Who Benefits from Electronic Commerce?

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Abstract: This paper evaluates the welfare impact of e-commerce. First, we show that e-commerce sometimes should be adopted by purely virtual firms, other times by firms that also have a physical shop, and other times by both. Second, we show that private investment in e-commerce can be socially excessive, insufficient, or even optimal. We conduct our analysis using a model developed by Mazón & Pereira (2001), where e-commerce reduces consumers' search costs, and retailing costs, and involves trade-offs for consumers.

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1 Introduction

It was claimed that ***electronic commerce*** (e-commerce)[1] would give consumers access to perfect information, create perfectly competitive markets and increase social welfare. The Economist (November 20 1999), asserted that: "The explosive growth of the Internet promises a new age of perfectly competitive markets. With perfect information about prices and products at their fingertips, consumers can quickly and easily find the best deals. In this brave new world, retailers' profit margins will be competed away, as they are forced to price at cost." However, all empirical studies made so far (Bailey (1998), Bakos, Lucas, Oh, Simon, Viswanathan, & Weber (2000), Brown & Goolsbee (2000), Brynjolfsson & Smith (1999), Chevalier & Goolsbee (2000), Clemons, Hann & Hitt (1999), Ellison & Ellison (2001), Friberg, Ganslandt & Sandstrom (2000), Karen, Krishnan, Wolff, & Fernandes (1999), Morton, Zettelmeyer & Risso (2000)), show that on-line markets are not perfectly competitive. Is the adoption of e-commerce, nevertheless, increasing welfare?

E-commerce is a new retailing technology or distribution channel, in the terminology of the Marketing literature, that allows retailing firms to produce at a lower cost a differentiated product relative to physical shop retailing[2]. In addition, virtual shop retailing reduces, although does not eliminate consumers' search costs, but requires consumers to wait for delivery. E-commerce introduces both horizontal and vertical product differentiation. Since search costs and waiting costs differ across consumers, the goods offered by physical and virtual shops are horizontally differentiated. If virtual and physical shop retailing involve the same search cost, or alternatively, if virtual and physical shop retailing involve the same waiting cost, as should be the case of ***information goods***[3], given enough bandwidth, the products are vertically differentiated, with the virtual shop retailing product being the lower and higher quality good, respectively. On this framework, the questions are how the cost reduction and the price equilibria that emerge from the adoption of e-commerce impact welfare.

This paper evaluates the welfare impact of e-commerce. First, we show that e-commerce, sometimes should be adopted by purely virtual firms, other times by firms that also have a physical shop, and other times by

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

[2] A good is characterized not only by its physical properties, but also by the time of availability, place of availability, etc.

[3] Goods that can be digitized, i.e., expressed as zeros and ones.

both. Second, we show that private investment in e-commerce can be socially excessive, insufficient, or even optimal.

We use a static, homogeneous product, partial equilibrium search model developed by Mazón and Pereira (2001), where e-commerce reduces consumers' search costs, involves trade-offs for consumers, and reduces retailing costs. 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. Virtual shops have lower marginal production costs than physical shops.

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

Virtual shops have the lowest cost and charge the lowest price. Thus, they are not constrained by consumer search, and charge their monopoly price.

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. 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. Sometimes it chooses to sell to all consumers, and other times only to old consumers. When both firms open virtual shops, if the 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. When only the old firm opens a virtual shop, it sells to new consumers only from its virtual shop. In Mazón and Pereira (2001) we give empirical evidence of these equilibria.

Opening a virtual shop impacts the agents' payoffs through 2 main effects. The old firm can sell to new consumers through its physical shop. But, if it opens a virtual shop it can sell to them at a lower cost and lower price. This ***Cost Reduction*** effect benefits the old firm and new consumers, and is increasing in the old consumers' reservation price. If the new firm opens a virtual shop and a ***Competing*** equilibrium emerges, the physical shop charges old consumers the new consumers' reservation price instead of its monopoly price. This ***Price Competition*** effect harms the old firm, benefits old consumers, and is overall positive and decreasing in the old consumers' reservation price.

If cost reduction is large, at a ***Segmentation*** equilibrium, the consumers surplus and the industry profits, excluding the set-up cost, are the same if at least one virtual shop opens. Thus, it is socially optimal for either the new or the old firm to open a virtual shop, but not both since that involves duplication of set-up costs. At a ***Competing*** equilibrium, if the old consumers' reservation price is high, the ***Cost Reduction*** effect dominates the ***Price Competition*** effect and it is socially optimal for the old firm to open a virtual; otherwise it is socially optimal for the new firm to open a virtual shop. If cost reduction is small, the previous discussion also applies; in addition it is also socially optimal for both firms to open a virtual shop, if the proportion of new consumers is sufficiently large.

If the proportion of new consumers is small, it is neither private nor socially optimal to open a virtual shop, and private investment is ***Optimal***. For intermediate low values of the proportion on new consumers, the set-up cost is larger than the ***Profit Cost Reduction*** effect, but smaller than the ***Cost Reduction*** effect. Since firms ignore the positive impact on the consumers' surplus of opening a virtual shop, no firm opens a virtual shop when it would be socially optimal for one firm to open a virtual shop, and private investment is ***Insufficient***. For intermediate high values of the proportion of new consumers, it is privately and socially optimal for one firm to open a virtual, and private investment is ***Optimal***. If the proportion of new consumers is large, and cost reduction is also large, since firms ignore the negative effect on welfare of the duplication of set-up costs, both open a virtual shop, when it would be socially optimal for only one firm to open a virtual shop, and private investment is ***Excessive***. When the proportion of new consumers is large, and cost reduction is small it may be socially optimal for both firms to open a virtual shop, in which case private investment is ***Optimal***.

Sections 2 and 3 present the model and characterize its equilibria. Section 4 does the welfare analysis. Section 5 reports work in progress. And section 6 discusses related literature. Proofs are in the Appendix.

2 The Model

In this section we present the model which is a simplified version of Mazón & Pereira (2001). The original reference gives a more detailed account of the model and its motivation.

(a) The Setting

Consider a retail market for a homogeneous search good that opens for 1 period.

There are 2 alternative ***retailing technologies***[4]: a ***New***, virtual shop based technology, and an ***Old***, physical shop based technology. 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. 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.

(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 ignore 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 r, where $D(r) \equiv 0$, buy and receive the product. When there are no virtual shops, new consumers behave similarly. Otherwise, new consumers canvass prices through the Web. 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. We assume that:

(H.1) Each new consumers 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, with $r_{vn} = r_{vo} = r_v$. When new consumers visit a virtual shop, if offered a price no higher than r_v, 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. In Mazón & Pereira (2001), 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. These costs endogenize the consumers' reservation prices.

(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, $K \in (0,+\infty)$. Firm j's decision of whether to open a virtual shop is $a_j \in \{0,1\}$, where *0* means "don't open" and *1* means "open"; let $a = (a_n, a_o)$. We assume that when a firm is indifferent between opening and not opening a virtual shop it chooses the former. At the end of stage 1 a is observed by all players. If at least 1 virtual shop opens, the physical shop creates its own Web site, where it posts its price.

Marginal production costs are constant for both shop types. The marginal cost of shop t is c_t. A virtual shop has a lower marginal cost than a physical shop. Let $c_p \in (0,r)$ and $c_{vn} = c_{vo} = c_v = c_p - \Delta_c$, where c_p is the common production cost, and $\Delta_c \in (0,c_p]$ is the ***production cost reduction*** induced by the new technology. All players know c_p and c_v.

The old firm can charge different prices at its 2 shops. Shop t's price and per consumer profit are p_t and $\pi(p_t;c_t) := (p_t - c_t)D(p_t)$. Let $\hat{p}_t := \arg\max_p \pi(p;c_t)$. Assume that $\pi(.)$ is strictly quasi-concave in p, and that even for the maximum cost reduction, the physical shop can charge $\hat{p}_v$ without losses, i.e., $c_p < \hat{p}_v$ for $\Delta_c = c_p$. Shop t's expected consumer share and expected profit are: $\phi_t(p_t)$ and $\Pi(p_t;c_t) := \pi(p_t;c_t)\phi_t(p_t)$. The new and old firm's net expected profits are: $V^n := [\Pi(p_{vn};c_v) - K]\alpha_n$ and $V^o := \Pi(p_p;c_p) + [\Pi(p_{vo};c_v) - K]\alpha_o$.

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

Assume that $K < p(\hat{p}_v; c_v)/3$. This assumption excludes the cases where it is not privately or socially optimal for firms to open virtual shops due only to K. Note that it might still not be optimal for firms to open virtual shops due to the value of other parameters Let. $\varpi := (\lambda, \rho_p)$.

A firm's stage 1 ***strategy***, is a rule that for every firm type, says if 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 profit, net of the investment expenditure.

(d) Equilibrium

A subgame perfect Nash ***Equilibrium*** in pure strategies 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: $max_{a_j} V^j$.

3 Equilibrium

In this section we construct the model's equilibrium by working backwards. First, given reservation prices and the profile of opening of virtual shops decisions, we derive the firms' equilibrium prices. Virtual shops charge their monopoly price. The physical shop charges sometimes the new consumers' reservation price, sometimes 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., $p \leq r_v$, is a. If virtual shop t charges a price higher than r_v, it makes no sales; if it charges a price no higher than r_v, given **(H.1)** and that there is a continuum of new consumers, its expected consumer share is l / a. Thus, for $0 < a$:

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

If the physical shop charges a price higher than r, it makes no sales; if it charges a price higher than r_p, but no higher than r, 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 $0 < a$:

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

To rule out the uninteresting cases, where although virtual shops exist, the physical shop is able to sell to new consumers at $\hat{p}_p$, its monopoly price, we assume that $r_p < \hat{p}_p$. In addition, we assume that.

(H.2) $\hat{p}_v < r_v$ and $c_p < r_p$

In Mazón & Pereira (2001) where r_t are endogenous, **(H.2)** follows if search and waiting for delivery are costly. For an ***Information Good***, i.e., a good that can be digitized, the cost of waiting for delivery of a product bought on-line is small relative to the cost of visiting a physical shop's physical location. Mazón & Pereira (2001), show that since buying on-line is more convenient, the physical shop must charge a lower price than virtual shops to sell to new consumers. Thus, if $r_p < \hat{p}_v$ we say that the product is an ***Information Good***; otherwise the product is a ***non-Information Good***. By **(H.2)**, and the definition of $\hat{p}_v$, $0 < a$.

When neither firm opens a virtual shop, $a = (0, 0)$, the industry is a monopoly. The number of shops that charge a price acceptable to new consumers when firms play (a_n, a_o) in stage 1 is $a^{a_n a_o}$; $a^{00} = 1$.

Next we examine the case where only the new firm opens a virtual shop, and hence the industry's supply side consists of the physical shop, and the new firm's virtual shop. The value of r_p for which the old firm is indifferent between charging $p_p = r_p$, and charging $p_p = \widehat{\rho}_p$, given $a = (1,0)$ and $p_{vn} \le r_v$, is p_o^s.[5] We assume that when the old firm is indifferent between selling to both consumers types and selling only to old consumers, it chooses the latter.

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

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

where $p_o^s(.)$ is decreasing, and $p_o^s(1) = c_p$. §

Since the new firm's virtual shop charges the lowest price in the market, and given **(H.2)**, it is never constrained by consumer search and 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. When the old firm does not open a virtual shop and charges r_p instead of $\widehat{p}_p$, it sells to $l/2$ new consumers. Thus, the physical shop trades-off ***Volume of Sales*** and ***per Consumer Profit***.

When only the new firm opens a virtual shop there can be 2 types of price equilibria. In both the virtual shop charges $\widehat{p}_v$. The physical shop at a ***Competing*** equilibrium charges r_p, and at a ***Segmentation*** equilibrium charges $\widehat{p}_p$. The ***Competing*** equilibrium occurs when (r_p, l) are large, and the ***Segmentation*** equilibrium occurs when (r_p, l) are small. From **Proposition 1**:

$$\alpha^{10} = \begin{cases} 2 & \Leftarrow \quad p_o^s(\lambda) < \rho_p \\ 1 & \Leftarrow \quad \rho_p \le p_o^s(\lambda) \end{cases}$$

Next we examine the case where both firms open virtual shops, and hence the industry's supply side consists of a physical shop and 2 virtual shops. The level of r_p for which the old firm is indifferent between its physical shop

[5] That is, $p(p_o^s(l);c_p)[l/2+1-l] \equiv p(\widehat{p}_p;c_p)(1-l)$.

selling to both consumer types and selling only to old consumers, given $a=(1,1)$ and $p_t \le \rho_v$, $t = vn, vo$, is p^s_m.[6] We assume that when the old firm is indifferent between its physical shop charging $p_p = \rho_p$, and charging $p_p = \widehat{p}_p$, it chooses the latter; and that for $\Delta_c = c_p$, $2 < p(\widehat{p}_v; c_v)/p(\widehat{p}_p; c_p)$, i.e., there are ***Large Cost Reduction Opportunities***. The value of Δ_c for which $p(\widehat{p}_v; c_v)/p(\widehat{p}_p; c_p) \equiv 2$, is Δ^c_c.

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

$$p^*_p = \begin{cases} \widehat{p}_p & \text{for } \Delta_c \in [\Delta^c_c, c_p] \\ \begin{cases} \rho_p \Leftarrow p^s_m(\lambda, \Delta_c) < \rho_p \\ \widehat{p}_p \Leftarrow \rho_p \le p^s_m(\lambda, \Delta_c) \end{cases} & \text{for } \Delta_c \in (0, \Delta^c_c) \end{cases}$$

where $p^s_m(.)$ is decreasing in λ, increasing in Δ_c, $p^s_o(\lambda) < p^s_m(\lambda, \Delta_c)$, and $p^s_m(1, \Delta_c) \in (c_p, \widehat{p}_p)$. §

Result $p^*_{vn} = p^*_{vo} = \widehat{p}_v$ is an expression of Diamond's (1971) paradox. When both firms open virtual shops, the old firm faces an additional effect, besides the ***Volume of Sales*** and ***per Consumer Profit*** effects. If its physical shop charges ρ_p instead of $\widehat{p}_p$, half of the new consumers it sells to, $\lambda/6$, would otherwise buy from the old firm's virtual shop, where per consumer profit is higher. This causes the old firm to only want to reduce its physical shop's price below $\widehat{p}_p$ to attract new consumers, if cost reduction is small, i.e., $\Delta_c \le \Delta^c_c$. Otherwise, the old firm prefers to sell to new consumers only from its virtual shop. From **Proposition 2**:

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

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

[6] That is, $p(\widehat{p}_v; c_v)(\lambda/3) + p(p^s_m(\lambda, \Delta_c); c_p)[\lambda/3 + 1 - \lambda] \equiv p(\widehat{p}_v; c_v)(\lambda/2) + p(\widehat{p}_p; c_p)(1-\lambda)$.

Next we examine the case where only the old firm opens a virtual shop, and hence the industry's supply side consists of the old firm's physical and virtual shops.

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

Now since the old firm is alone in the industry, it has no incentive to reduce its physical shop's price below $\widehat{p}_{p}$. Any new consumer its physical shop might attract is stolen from its virtual shop, where per consumer profit is no smaller. 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]

Stage 1: The Opening of Virtual Shops Game

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

Firm j's net profit when in stage 1 firms play (a_n, a_o), and after firms and consumers play optimally is $V^{j}_{a_n a_o}$. The difference between firm j's net profits when it opens a virtual shop, and when it does not, given that firm j plays $d=0,1$ in stage 1 is $D^{j}_{1|d}$, e.g., $D^{o}_{1|1}=V^{o}_{11}-V^{o}_{10}$ and $D^{n}_{1|1}=V^{n}_{11}-V^{n}_{01}=V^{n}_{11}$. Firm j's ***Incremental Profit*** of opening a virtual shop is $S_j := a_{j'}D^{j}_{1|1}+(1-a_{j'})D^{j}_{1|0}$, $j'\neq j$.

Firm j's optimal stage 1 decision is to open a virtual shop if $0\leq S_j$.

The next lemma orders the $D^{j}_{1|d}$. The value of D_c for which $p(\widehat{p}_v;c_v)/p(\widehat{p}_p;c_p)\equiv 3/2$, is $\widehat{D}_c(3/2)$.

Lemma: **(i)** $D^{0}_{1|1}\leq V^{n}_{11}\leq V^{n}_{10}$. **(ii)** If $(D_c, r_p)\in\left(0,\widehat{D}_c(3/2)\right]\times\left(c_p,\widehat{p}_p\right)\cup\left(\widehat{D}_c(3/2),D^{c}_{c}\right]\times\left(c_p,p^{s}_{m}\right]$, then $\max\left\{D^{o}_{1|0},D^{0}_{1|1}\right\}\leq V^{n}_{11}\leq V^{n}_{10}$. **(iii)** If $(D_c, r_p)\in\left(\widehat{D}_c(3/2),D^{c}_{c}\right]\times\left(p^{s}_{m},\widehat{p}_p\right)\cup\left(D^{c}_{c},c_p\right]\times\left(c_p,p^{s}_{o}\right]$, then $D^{o}_{1|1}\leq V^{n}_{11}<D^{o}_{1|0}\leq V^{n}_{10}$. **(iv)** If $(D_c, r_p)\in\left(D^{c}_{c},c_p\right]\times\left(p^{s}_{o},\widehat{p}_p\right)$, then $D^{o}_{1|1}<V^{n}_{11}=V^{n}_{10}\leq D^{o}_{1|0}$. **(v)** $\widehat{D}_c(3/2)<D^{c}_{c}$. §

Since the new firm's consumer share is no bigger when the old firm opens a virtual shop than when it does not: $V^{n}_{11}\leq V^{n}_{10}$. When both firms open a virtual shop, the difference between a firm's net profit when it opens and does not open a virtual shop, is larger for the new firm: $D^o_{1|1} \leq V^n_{11}$, and thus $D^o_{1|1} \leq V^n_{11} \leq V^n_{10}$. The relation between $D^o_{1|0}$ and V^n_{1d}, $d = 0,1$, depends on (D_c, r_p).

Next we characterize the opening of virtual shops equilibrium profiles.

Proposition 4:

$$a^* = \begin{cases} (0,0) & \Leftarrow \left\{\varpi \middle| \max\left\{\Delta^o_{1|0}, V^n_{10}\right\} < 0\right\} \\ (1,0) & \Leftarrow \left\{\varpi \middle| \Delta^o_{1|0} < 0 \leq V^n_{10},\ \Delta^o_{1|1} < 0 \leq V^n_{11}\right\} \\ (0,1) & \Leftarrow \left\{\varpi \middle| V^n_{10} < 0 \leq \Delta^o_{1|0}\right\} \\ \left\{(1,0)(1,0)\right\} & \Leftarrow \left\{\varpi \middle| V^n_{11} < 0 \leq \Delta^o_{1|0}\right\} \\ (1,1) & \Leftarrow \left\{\varpi \middle| 0 \leq \Delta^o_{1|1}\right\} \end{cases}$$

§

Since **Proposition 4** covers all the parameter set, it establishes constructively existence of equilibrium.

[Insert Figure 1 here]

4 Analysis

In this section, we conduct the welfare analysis of the model. First, we show that e-commerce, sometimes should be adopted by purely virtual firms, other times by firms that also have a physical shop, and other times by both. Second, we show that private investment in e-commerce can be socially excessive, insufficient, or even optimal.

Social welfare is the sum of consumers' surplus and firms' profits. Social welfare when in stage 1 firms play (a_n, a_o) and after all agents play optimally is $W^{a_n a_o}$. Let $a^w := argmax_a W$. Private investment in e-commerce is socially ***Excessive*** if $a^w < a^*$, ***Insufficient*** if $a^* < a^w$, and ***Optimal*** if $a^w = a^*$.[7]

We start by discussing how opening a virtual shop impacts the agents' payoffs. The old firm can sell to new consumers through its physical shop. But if it opens a virtual shop, it can sell to them at a lower cost. The profit cost reduction effect, is the increase in the old firm's profit from selling to new consumers through its virtual shop, instead of its physical shop, $\left[p(\hat{p}_v; c_v) - p(p^*_p; c_p)\right](l/m)$, where l/m is the proportion of new consumers that buy from the

[7] Note that a^w and a^* may not comparable, which occurs, e.g., when $a^w = (0,1)$ and $a^* = (1,0)$.

old firm's virtual shop, but that would buy from the physical shop if the old firm did not open a virtual shop. The consumer surplus cost reduction effect is the increase in the new consumers' surplus from buying from the old firm's virtual shop instead of the physical shop, $\left[S(\hat{p}_v) - S(p_p^*)\right](l/m)$. The ***Cost Reduction*** effect, is the sum of the profit cost reduction and the consumer surplus cost reduction effects: $\left[p(\hat{p}_v; c_v) - p(p_p^*; c_p) + S(\hat{p}_v) - S(p_p^*)\right](l/m)$. Let $W^c(p_p^*, D_c) := \left[p(\hat{p}_v; c_v) - p(p_p^*; c_p) + S(\hat{p}_v) - S(p_p^*)\right]$; $W^c(.)$ is increasing in D_c and p_p^*, and to simplify exposition we assume that:

(H.3) $\Omega^c(c_p, \Delta_c) \leq 0$.[8]

If the new firm opens a virtual shop and a ***Competing*** equilibrium emerges, the physical shop charges old consumers the new consumers' reservation price instead of its monopoly price. The profit price competition effect is the decrease in the physical shop's profit from charging old consumers, the new consumers' reservation price instead of its monopoly price: $\left[p(r_p; c_p) - p(\hat{p}_p; c_p)\right](1 - l)$. The consumer surplus price competition effect is the increase in the old consumers' surplus from paying the new consumers' reservation price instead of the physical shop's monopoly price: $\left[S(r_p) - S(\hat{p}_p)\right](1 - l)$. The ***Price Competition*** effect is the sum of the profit price competition and the surplus price competition effects: $\left[p(r_p; c_p) - p(\hat{p}_p; c_p) + S(r_p) - S(\hat{p}_p)\right](1 - l)$. Let $W^p(r_p) := \left[p(r_p; c_p) - p(\hat{p}_p; c_p) + S(r_p) - S(\hat{p}_p)\right]$. Since $W^p(\hat{p}_p) = 0$ and $W^p(.)$ is strictly decreasing, the ***Price Competition*** effect is positive.

Next we introduce notation. Let $D_P := p(\hat{p}_v; c_v) - p(\hat{p}_p; c_p)$ and $D_S := \left[S(\hat{p}_v) - S(\hat{p}_p)\right]$. Let $l_a^n(D_c)\ p(\hat{p}_v; c_v)/a - K \equiv 0$, $l_a^o(D_c)\ D_P/a - K \equiv 0$, and $l_a^w(D_c)\ W^c(\hat{p}_p, D_c)/a - K \equiv 0$. The value of r_p for which the welfare is the same if $a = (a_n, a_o)$ or if $a = (a_n', a_o')$, i.e., $W^{a_n a_o} \equiv W^{a_n' a_o'}$, is $p_{a_n' a_o'}^{a_n a_o}(l, D_c)$.

Next we characterize the socially optimal investment opening of virtual shops' profile.

Proposition 5: (i) For $D_c^c < D_c$

$$a^w = \begin{cases} (0,0) & \Leftarrow \ \varpi \in \left(0,\lambda_1^w\right) \times \left[c_p,\hat{p}_p\right) - \left(\lambda',\lambda_1^w\right) \times \left[p_o^s, p_{00}^{10}\right] \\ \{(1,0),(0,1)\} & \Leftarrow \ \varpi \in \left[\lambda_1^w, 1\right] \times \left[c_p, p_o^s\right) \\ (1,0) & \Leftarrow \ \varpi \in \left[\lambda_1^w, 1\right] \times \left(p_o^s, p_{10}^{01}\right) \cup \left(\lambda',\lambda_1^w\right) \times \left[p_o^s, p_{00}^{10}\right] \\ (0,1) & \Leftarrow \ \varpi \in \left[\lambda_1^w, 1\right] \times \left[\max\left\{p_o^s, p_{10}^{01}\right\}, \hat{p}_p\right) \end{cases}$$

(ii) For $D_c^c < D_c$, $\exists \underline{\lambda} \in (0,1)$: $\varpi \in \left[p_o^s, p_{10}^{01}\right] \times \left[\underline{\lambda},1\right] \Rightarrow a^w = (1,0)$

(iii) For $D_c \leq D_c^c$

$$a^w = \begin{cases} (0,0) & \Leftarrow \ \varpi \in \left(0,\lambda_1^w\right) \times \left[c_p,\hat{p}_p\right) - \left(\lambda',\lambda_1^w\right) \times \left[p_o^s, p_{00}^{10}\right] \\ \{(1,0)(0,1)\} & \Leftarrow \ \varpi \in \left[\lambda_1^w, 1\right] \times \left[c_p, p_o^s\right) \\ (1,0) & \Leftarrow \ \varpi \in \left[\lambda_1^w, 1\right] \times \left(p_o^s, p_{10}^{01}\right) \cup \left(\lambda',\lambda_1^w\right) \times \left[p_o^s, p_{00}^{10}\right] \\ (1,1) & \Leftarrow \ \varpi \in \left[\lambda_1^w, 1\right] \times \left(\max\left\{p_m^s, p_{10}^{01}\right\}, p_{11}^{01}\right) \\ (0,1) & \Leftarrow \ \varpi \in \left[\lambda_1^w, 1\right] \times \left[\max\left\{p_o^s, p_{11}^{01}, p_{10}^{01}\right\}, \hat{p}_p\right) \end{cases}$$

§

[Insert figure 2 here]

Let $D_c^c < D_c$ (**figure 2 (a)**). If $l < l_1^w$, the increase in consumer surplus, and the net increase in profits, is smaller than K, thus: $a^w = (0,0)$. If $l_1^w < l$, there are 2 cases to consider: $r_p \leq p_o^s(l)$ and $p_o^s(l) < r_p$. First consider $r_p \leq p_o^s(l)$. Since for $a = (1,0)(0,1)(1,1)$, there is a ***Segmentation*** equilibrium, consumer surplus, $l\,S(\hat{p}_v) + (1-l)S(\hat{p}_p)$, and industry profits excluding K, $l\,p(\hat{p}_v; c_v) + (1-l)p(\hat{p}_p; c_p)$, are identical. Thus, $a^w = \{(1,0),(0,1)\}$, since $a = (1,1)$ involves duplication of K. Now consider $p_o^s(l) < r_p$. If $D_c^c < D_c$, there is a ***Segmentation*** equilibrium for $a = (1,1)$. Thus, $W^{01} > W^{11}$ by the previous argument. Then, $W^{10} > W^{01}$, or $W^{01} > W^{10}$, and in either case $a^w \neq (1,1)$. When comparing $a = (0,1)$ with $a = (1,0)$, there are 3 effects involved. First, $l\,p(\hat{p}_v; c_v)/2$ is redistributed from the new to the old firm, with no net welfare impact; second, the old firm and new consumers gain from the ***Cost Reduction*** effect, and third, the old firm gains and old consumers lose with the ***Price***

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[8] The cases **(H.3)** allows us to discard, are qualitatively similar to those we analyze.

Competition effect, with a negative net impact: $W^{01} - W^{10} = lW^c(D_c, r_p)/2 - (1-l)W^p(r_p)$. Since $W^c(.)$ is increasing and $W^p(.)$ is decreasing in r_p, overall $W^{01} - W^{10}$ is increasing in r_p. If $p_{10}^{01} < r_p$, the ***Cost Reduction*** dominates the ***Price Competition*** effect, and $a^w = (0,1)$; otherwise, $a^w = (1,0)$. **Proposition 5 (a)** is more convoluted than **figure 2 (a)** suggests, because except for high (low) values of l (r_p), p_{10}^{01} and p_o^s cannot be ordered without additional assumptions.

Now let $D_c \le D_c^c$ (**figure 2 (b)**). If $(l, r_p) < (l_1^w, p_m^s(l, D_c))$ the analysis is identical to $D_c^c < D_c$. So consider $(l_1^w, p_m^s(l, D_c)) < (l, r_p)$. If $D_c \le D_c^c$ and $p_m^s(l, D_c) < r_p$, there is a ***Segmentation*** equilibrium for $a = (1,1)$. When comparing $a = (0,1)$ with $a = (1,1)$, there are 4 effects involved. First, $lp(\hat{p}_v; c_v)/3$ is redistributed from the new to the old firm, with no net welfare impact; second, expenditure on set-up costs falls by K, with a positive welfare impact; third, the old firm and new consumers gain from the ***Cost Reduction*** effect; and fourth, the old firm gains and old consumers lose with the ***Price Competition*** effect, with a negative net impact: $W^{01} - W^{11} = K + lW^c(D_c, r_p)/3 - (1-l)W^p(r_p)$. As before $W^{01} - W^{11}$ is increasing in r_p. If $p_{11}^{01} < r_p$, the ***Cost Reduction*** and the ***Set-up Cost*** effects dominate the ***Price Competition*** effect, and $a^w = (0,1)$; otherwise, $a^w = (1,1)$. If $p_{11}^{01} < p_m^s$, the set of parameter values for which $a^w = (1,1)$ is empty.

The cost reduction level for which $l_1^w \equiv l_1^n$, i.e., $p(\hat{p}_p; c_p) - [S(\hat{p}_v) - S(\hat{p}_p)] \equiv 0$, is D_c'';[9] $p(\hat{p}_p; c_p) - [S(\hat{p}_v) - S(\hat{p}_p)]$ is decreasing in D_c''. The value of r_p for which the old firm is indifferent between opening and not opening a virtual shop, given that the new firm does, i.e., $D_{1|1}^o \equiv 0$, is p^{11}.

Next we evaluate the optimality of private investment in e-commerce.

Proposition 6: (i) For $max\{D_c^c, D_c''\} < D_c$

[9] Such number exists because .

$$
a^{w}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix} a^{*} \quad \Leftarrow \quad \begin{cases} \varpi \in \left[c_p , \widehat{p}_p\right) \times \left(\lambda_1^{w} , \lambda_1^{n}\right] \cup \left[p_o^{s} , \widehat{p}_p\right) \times \left(\lambda_1^{n} , \lambda_1^{o}\right] \\ \varpi \in \left[c_p , \widehat{p}_p\right) \times \left(0, \lambda_1^{w}\right] \times \cup \left(\max\left\{p_o^{s}, p_{10}^{01}\right\} \widehat{p}_p\right) \times \left(\lambda_1^{o}, \lambda_2^{n}\right] \cup \\ \qquad \left[c_p , p_o^{s}\right) \times \left(\lambda_1^{o}, \lambda_2^{n}\right] \cup \left[p^{11}, \max\left\{p_o^{s}, p_{10}^{01}\right\}\right) \times \left(\lambda_2^{n}, \lambda_2^{o}\right] \\ \varpi \in \left[c_p , p^{11}\right] \times \left(\lambda_2^{n} , 1\right] \end{cases}
$$

(ii) For $D_c' < D_c \le D_c^c$

$$
a^{w}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix} a^{*} \quad \Leftarrow \quad \begin{cases} \varpi \in \left[c_p , \widehat{p}_p\right) \times \left(\lambda_1^{w} , \lambda_1^{n}\right] \cup \left[p_o^{s} , \widehat{p}_p\right) \times \left(\lambda_1^{n} , \lambda_2^{n}\right] \\ \varpi \in \left[c_p , \widehat{p}_p\right) \times \left(0, \lambda_1^{w}\right] \cup \left(p^{11}, \max\left\{p_o^{s}, p_{10}^{01}\right\}\right) \times \left(\lambda_2^{n}, \lambda'''\right] \cup \\ \qquad \left[c_p , p_o^{s}\right) \times \left(\lambda_1^{n}, \lambda_2^{n}\right] \cup \left[\max\left\{p_{10}^{01}, p_m^{s}\right\} p_{11}^{01}\right) \times \left(\lambda'', 1\right] \\ \varpi \in \left[c_p , p^{11}\right] \times \left(0, \lambda_2^{n}\right] \end{cases}
$$

§

[Insert figure 3 here]

Let $D_c^c < D_c$ (**figure 3 (a)**). There are 2 cases to consider: $r_p \le p_o^s(l)$ and $p_o^s(l) < r_p$. First consider $r_p \le p_o^s(l)$. If $l < l_1^w$, it is neither private nor socially optimal to open a virtual shop, i.e., $a^w = a^* = (0,0)$, and private investment is ***Optimal***. If $l_1^w < l \le l_1^n$, the ***Profit Cost Reduction*** effect is smaller than K, but the ***Cost Reduction*** effect is larger: $D_{1|0}^o = lD_P - K < 0 \le l\left(\Delta_\Pi + \Delta_S\right) - K = W^{01} - W^{00} = W^{10} - W^{00}$. Since firms ignore the positive impact on the consumers' surplus of opening a virtual shop, $a^* = (0,0) < (1,0),(0,1) = a^w$, and private investment is ***Insufficient***. If $l_1^n < l \le l_2^n$: $D_{1|1}^o = lp(\widehat{p}_v; c_v)/2 - K < 0 \le \min\left\{V_{10}^n, D_{1|0}^o\right\} D_{1|0}^o + lD_S$. Thus, $a^* = (1,0)(0,1) = a^w$, and private investment is ***Optimal***. Note however, that for $l_1^n < l \le l_1^o$, $a^w = (1,0)\,(0,1)$ and $a^* = (1,0)$. If $l_2^n < l : W^{11} - W^{01} = W^{11} - W^{10} = -K < 0 \le D_{1|1}^o$. Since firms ignore the negative effect on welfare of the duplication of K, $a^w = (1,0)\,(0,1) < (1,1) < a^*$, and private investment is ***Excessive***. Case $p_o^s(l) < r_p$ is identical, expect for that for some parameter values a^* and a^w are not comparable. If $D_c^c < D_c < D_c''$, $a^w = (0,0) < (1,0) = a^*$ for $(r_p, l) \in \left[c_p, p_o^s\right] \times \left[l_1^n, l_1^w\right]$.

Let $D_c \leq D_c^c$ (**figure 3 (b)**). This case is similar to $D_c^c < D_c$, except that private investment may also be optimal for large values of l.

5 Work in Progress

We are currently analyzing the case where the new and old firm differ in their ability to achieve the new technology's cost reduction.

6 Related Literature

This section inserts the paper on the literature. Our paper relates to several 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, i.e., locations. 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), Michael (1994), and Legros & Stahl (2000). 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 literature that discusses whether free entry is socially efficient: Bulow, Geanokoplos & Klemperer (1985), Klemperer (1988), Mankiw & Whinston (1986), Nachbar et al (1998), Perry (1984) and von Weizsäcker (1980). If a firm by entering a market causes other firms to reduce their output, and if the other firms have positive profit margins, they lose revenue. If the social value of this output reduction exceeds the entrant's profit, entry is more valuable to the entrant than to society.

Fourth, our paper relates to the literature that analyzes the welfare effects of cost reductions: Lahiri & Ono (1988), and Zhao (2001). If cost reduction occurs for higher cost firms, production shifts from the lower to the higher cost firms, which can decrease welfare.

Fifth, our paper relates to the literature on product innovation. Greenstein & Ramey (1998) analyze vertically differentiated product innovations. Private investment may be socially excessive.

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Table 1: Summary of Model's Price Equilibria

<table>
<tr><th>a</th><th colspan="2"></th><th>p_p^*</th><th>Share vn</th><th>Share vo</th><th>Share p</th><th>Equilibrium</th></tr>
<tr><td rowspan="2">$(1,0)$</td><td colspan="2">$p_o^s < r_p$</td><td>r_p</td><td>$l/2$</td><td>$-$</td><td>$l/2+1-l$</td><td>Competing</td></tr>
<tr><td colspan="2">$r_p \leq p_o^s$</td><td>$\widehat{p}_p$</td><td>l</td><td>$-$</td><td>$1-l$</td><td>Segmentation</td></tr>
<tr><td>$(0,1)$</td><td colspan="2">$-$</td><td>$\widehat{p}_p$</td><td>$-$</td><td>$l/2$</td><td>$1-l$</td><td>Segmentation</td></tr>
<tr><td rowspan="3">$(1,1)$</td><td rowspan="2">$D_c \leq D_c^c$</td><td>$p_m^s < r_p$</td><td>r_p</td><td>$l/3$</td><td>$l/3$</td><td>$l/3+1-l$</td><td>Competing</td></tr>
<tr><td>$r_p \leq p_m^s$</td><td>$\widehat{p}_p$</td><td>$l/2$</td><td>$l/2$</td><td>$1-l$</td><td>Segmentation</td></tr>
<tr><td colspan="2">$D_c^c < D_c$</td><td>$\widehat{p}_p$</td><td>$l/2$</td><td>$l/2$</td><td>$1-l$</td><td>Segmentation</td></tr>
</table>

Figure 1 (a) : Equilibrium Opening Profiles for $D_c^c < D_c$

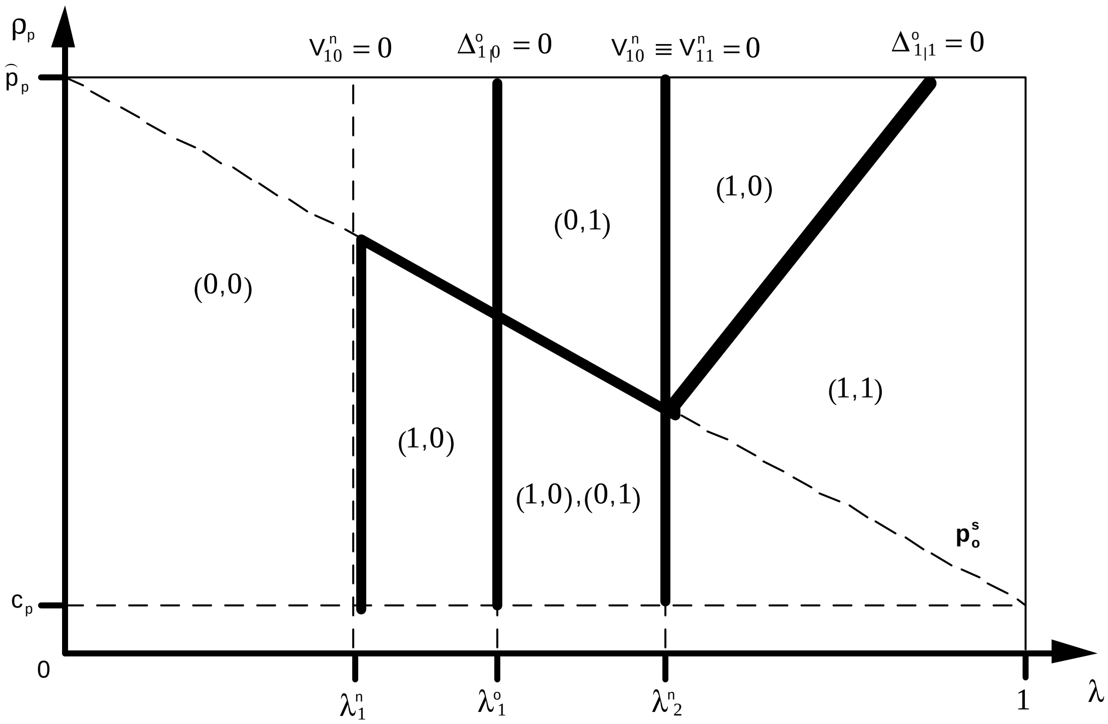

Figure 1 (b) : Equilibrium Opening Profiles for $D_c \leq \hat{D}_c(3/2)$

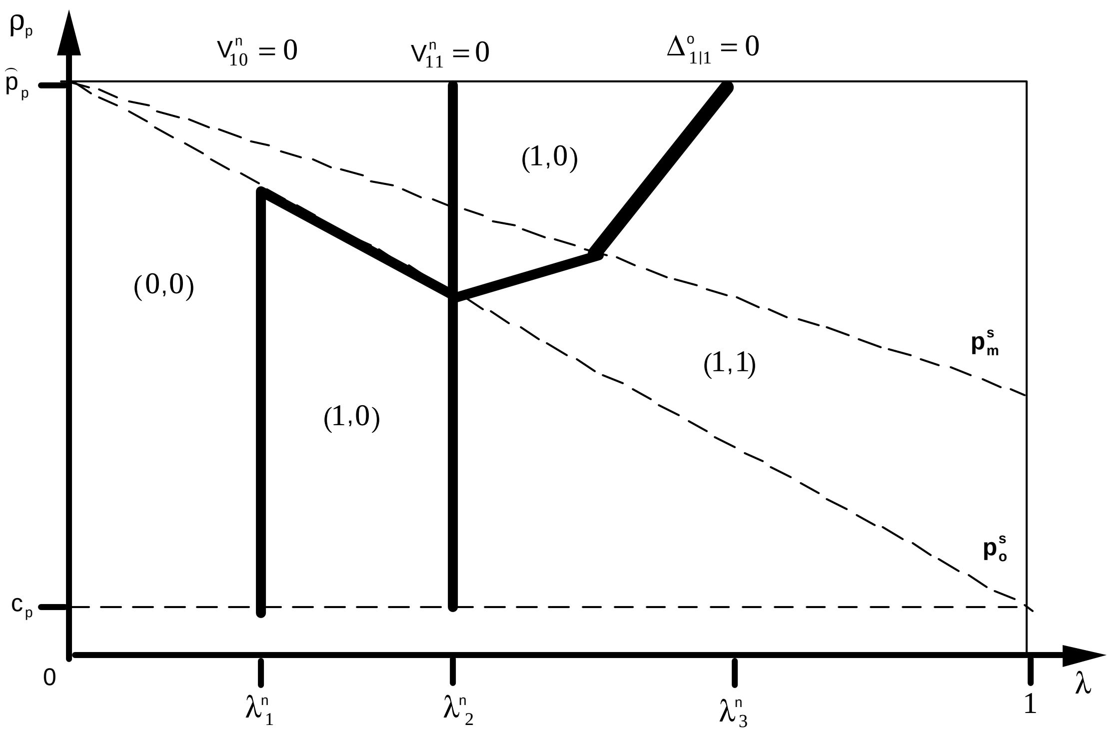

Figure 2 (a) : Socially Optimal Opening Profiles for $\mathcal{D}_c^c < \mathcal{D}_c$ **and** $p_o^s < p_{10}^{01}$

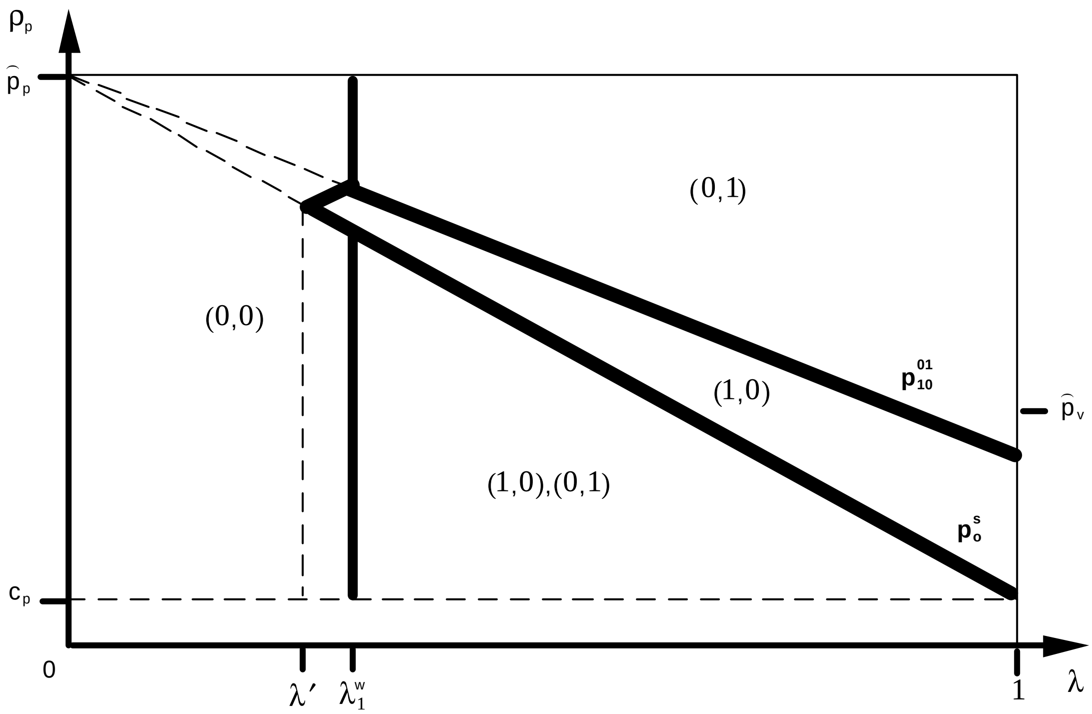

Figure 2 (b) : Socially Optimal Opening Profiles for $\mathcal{D}_c \le \mathcal{D}_c^c$ **and** $p_m^s < p_{10}^{01} < p_{11}^{01}$

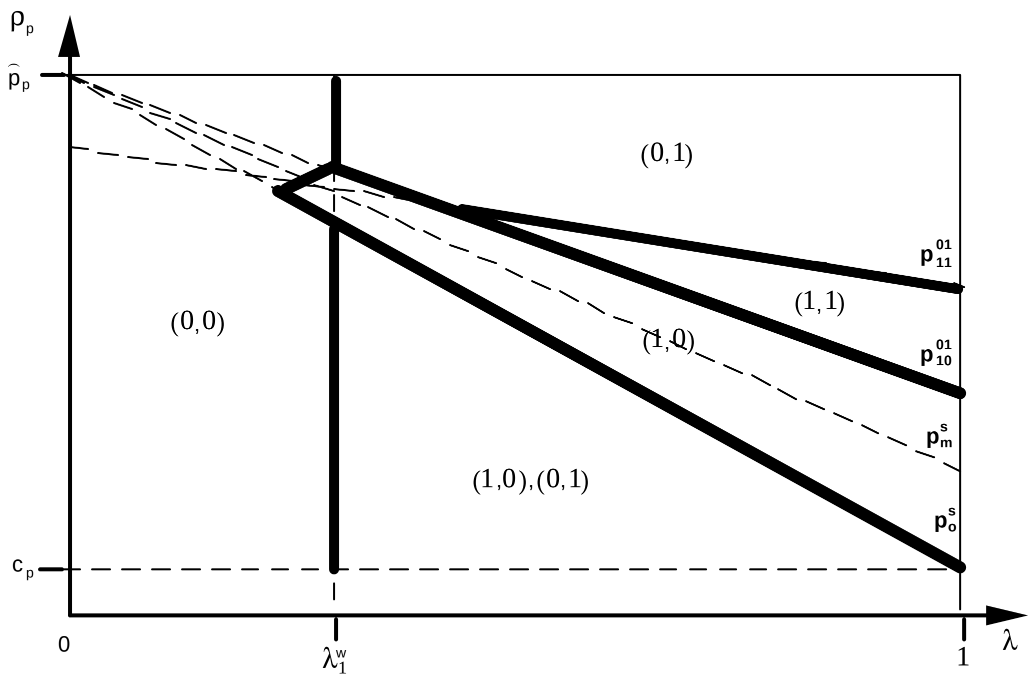

Figure 3 (a) : Optimality of Private Investment for $max\{D_c^c, D_c''\} < D_c$

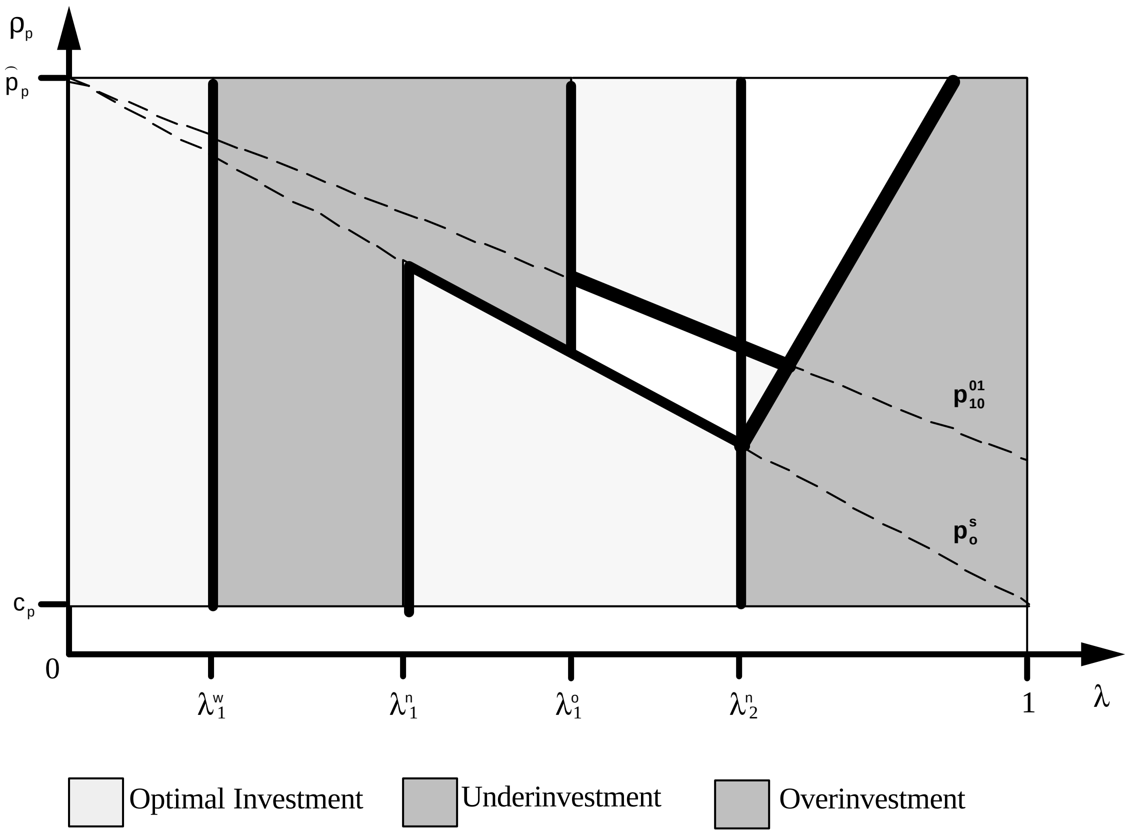

Figure 3 (b) : Optimality of Private Investment for $D_c'' < D_c \leq D_c(3/2)$