Price Dynamics and Shake-Outs in Electronic Markets

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Abstract: This paper presents a model that explains the recent evolution of e-commerce, where over time, prices can increase if no exit occurs, or decrease, if exit occurs. In the model there is uncertainty about the firms’ costs, because the technology is new, and consumers face a switching cost, because it is easier to observe the current price of a previous supplier, than the price of other firms.

Key Words: E-Commerce, Industry Evolution, Search, Switching Costs, Learning

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1 Introduction

This paper presents a model that fits well with the recent evolution of electronic commerce.

The development of the Internet allowed the creation of a new retailing technology: e-commerce. Initially, the creation of new markets suggested a big growth potential. Between January 1998 and July 2000, venture capital invested $65 billion in Internet companies (Fortune, October 30, 2000). In spite of all this investment euphoria, firms generated very small revenues. One reason was that firms deliberately charged very low prices, justifying their behavior by saying that they were investing in Consumer Acquisition, which suggests the existence of switching costs. After the fall of the NASDAQ in April 2000, capital markets closed for most Net companies, which then faced one of three options: survive on their own revenues, often minimal, sell out, or go bankrupt. In either case, a wave of consolidation started, and it is expected that of the large number of entrants, few will survive. Note that in new industries, a building up in the number of firms followed by a shakeout is a well-documented phenomenon (Klepper & Simons (1999,1997))\textsuperscript{2}.

To explain this process, I’m going to develop a model, which is a special case of Pereira (2001), and is related to Reinganum (1979) and Fishman & Rob (1995), where there are 2 distinct phases. First, a phase where there is a build up in the number of firms and intense price competition, and second, a phase where there is a shakeout. The driving forces of this process are: Cost Uncertainty, and Switching costs\textsuperscript{3}. Regarding cost uncertainty, e-commerce allows costs savings, compared to physical shop retailing. But since the technology is new, achieving these cost reductions is uncertain, and firms only learn over time, by producing, if they succeeded. I also assume, that a firm that initially has low costs, is more likely to have low costs latter, than a firm that initially has high costs. Regarding switching costs, e-commerce reduces search and switching costs, compared with physical shop retailing, but it does not eliminate them. Browsing Web sites is not costless, and it is easier to learn the current price of a previous supplier, than the price of another firm. Internet shoppers can be e-mailed price updates by their current vendor, while they have to search to learn the price of a new firm. Opening an account with a Web merchant, also creates a switching cost. Amazon tried to patent the “one click shopping”. Thus, since there are switching costs that lock-in

consumers, Internet firms are prepared to initially charge low prices to build a customer base for the future, where they hope to have low costs. If, however, firms fail to reduce costs, they exit the industry.

Since search is costly, consumers accept prices above the minimum charged in the market. This gives firms market power\(^4\). Switching costs lock-in consumers to their period 1 suppliers. With the prospect of buying twice from the same firm, since period 1’s production costs are correlated with period 2’s costs, in period 1 consumers conduct a more thorough search than they would for a single purchase, i.e., in period 1 they hold a lower reservation price than in the period 2.

Since low cost firms charge the lowest price, they are not constrained by consumer search, and charge their monopoly price. High cost firms may also benefit from the market power generated by costly search. If the reservation price is higher than marginal cost, they charge the reservation price. If the reservation price is lower than marginal cost, in period 2 they exit the industry; but in period 1, due to the lock-in effect, they remain active to secure a larger consumer share in period 2.

Over time, prices increase if no exit occurs, and decrease if exit occurs.

Clay, Krishnan & Wolff (2000) found that after falling between the spring and fall of 1999, online book prices were flat or rising for several months. This trend picked up in 2000, when Amazon.com raised prices by 10\%–20\%, bringing them to level with offline prices (D. Kirkpatrick, The New York Times, Oct. 9, 2000). In my model prices necessarily decrees if exit occurs, because there are only two production cost types.

These results contrast with the switching costs literature (see Klemperer (1992) for a survey), where typically emerges a pattern of price cuts followed by price hikes.

In section 2 I present the model, in section 3 I characterize its equilibria, in section 4 I conduct its analysis, and in section 5 I discuss some generalizations. Proofs are in the Appendix.

### 2 The Model

In this section I present the model.

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3 *Switching cost* is a one-time product specific cost, a consumer must bare in order to consume a product, e.g., learning to use a word processor, or finding a new store (for more examples see Beggs & Klemperer (1992) and the references therein).

4 The ability to raise price above marginal cost.
(a) The Setting

Consider a market of a perishable homogeneous good that opens 2 periods. Subscript $t$ refers to time.

Each of the game’s 2 periods is composed of 2 stages. In each period, in stage 1 firms choose prices, and in stage 2 consumers search for prices. Then agents receive their period payoffs.

(b) Consumers

There is a unit measure continuum of risk neutral identical consumers. A consumer who buys at price $p$ demands $D(p)$, where $D(.)$ is a twice differentiable, bounded function, with a bounded inverse, and decreasing in $p$. The surplus of a consumer who pays $p$ is $S(p) := \int_p^\infty D(t) dt$.

Consumers do not know the prices charged by individual firms. However, they hold common beliefs about the price distribution. Cumulative distribution function, $F_t(.)$, gives the consumers' beliefs about the (unconditional) period $t$ price distribution; the lowest and highest prices on its support are $p_t$ and $\tilde{p}_t$; $H(\cdot | q)$ gives the consumers’ beliefs about the price that a firm that charged $q$ in period 1, charges in period 2.

To observe a price a consumer must pay a constant amount, the search cost: $\sigma \in (0, +\infty)$. Within each period search is sequential, instantaneous, a consumer may observe any number of prices, and may at any time accept any offer received to date. In each search session a consumer picks randomly which firm to sample, from the set of firms whose current price he does not know. In period 2, a consumer learns for free (only) the current price of his period 1 supplier. This creates a Switching Cost, equal to the expected search expenditure.

A consumer’s information set just after his $k$-th search (or return) step, consists of all previously observed prices. A consumer’s strategy for stage 2 of period $t$ is a stopping rule, $s_t$, that says if search should stop or continue, for every search cost, and sequence of observations. A consumer’s payoff is the sum of expected period surpluses, net of the search expenditure.

(c) Firms

There is a unit measure continuum of risk neutral firms$^5$.

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$^5$ I could include a stage 0 where firms decide if they enter the market, for which they would have to pay a set-up cost, and normalize the measure of firms that enter to 1.
Marginal costs are constant, and can be low, \( c_l \), or high, \( c_h \), where \( 0 \leq c_l < c_h < +\infty \). In period 1 a firm has marginal cost \( c_l \) with probability \( \mu \in (0, 1) \). In period 2, a firm that had cost \( c_l \) in period 1 has cost \( c_i \) with probability \( v_{il} \), \( s = l, h \). A period 1 low cost firm is more likely to have a low cost in period 2, than a period 1 high cost firm, \( v_{hl} < v_{ll} \), i.e., costs are positively correlated across periods. The probability of a firm having a low cost in period 2 is \( m := \mu v_{ll} + (1 - \mu)v_{hl} \). The cost distribution is the same in both periods, i.e., \( \mu = m \). In each period, each firm observes only its cost level, before choosing prices. I assume that the realized value of a random variable equals its expectation.

The period \( t \) price and per consumer profit of a cost \( c_i \) firm are \( p_{ti} \) and \( \pi(p_{ti}, c_i) := (p_{ti} - c_i)D(p_{ti}) \). Let \( \hat{p}_i := \text{argmax}_p \pi(p; c_i) \). I assume that \( \pi(\cdot) \) is strictly quasi-concave in \( p \), and that high cost firms lose money if they charge \( \hat{p}_i \), i.e., \( \hat{p}_i < c_h \). See footnote 10 for additional comments. The period \( t \) expected consumer share and expected profit of a cost \( c_i \) firm are \( \Phi_i(p_{ti}) \) and \( \Pi_i(p_{ti}, c_i) := \pi(p_{ti}; c_i)\Phi_i(p_{ti}) \). The sum of the expected period profits of a period 1 cost \( c_i \) firm is \( V^i := \Pi_i(p_{ti}; c_i) + [v_{ih}\Pi_2(p_{2h}; c_i) + v_{il}\Pi_2(p_{2l}; c_h)] \).

In either period, the maximum price consumers are willing to pay is lower than \( \hat{p}_h \). If a firm charges a price higher than the maximum consumers are willing to pay, the firm is \text{Inactive}; otherwise it is \text{Active}. When indifferent between being active and inactive, a firm chooses the latter, and that consumers know if a firm is inactive without searching. The measure of period \( t \) active firms is \( n_t \).

A firm’s period \( t \) information set consists of its previous prices, costs, and consumer share realizations. A firm’s stage 1 \text{strategy} for period \( t \) is a rule that for every possible history, say which price a firm should charge. A firm's \text{payoff} is the sum of the expected period profit.

**(d) Equilibrium**

An \textit{equilibrium} is: a stopping rule for each period, consumer beliefs, and a pricing rule for each period and cost type, \( \{\hat{p}_{ti}^*, F_{ti}^*, H^*, p_{ti}^*\}_{t=1,2; i=l,h} \), such that\(^6\):

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\(^6\) Equilibrium requires also restrictions of the consumers’ beliefs about the price distribution. See Pereira (2001).
(E1) Given $\{F^*_t, H^*_t\}$ consumers choose $s^*_t$ to maximize the net sum of the expected surpluses;

(E2) Given $s^*_t$ and $c_t$, firms choose $p^*_t$ to solve the problem: $\max_{(p_1, p_2)} V'$;

(E3) Beliefs $\{F^*_t, H^*_t\}$ agree with the price distributions induced by $p^*_t$, $\mu$ and $\nu_s$.

3 Characterization of Equilibrium

In this section I construct the equilibrium by working backwards. The consumers’ equilibrium search behavior consists of holding reservation prices. Low cost firms are always active and charge their monopoly price. High cost firms, in either period, are sometimes active others inactive; when active, high cost firms charge the minimum of the period reservation price and their monopoly price.

3.1 Second Period

3.1.1 Second Stage: The Search Game

In this sub-section I characterize period 2’s search equilibrium.

In period 2, if consumers search, their optimal strategy consists of holding a reservation price, $p_2$, that equates the expected marginal benefit to the search cost$^7$,$^8$:

$$\int_{\rho_2}^{p_2} [S(p) - S(\rho_2)] dF_2(p) = \sigma$$

As it will become clear in Sub-Section 3.1.2, on the equilibrium path, consumers that patronized in period 1 a firm that has a low cost in period 2, do not search. Inspection of (1) and implicit differentiation lead to the next result stated without proof.

Lemma 1: (i) For all $\sigma > 0$, $p_2 < \rho_2$; (ii) $p_2$ is increasing in $\sigma$, and in first order stochastic dominance shifts in the price distribution$^9$.

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7 See Reinganum (1979) or Benabou (1993). Given (A.2) consumers optimize with respect to beliefs, which given (A.3) do not depend on observed prices. Thus, the consumers’ search problem can be solved through dynamic programming.

8 The usual assumption to ensure that search occurs, is that consumers get the first price quote for free. An alternative is for the search cost to be “small enough”.

9 Distribution $F(.)$ dominates in the first-order stochastic sense distribution $F'(.)$, if $F(.) \leq F'$, for all $p$.  

From Lemma 1: (i) costly search gives firms market power, since it leads consumers to accept prices above the minimum charged in the market. Also, \( n_2 > 0 \).

### 3.1.2 First Stage: The Pricing Game

In this sub-section I characterize period 2’s equilibrium prices.

The measure of consumers searching in period 2, i.e., consumers that in period 1 patronized a firm inactive in period 2, is \( \Delta C \). If a firm charges a price higher than \( \rho_2 \) it makes no sales; if it charges a price no higher than \( \rho_2 \) it keeps its period 1 consumers \( \varphi_i \), and gets an expected consumer share of \( \Delta C/n_2 \). Thus:

\[
\varphi_2(p) = \begin{cases} 0 & \iff \rho_2 < p \\ \varphi_1 + \Delta C/n_2 & \iff p \leq \rho_2 \end{cases}
\]

**Lemma 2:**

(i) \( p_2^* = \hat{p}_l \); (ii)

\[
p_2^* = \begin{cases} \rho_2 & \iff c_h \leq \rho_2 \\ \rho_l \in (\rho_2, +\infty) & \iff \rho_2 < c_h \end{cases}
\]

§

Since low cost firms charge the lowest price, and given Lemma 1: (i), they are never constrained by consumer search and always charge their monopoly price. High cost firms also benefit from the market power generated by costly search, by charging a higher price than low cost firms. They are, nevertheless, disciplined by consumer search. If the reservation price is high, i.e., \( c_h \leq \rho_2 \), high cost firms charge the reservation price. If the reservation price is low, i.e., \( \rho_2 < c_h \), high cost firms are inactive\(^{10}\). From Lemma 2:

\[
n_2 = \begin{cases} 1 & \iff c_h \leq \rho_2 \\ m & \iff \rho_2 < c_h \end{cases}
\]

### 3.2 First Period

#### 3.2.1 Second Stage: The Search Game

In this sub-section I characterize the period 1 equilibrium search.

Period 2’s net maximum expected surplus of a consumer who’s best available offer in period 1 is \( p \) and behaves optimally is \( G(p) \). In Pereira (2001), I show that in period 1, if consumers search, their optimal period 1 strategy consists

\(^{10}\) If \( c_h \leq \tilde{p}_l \), high cost firms are always active in period 2, whereas if \( \tilde{p}_l < c_h \), they may or may not, depending on \( \tilde{p}_l \), i.e., case \( \tilde{p}_l < c_h \) encompasses case \( c_h \leq \tilde{p}_l \).
of holding a reservation price, $\rho$, that equates the sum of the expected marginal benefit of search for periods 1 and 2, to the search cost\(^{11}\):

$$\int_{\rho_1}^{\rho} \left[ S(p) - S(\rho_1) \right] dF_1(p) + \int_{\rho_1}^{\rho} \left[ G(p) - G(\rho_1) \right] dF_1(p) = \sigma$$

(2)

Consumers learn for free the period 2 price of their period 1 supplier. Thus, they tend to buy at the same firm in both periods. With the prospect of buying twice from the same firm, the consumers’ period 1 incentives to search depend on current savings, $\left[ S(p) - S(\rho_1) \right]$ and also on future savings, $\left[ G(p) - G(\rho_1) \right]$. As before, $n > 0$.

### 3.2.2 First Stage: The Pricing Game

In this sub-section I characterize period 1’s equilibrium prices.

The period 1 expected consumer share of a firm that charges $p$ is:

$$\phi_1(p) = \begin{cases} 0 & \rho_1 < p \\ 1/n_1 & p \leq \rho_1 \end{cases}$$

To ensure that high cost firms are active in period 1, let: $0 \leq \pi(\tilde{p}_1, c_h) + \left[ \nu_h \pi(\tilde{p}_1, c_s) + (1 - \nu_h) \pi(\tilde{p}_h, c_s) \right]^{12}$

**Lemma 3:** (i) $p_{1l}^* = \tilde{p}_1$; (ii) $p_{1h}^* = \rho_1$

Due to the lock-in effect, even if a firm charges a price acceptable to consumers in period 2, it will only sell either to its period 1 customers, or to consumers that are searching. Thus, when the reservation price falls below the high cost level, $\rho_1 < c_h$, a high cost firm sells below marginal cost in period 1, but secures a larger consumer share for period 2. From **Lemma 3**: $n_l = 1$ and

$$\Delta C = \begin{cases} 0 & c_h \leq \rho_2 \\ (1 - m) & \rho_2 < c_h \end{cases}$$

### 4 Price Dynamics and Shakeout

\(^{11}\) If $S(.) + G(.)$ is monotonic the optimal acceptance set is connected, and the optimal strategy has the reservation price property. To determine if $G(.)$ is monotonic one ought to know $H(.)$. However, I show in Pereira (2001) that $G(.)$ is non-increasing for $\tilde{p}_1 \leq p$.

\(^{12}\) Under the alternative assumption, a high cost firm becomes inactive in period 1 if $\tilde{p}_1$ is low enough, and there is a level of $\tilde{p}_1$ for which a high cost firm is indifferent between being active and inactive in period 1. $p^\rho$. My analysis corresponds to case $p^\rho \leq \rho_1$. 

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In this section I discuss price dynamics.

I start by establishing some useful expressions and results about the reservation prices.

Using Lemma 2, (1) can be written as:

\[
\begin{align*}
\mu \left[ S(p_1) - S(p_2) \right] - \sigma &= 0 \quad \iff \quad c_h \leq \rho_2 \\
\left[ S(p_1) - S(p_2) \right] - \sigma &= 0 \quad \iff \quad \rho_2 < c_h
\end{align*}
\] (4)

From Lemmas 2 and 3, and the definition of \( v_{il} \), \( G(p_{il}) = v_{il} S(p_1) + (1 - v_{il}) S(p_2) \), \( G(p \neq p_{il}) = v_{hl} S(p_1) + (1 - v_{hl}) S(p_2) \), and thus:

\[
G(p_{il}) - G(p) = (v_{il} - v_{hl}) \left[ S(p_1) - S(p_2) \right]
\] (5)

Let \( \mathcal{M}(\sigma, \mu, v_{il}, v_{hl}) := \left[ 1 - (v_{il} - v_{hl}) \right] \mathcal{M} \) where

\[
\mathcal{M} = \begin{cases} 
1 & \iff c_h \leq \rho_2 \\
\mu & \iff \rho_2 < c_h
\end{cases}
\]

Assume that \( (v_{il} - v_{hl}) < \mu < (v_{il} + v_{hl}) \). The first inequality ensures that \( 0 < \mathcal{M}(\sigma, \mu, v_{il}, v_{hl}) \), and the second simplifies exposition. Using Lemma 3 and (5), (2) can be written as:

\[
\mu \left[ S(p_1) - S(p_2) \right] + (v_{il} - v_{hl}) \left[ S(p_1) - S(p_2) \right] - \sigma = 0
\]

or using (4) and \( \mathcal{M}(\sigma, \mu, v_{il}, v_{hl}) \), as:

\[
\mu \left[ S(p_1) - S(p_2) \right] - \mathcal{M}(\sigma, v_{il}, v_{hl}) = 0
\] (6)

**Proposition 1:** (i) \( c_h \leq \rho_2 \implies \rho_2 < \rho_c \); (ii) \( \rho_2 < c_h \implies \rho_2 < \rho_c \); (iii) \( \partial \rho_c / \partial \mu < 0 < \partial \rho_c / \partial \sigma \). §

Since period 1’s costs are positively correlated with period 2’s costs, period 1’s costs are informative of period 2’s costs. And, since high cost firms charge higher prices than low cost firms, period 1’s prices are also informative of period 2’s prices.

Consumers tend to buy at the same firm in both periods, and period 1’s prices are informative of period 2’s prices. If in period 2 high cost firms are active, in period 1 consumers conduct a more thorough search than they
would for a single purchase. That is, in period 1 consumers hold a lower reservation price than in period 2, \( r_1 < r_2 \). If, however, in period 2 high cost firms are inactive, consumers face lower prices in period 2 than in period 1, and therefore, hold a lower reservation price in period 2 than in period 1, \( r_2 < r_1 \).

If the search cost rises, the expected marginal benefit of search in both periods must increase for consumers to remain in equilibrium, which requires both reservation prices to rise. A fall in the probability of a firm having a low cost in period 1, reduces the marginal benefit of search, leading to higher reservation prices.

Next I establish the results about price dynamics.

**Proposition 2:** (i) \( c_h \leq r_2 \Rightarrow F_2^* \) first order stochastically dominates \( F_1^* \); (ii) \( r_2 < c_h \Rightarrow F_1^* \) first order stochastically dominates \( F_2^* \).

If high cost firms are active in period 2, since in period 1 the reservation price is lower than in period 2, \( r_1 < r_2 \), prices increase from period 1 to period 2. If high cost firms are inactive in period 2, prices decrease from period 1 to period 2. The number of inactive firms in period 2 is non-decreasing in the search cost and decreasing in the probability of a firm having a low cost in period 1.

In short, since there are switching costs that lock-in consumers, firms are prepared to initially charge very low prices to build a customer base for the future, where they hope to have low costs. If however firms fail to reduce costs, and reservations prices are low, firms exit the industry. Over time, prices increase, if no exit occurs, and decrease, if exit occurs.

In this model, high cost firms can charge prices below marginal cost in period 1, and by doing so, earn higher profits in period 2. But the period 1 high cost firms’ purpose is not to expel rivals, but rather to build a customer base for period 2, which is necessary, since due to the lock-in consumers do not move freely between firms. Thus, below marginal cost pricing need not a sign predatory behavior (Bagwell, Ramey & Spulber (1997))

### 5 Generalizations

In Pereira (2001), I extend the model to the cases of: infinite horizon, continuum of cost types, endogenous cost distribution, and where it is costly to observe the current price of a previous supplier. I allow also costs to be uncorrelated across period, and high cost firms to be inactive in period 1.
Appendix

In the appendix I prove the text’s Lemmas and Propositions.

Lemma 2: (i) I proceed in 3 steps. In step 1 I show that $p_2 = \tilde{p}_2 < p_{2h} = \tilde{p}_2$. Suppose that $p_{2h} < \tilde{p}_2$. By definition: $\Pi(p_{2h}; \tilde{p}_2, c_i) \leq \Pi(p_{2h}; \tilde{p}_2, c_i)$ and $\Pi(p_{2h}; \tilde{p}_2, c_i) \leq \Pi(p_{2h}; \tilde{p}_2, c_i)$. Adding the inequalities one gets $0 \leq (c_h - c) \left[ D(\tilde{p}_2) \varphi_2(p_{2h}) - D(\tilde{p}_2) \varphi_2(p_{2h}) \right]$, which is false if $p_{2h} < \tilde{p}_2$, since $\varphi_2(.)$ is non-increasing and $D(.)$ is strictly decreasing. Thus $\tilde{p}_2 \leq p_{2h}$. In step 2 I show that $p_{2i} < \tilde{p}_2$. Follows from step 1 and Lemma 1: (i). In step 3 I show that $p_{2i} = \tilde{p}_i$. Follows from Lemma 2 and the definition of $\varphi_2(.)$, from the $c_i$ firms’ perspective, $\varphi_2(p_{2i})$ is given. Thus, only $\pi(.)$ matters to determine $p_{2i}$. Suppose $p_{2i} \neq \tilde{p}_i$. Consider first $p_{2i} < \tilde{p}_i$. There is a $\varepsilon > 0$ sufficiently small such that $p_{2i} + \varepsilon < p_{2i}$. Thus, if a $c_i$ firm deviates and charges $p_{2i} + \varepsilon$, it loses no customers, and by strict quasi-concavity of $\pi(.)$ rises. Thus, $\tilde{p}_i \leq p_{2i}$. Now suppose, $\tilde{p}_i < p_{2i}$. If a $c_i$ firm deviates and charges $p_{2i} = \tilde{p}_i$, given (A.3), and by definition $\tilde{p}_i$ profit rises. Thus, $p_{2i} \leq \tilde{p}_i$, and therefore, $p_{2i} = \tilde{p}_i$. (ii) Consider first $c_h < p_{2h}$. Suppose $p_{2h} < p_{2h}$. If a $c_h$ firm charges $p_{2h} = \tilde{p}_h$, it loses no customers, and $\pi(.)$ rises, as in step 3 of (i). Suppose $p_{2h} < p_{2h}$. A $c_h$ firm charges makes no sales, whereas if $p_{2h} = \tilde{p}_h$, it has a strictly positive profit. It follows that $p_{2h} = \tilde{p}_h$ for $c_h < p_{2h}$. If $p_{2h} < c_h$, $c_h$ firms make zero profits for any $p' \in (p_{2i}, +\infty)$; otherwise they make a negative profit. 

Lemma 3: (i)-(ii) As in Lemma 1.

Proposition 1: (i)-(ii) Follow from (4) and (6). (iii) By the implicit differentiation of (4) and (6).

Proposition 2: (i)-(ii) Follow from $\mu = m$, Lemmas 2 and 3, and Proposition 1.

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