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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.

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JEL Classification: *D43, D83, L11, L13, L41, L81, O31, O33*

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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 where investing in ***Consumer Acquisition***, which suggests the existence of switching costs[1]. 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.

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***[2]. 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 and 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.

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1 See Hoffman & Novak (2000).

2 ***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).

Since search is costly, consumers accept prices above the minimum charged in the market. This gives firms market power[3]. 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.

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 my model, although consumers have a switching cost, prices need not increase over time. And when they do, it is not because the consumers' reservation prices increase over time, not because firms exploit their locked-in consumers in period 2.

In new industries, a building up in the number of firms followed by a shakeout is a well-documented phenomenon (Klepper & Simons (1999,1997))[4].In the case of Internet technologies, parallel to the cycle of entry and shakeout, there was also a cycle of boom and burst in the stock market. That was also the case of railroads in the late 19th, century and the case of electricity in the early 20th century. Are these 2 cycles related? In case of Internet technologies, once the stock market boom started, the initial public offerings gave firms access to virtually free capital, which fuelled the entry cycle. However, why does the emergence of a new technology generate a stock market boom?

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.

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3 The ability to raise price above marginal cost.

4 See Ericsson & Pakes (1995), Hopenhayn (1992), Jovanovic (1982) and Lippman & Rumelt (1982), for models of industry evolution.

2 The Model

In this section I present the model, which is very simple to convey the paper's main ideas as clearly as possible. In **Section 5** I point out several generalizations analyzed in Pereira (2001).

(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 $\underline{p}_t$ and $\bar{p}_t$; $H(.|q)$ 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***: $s \in (0,+\infty)$. 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].

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 $m\ Î\ (0, 1)$. In period 2, a firm that had cost c_i in period 1 has cost c_s with probability v_{is} $(i, s = l, h)$. 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 $m := m v_{ll} + (1 - m) v_{hl}$. The cost distribution is the same in both periods, i.e., $m = m$. In each period, each firm observes only its cost level, before choosing choose 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 $p(p_{ti}; c_i) := (p_{ti} - c_i) D(p_{ti})$. Let $\widehat{p}_i := argmax_p\ p(p; c_i)$. I assume that $p(.)$ is strictly quasi-concave in p, and that high cost firms lose money if they charge $\widehat{p}_l$, i.e., $\widehat{p}_l < c_h$. See footnote 10 for additional comments. The period t expected consumer share and expected profit of a cost c_i firm are $j_t(p_{ti})$ and $P_t(p_{ti}; c_i) := p(p_{ti}; c_i) j_t(p_{ti})$. The sum of the expected period profits of a period 1 cost c_i firm is $V^i := P_1(p_{1i}; c_i) + [v_{il} P_2(p_{2l}; c_l) + v_{is} P_2(p_{2h}; c_h)]$.

In either period, the maximum price consumers are willing to pay is lower than $\widehat{p}_h$. If a firm charges a price higher than the maximum consumers are willing to pay, the firm is ***Inactive***; otherwise it is ***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 ***strategy*** for period t is a rule that for every possible history, say which price a firm should charge. A firm's ***payoff*** is the sum of the expected period profit.

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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.

(d) Equilibrium

An ***equilibrium*** is: a stopping rule for each period, consumer beliefs, and a pricing rule for each period and cost type, $\left\{s_t^*, F_t^*, H^*, p_{ti}^* \middle| t = 1, 2;\ i = l, h\right\}$, such that[6]:

(E1) Given $\left\{F_t^*, H^*\right\}$ consumers choose s_t^* to maximize the net sum of the expected surpluses;

(E2) Given s_t^* and c_i, firms choose p_{ti}^* to solve the problem: $max_{\{p_{1i}, p_{2i}\}} V^i$;

(E3) Beliefs $\left\{F_t^*, H^*\right\}$ agree with the price distributions induced by p_{ti}^*, m and v_{is}.

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, r_2, that equates the expected marginal benefit to the search cost[7],[8],[9]:

$$\int_{\underline{p}_2}^{\rho_2} \left[S(p) - S(\rho_2)\right] dF_2(p) = \sigma \qquad (1)$$

Inspection of (1) and implicit differentiation lead to the next result stated without proof.

Lemma 1: (i) For all $s > 0$, $\underline{p}_2 < r_2$; **(ii)** r_2 is increasing in s, and in first order stochastic dominance shifts in the price distribution[10]. **§**

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[6] Equilibrium requires also restrictions on the consumers' beliefs about the price distribution. See Pereira (2001).

[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".

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 DC. If a firm charges a price higher than r_2 it makes no sales; if it charges a price no higher than r_2 it keeps its period 1 consumers j_1, and gets an expected consumer share of DC/n_2. Thus:

$$\varphi_2(p) = \begin{cases} 0 & \Leftarrow \quad \rho_2 < p \\ \varphi_1 + \Delta C / n_2 & \Leftarrow \quad p \leq \rho_2 \end{cases}$$

Lemma 2: (i) $p^*_{2l} = \hat{p}_l$; **(ii)**

$$p^*_{2h} = \begin{cases} \rho_2 & \Leftarrow \quad c_h \leq \rho_2 \\ p'_2 \in (\rho_2, +\infty) & \Leftarrow \quad \rho_2 < c_h \end{cases}$$

§

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., $c_h \leq r_2$, high cost firms charge the reservation price. If the reservation price is low, i.e., $r_2 < c_h$, high cost firms are inactive[11]. From **Lemma 2**:

$$n_2 = \begin{cases} 1 & \Leftarrow \quad c_h \leq \rho_2 \\ m & \Leftarrow \quad \rho_2 < c_h \end{cases}$$

3.2 First Period

3.2.1 Second Stage: The Search Game

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

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[9] 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. However, if they did, would they hold the same reservation price as consumers that patronized in period 1 a firm that has a high cost in period 2? In other words, is the optimal strategy for sequential search with recall stationary? The answer is yes (DeGroot (1970), Kohn & Shavell (1974), or Yahav (1966)).

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

[11] If $c_h \leq \hat{p}_l$, high cost firms are always active in period 2, whereas if $\hat{p}_l < c_h$, they may or may not, depending on r_2, i.e., case $\hat{p}_l < c_h$ encompasses case $c_h \leq \hat{p}_l$.

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 of holding a reservation price, r_1, that equates the sum of the expected marginal benefit of search for periods 1 and 2, to the search cost[12]:

$$\int_{\underline{p}_1}^{\rho_1} \left[S(p) - S(\rho_1)\right] dF_1(p) + \int_{\underline{p}_1}^{\rho_1} \left[G(p) - G(\rho_1)\right] dF_1(p) = \sigma \qquad (2)$$

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, $\left[S(p) - S(r_1)\right]$, and also on future savings, $\left[G(p) - G(r_1)\right]$. As before, $n_1 > 0$.

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:

$$\varphi_1(p) = \begin{cases} 0 & \Leftarrow \quad \rho_1 < p \\ 1/n_1 & \Leftarrow \quad p \le \rho_1 \end{cases}$$

To ensure that high cost firms are active in period 1, let: $0 \le p(\hat{p}_l, c_h) + \left[n_{hl} p(\hat{p}_l, c_l) + (1 - n_{hl}) p(\hat{p}_h, c_h)\right]$.[13]

Lemma 3: **(i)** $p_{1l}^* = \hat{p}_l$; **(ii)** $p_{1h}^* = r_l$ §

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, $r_1 < c_h$, a high cost firm sells below marginal cost in period 1, but secures a larger consumer share for period 2. From **Lemma 3**: $n_1 = 1$ and

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

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[12] 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 $\hat{p}_l \le p$.

4 Price Dynamics and Shakeout

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:

$$\begin{cases} \mu\left[S(\hat{p}_1)-S(\rho_2)\right]-\sigma=0 & \Leftarrow\ c_h \le \rho_2 \\ \left[S(\hat{p}_1)-S(\rho_2)\right]-\sigma=0 & \Leftarrow\ \rho_2 < c_h \end{cases} \tag{4}$$

From **Lemmas 2** and **3**, and the definition of v_{il}, $G(p_{1l}) = v_{ll}S(\hat{p}_l) + (1-v_{ll})S(\bar{p}_2)$, $G(p \neq p_{1l}) = v_{hl}S(\hat{p}_l) + (1-v_{hl})S(\bar{p}_2)$, and thus:

$$G(p_{1l}) - G(p) = (v_{1l} - v_{hl})\left[S(\hat{p}_1) - S(\bar{p}_2)\right] \tag{5}$$

Let $v(s,m,v_{ll},v_{hl}) := \left[1-(v_{ll}-v_{hl})M\right]s$ where

$$M = \begin{cases} 1 & \Leftarrow\ c_h \le \rho_2 \\ \mu & \Leftarrow\ \rho_2 < c_h \end{cases}$$

Assume that $(v_{ll}-v_{hl}) < m < 1/(v_{ll}+v_{hh})$. The first inequality ensures that $0 < v(s,m,v_{ll},v_{hl})$, and the second simplifies exposition[14]. Using **Lemma 3** and (5), (2) can be written as:

$$\mu\left\{\left[S(\hat{p}_1) - S(\rho_1)\right] + (v_{1l}-v_{hl})\left[S(\hat{p}_1) - S(\rho_2)\right]\right\} - \sigma = 0$$

or using (4) and $v(s,m,v_{ll},v_{hl})$, as:

$$\mu\left[S(\hat{p}_1) - S(\rho_1)\right] - \varpi(\sigma, v_{1l}, v_{hl}) = 0 \tag{6}$$

Proposition 1: (i) $c_h \le r_2 \Rightarrow r_1 < r_2$; **(ii)** $r_2 < c_h \Rightarrow r_2 < r_1$. §

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.

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[13] Under the alternative assumption, a high cost firm becomes inactive in period 1 if r_1 is low enough, and there is a level of r_1 for which a high cost firm is indifferent between being active and inactive in period 1, p^s. The analysis in this paper corresponds to case $p^s \le r_1$. See Pereira (2001) for the alternative case.

[14]

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, $r_2 < r_1$.

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 and Qualifications

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.

Uncorrelated costs allow prices to remain flat over time, and many cost types allow prices to increase over time even when exit occurs.

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 $\underline{p}_2 = p^*_{2l} \leq p^*_{2h} = \overline{p}_2$. Suppose that $p^*_{2h} < p^*_{2l}$. By definition: $P(p^*_{2h}; r_2, c_l) \leq P(p^*_{2l}; r_2, c_l)$ and $P(p^*_{2l}; r_2, c_h) \leq P(p^*_{2h}; r_2, c_h)$. Adding the inequalities one gets $0 \leq (c_h - c_l)\left[D(p^*_{2l}) j_2(p^*_{2l}) - D(p^*_{2h}) j_2(p^*_{2h})\right]$, which is false if $p^*_{2h} < p^*_{2l}$, since $j_2(.)$ is non-increasing and $D(.)$ is strictly decreasing. Thus $p^*_{2l} \leq p^*_{2h}$. In step 2 I show that $p^*_{2l} < r_2$. Follows from step 1 and **Lemma 1: (i)**. In step 3 I show that $p^*_{l2} = \hat{p}_l$. Given step 2 and the definition of $j_2(.)$, from the c_l firms' perspective, $j_2(p_{2l})$ is given. Thus, only $p(.)$ matters to determine p^*_{2l}. Suppose $p^*_{2l} \neq \hat{p}_l$. Consider first $p^*_{2l} < \hat{p}_l$. There is a $e > 0$ sufficiently small such that $p^*_{2l} + e < r_2$. Thus, if a c_l firm deviates and charges $p^*_{2l} + e$, it loses no customers, and by strict quasi-concavity of $p(.)$ rises. Thus, $\hat{p}_l \leq p^*_{2l}$. Now suppose, $\hat{p}_l < p^*_{2l}$. If a c_l firm deviates and charges $p_{2l} = \hat{p}_l$, given **(A.3)**, and by definition $\hat{p}_l$ profit rises. Thus, $p^*_{2l} \leq \hat{p}_l$, and therefore, $p^*_{2l} = \hat{p}_l$. **(ii)** Consider first $c_h < r_2$. Suppose $p_{2h} < r_2$. If a c_h firm charges $p^*_{2h} = r_2$, it loses no customers, and $p(.)$ rises, as in step 3 of **(i)**. Suppose $r_2 < p_{2h}$. A c_h firm charges makes no sales, whereas if $p^*_{2h} = r_2$, it has a strictly positive profit. It follows that $p^*_{2h} = r_2$ for $c_h < r_2$. If $r_2 < c_h$, c_h firms make zero profits for any p'_2 Î $(r_2, +\infty)$; 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 $m = m$, **Lemmas 2** and **3**, and **Proposition 1**. §

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