson, E.** & **Smith, M.,** (2000b), “The Great Equalizer? Consumer Choice Behaviour and Internet Shopbots”, *H. John Heinz III School of Public Policy and Management*

**Burdett**, **K**. & **Judd**, **K**., 1983, "Equilibrium Price Dispersion”, *Econometrica*, **51**, 955-69

**Caillaud**, **B**. & **Jullien**, **B**, 2000, “Competing Cybermediaries”, *IDEI*

**Carlton, D.** & **Chevalier, J.**, 2001, “Free Riding and Sales Strategies for the Internet”, *NBER Working Paper*, W8067

**Clay, K., Krishnan, R., Wolff, E.** & **Fernandes, D.**, (1999), “Retail Strategies on the Web: Price and Non-price Competition in the Online Book Industry”, *Heinz School of Public Policy and Management, Carnegie Mellon University*

**Clay, K., Krishnan, R.** & **Wolff, E.**, (2001), “Prices and Price Dispersion on the Web: Evidence from the Online Book Industry”, *NBER Working Paper*, W8271

**Clemons**, **E**., **Hann**, **I**. & **Hitt**, **L**., 1999, “The Nature of Competition in Electronic Markets: An Empirical Investigation of Online Travel Agent Offerings”, *The Wharton School*

**Davis**, **D**. & **Holt**, **C**., 1996, "Consumer Search Costs and Market Performance", *Economic Inquiry*, **34**, 133-151

**Diamond, P.,** 1971, "A Model of Price Adjustment", *Journal of Economic Theory*, **3**, 156-168

**Ellison**, **G**. & **Ellison**, **S**., 2001, “Search, Obfuscation, and Price Elasticities on the Internet”; M.I.T.

**Friberg**, **R**., **Ganslandt**, **M**. & **Sandstrom**, **M**., 2000, “E-Commerce and Prices: Theory and Evidence”, *Stockholm School of Economics, EFI*

**Gulati, R.**, & **Garino, J.**, 2000, “Get the Right Mix of Bricks and Clicks”, *Harvard Business Review*, May-June

**Iyer**, **G**. & **Pazgal**, **A**., 2000, “Internet Shopping Agents: Virtual Co-Location and Competition”,

**Kephart**, **J**. & **Greenwald**, **A**., 1999, “Shopbot Economics”, *IBM Institute for Advanced Commerce*

**Kotler**, **P.**, 1994, *Marketing Management*, 8th ed., Prentice Hall

**Lal**, **R**. & **Sarvary**, **M**., 1998 "When and How is the Internet Likely to Decrease Competition?", *Harvard Business School Management Science*

**Lee, M.**, (2000), "A Comparative Analysis of Pharmaceutical Pricing", *University of Illinois*

**Legros**, **P**. & **Stahl**, **K**., , "Global vs. Local Competition: The Case of E-Commerce", *ECARES*

**MacMinn, R.**, 1980, "Search and Market Equilibrium", *Journal of Political Economy*, **88**, 308-327

**Mazón**, **C**. & **Pereira**, **P**., 2001a, "Cost Reduction and the Adoption of E-Commerce", *U.C.M.*

**Mazón**, **C**. & **Pereira**, **P**., 2001b, "Some Welfare of the Adoption of E-Commerce", *U.C.M.*

**Michael**, **S**., 1994, "Competition in Organizational Form: Mail Order versus Retail Stores, 1910-1940", *Journal of Economic Behavior and Organization*, **23**, 269-286.

**Morton**, **F**., **Zettelmeyer**, **F**., & **Risso**, **J**., 2000, "Internet Car Retailing", *Haas Business School*

**Pan, X., Ratchford, B.** & **Shankar, V.**, 2001, "Whay Aren't the Prices of the Same Item the Same at Me.com and You.com?: Drivers of Price Dispersion Among E-Tailers", *Robert H. Smith School of Business, University of Maryland*

**Peterson**, **R**., **Balasubramanian**, **S**., & **Bronnenberg**, **B**., 1997, "Exploring the Implications of the Internet for Consumer Marketing", *Journal of the Academy of Marketing Science*, **25**, 329-346

**Reinganum**, **J**., 1979, "A Simple Model of Equilibrium Price Dispersion", *Journal of Political Economy*, **87**, 851-858

**Rob**, **R**., 1985, "Equilibrium Price Distributions", *Review of Economic Studies*, **52**, 487-504

**Rosenthal**, **R**., 1980, "A Model in Which an Increase in the Number of Sellers Leads to a Higher Price", *Econometrica*, **48**, 1575-79

**Salop**, **S**. & **Stiglitz**, **J**., 1976, "Bargains and Rip-offs: A Model of Monopolistically Competitive Price Dispersion", *Review of Economic Studies*, **44**, 493-510

**Sinha**, **I**., 2000, "Cost Transparency: The Net's Real Threat to Prices and Brands", *Harvard Business Review*, March-April

**Smith, M.**, 2001, "The Law of One Price? Price Dispersion and Parallel Pricing in Internet Markets", *H. John Heinz III School of Public Policy and Management*

**Stahl, D.**, 1989, "Oligopolistic Pricing with Sequential Consumer Search", *American Economic Review*, **79**, 700-12

**Tang, F., Lu, D.** & **Ho, H.**, (2000), "Paradox of Online Trading: Evidence and Interpretation", *Nanayang Business School*

**Varian**, **H.,** 1980, "A Model of Sales", *American Economic Review*, **70**, 651-59

**Wilde**, **L**. & **Schwartz**, **A**., 1979, "Equilibrium Comparison Shopping", *Review of Economic Studies*, **46**, 543-53

**Zettelmeyer**, **F**., 2000, "Expanding to the Internet: Pricing and Communications Strategies When Firms Compete on Multiple Channels", *Journal of Marketing Research (Forthcoming)*