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Michael R. Baye

ORGANIZING THE NEW INDUSTRIAL ECONOMY

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ORGANIZING THE NEW INDUSTRIAL ECONOMY

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EDITOR'S INTRODUCTION

The growing use of the Internet by businesses and consumers is rapidly changing the structure, conduct, and performance of different sectors of the global economy. This volume on organizing the "new economy" documents some of these changes, and examines the ramifications for business strategy and public policy.

Michael Doane, Kenneth Hendricks and Preston McAfee open this volume by examining how the Internet has changed the structure of the market for air-travel information, and in turn, the conduct of its market participants. The authors provide an interesting discussion of the evolution of the market, and address policy questions raised by the U.S. Department of Transportation in its recent *Notice of Proposed Rulemaking* for airline computer reservation systems. Besides its obvious contribution to the policy debate, this chapter is also an excellent case study for use by students of economics, business, or public policy. In addition, it also has potential implications for other sectors of the new economy.

Chapter 2 takes a broad look at how the Internet has impacted the technological structure of different industries within the United States. The authors – Chris Forman, Avi Goldfarb, and Shane Greenstein – share the results of an industrial census of Internet usage among commercial business establishments. Their analysis provides cross-industry (two- and three-digit NAICS level) comparisons of Internet participation and Internet enhancement. Here, *participation* refers to minimal investments in the Internet required to merely operate a business, while *enhancement* refers to investments aimed at enhancing computing processes for competitive advantage. The data analysis and accompanying tables reveal wide variations across industries in both the levels and types of Internet usage, and is foundational for anyone seeking to understand how the Internet is impacting business in the U.S.

Judith Chevalier and Austan Goolsbee address the problem of evaluating online-retailer performance in Chapter 3. They note that, based on sales and gross profit data, Amazon would appear to be worth about 10 times that of Barnes and Noble; yet, Amazon's market capitalization is more than 50 times greater. The authors provide an interesting economic rationale for these differences. Based on their own estimates of the elasticity of demand for books sold through these online retailers, the authors argue that Amazon's current prices (and hence margins) are below short-run profit-maximizing levels. However, in light of potential network effects and dynamic considerations, this pricing strategy has a rational theoretical basis in that it permits Amazon to profitably raise prices (and hence margins) over time. In short, the authors provide a plausible explanation for the capital market's valuation of Amazon relative to Barnes and Noble: The market projects greater growth in Amazon's margins and profitability. The methodology and insights offered in this paper extend beyond the market for online retailers, and are likely to be of value to those interested in other sectors of the global economy, including traditional retail establishments and service companies.

Chapters 4, 5, and 6 examine the pricing conduct of firms competing in online retail environments. These chapters document that price dispersion for homogeneous products: (a) has persisted for a number of years (Xing Pan, Brian Ratchford & Venkatesh Shankar's contribution in Chapter 4); (b) is prevalent in different countries and across different product categories (Chapter 5, by Rupert Gatti & Paul Kattuman); and (c) varies with product characteristics (Jihui Chen & Patrick Scholten's Chapter 6). Together, these three chapters provide one of the most comprehensive looks at price dispersion available to date, with pricing data from eight different countries and products ranging from books and CDs to computers and consumer electronics products.

Chapter 7 provides an empirical investigation of the importance of reputation in online auction markets. Motivated by the millions of items for sale at eBay on any given day – and dozens of sellers attempting to auction off the same item – Jeffrey Livingston examines factors that induce bidders to participate in a particular seller's auction. Among other things, he finds that potential bidders seek out sellers with reputations above a threshold quality level, but beyond this threshold, reputation has minimal impact on the number of bidders participating in a given auction.

The final three chapters of *Organizing the New Industrial Economy* examine conduct in "new economy" settings where network effects, product compatibility, and/or market dynamics impact optimal firm behavior. Sujoy Chakravarty's contribution in Chapter 8 offers some experimental tests of the Katz-Shapiro model, while Dong Chen examines in Chapter 9 duopolists' incentives to preserve compatibility between new generations of products. Finally, in Chapter 10, Krina Griva and Nikolaos Vettas examine two-part pricing in "new economy" settings, and show that endogenous market segmentation can arise whereby "light" users opt for services provided by a firm charging a low fixed fee, and "heavy" users opt for the product sold by a rival charging a lower per-usage fee. These three papers are of practical importance to those working in a variety of industry settings, including telecommunications and consumer credit markets.

I hope you agree that the breadth of topics in this volume, coupled with the diverse backgrounds of its contributors, make *Organizing the New Industrial Economy* a unique and valuable addition to the growing literature in the area.

This volume is part of Elsevier's *Advances in Applied Microeconomics* series – an annual research volume that disseminates frontier research well in advance of journals and other outlets. For additional information about Internet-related projects, or for more information about this series and planned future volumes, please visit the editor's site at http://www.nash-equilibrium.com

Michael R. Baye
Editor

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EVOLUTION OF THE MARKET FOR AIR-TRAVEL INFORMATION

Michael Doane, Kenneth Hendricks
and R. Preston McAfee

ABSTRACT

The Internet has enabled consumers to act as their own travel agents and to verify independently the accuracy of the information provided by airlines through the CRSs and travel agents. As a result, the relationships between consumers and the suppliers of air-travel information have been radically altered, and we document these changes. We identify the relevant market for air-travel information, which includes CRSs, online travel agencies, and the websites and call centers of individual carriers. We determine market concentration and market shares using the Herfindhal-Hirschman Index. Based on our analysis, we argue that there is no longer any need to regulate independent CRSs. However, airlines that own CRSs continue to have an incentive to withdraw their flight and fare information from rival CRSs and, to prevent this from happening, the mandatory participation rule adopted in 1992 should be maintained.

1. INTRODUCTION

The U.S. Department of Transportation's ("Department") Notice of Proposed Rulemaking ("NPRM") of November 15, 2002, proposes extensive regulation

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of both independent and integrated computer reservation systems ("CRSs" or "systems"). The fundamental economic issue raised in the NPRM is whether there is a competitive problem in the supply of information regarding air travel to passengers. This paper provides an analysis of this issue.

The relevant market for an antitrust analysis is the market for air-travel information. The sources for air-travel information include CRS providers and their travel agency subscribers, consolidators, content aggregators such as FareChase.com, and the websites and call centers of individual airlines. In addition, online travel agencies – Orbitz in particular – are increasingly bypassing CRSs by going directly to air carriers' internal reservation systems, thereby becoming independent sources of air-travel information. The share of total bookings made via CRS systems in the market for air-travel information has declined considerably since the early 1980s, such that CRSs handle only about one-half of total bookings. This fact is strong evidence that the relevant market for air-travel information is not limited to CRS providers, but includes online travel agencies and the websites and call centers of individual carriers. Any analysis of the competitive constraints faced by CRSs must take all of these competitors into account.

The air-travel information market is only moderately concentrated, according to criteria in the U.S. Department of Justice and Federal Trade Commission's "Horizontal Merger Guidelines," with an Herfindahl-Hirschman Index ("HHI") of approximately 1,200. In that market, Sabre's share is approximately 24.6%, which does not represent a predominant market share.

Historically, the air-travel information market was believed to suffer from a market failure, in that consumers lacked independent methods with which to verify the accuracy of information provided by airlines via their CRSs and by travel agents. The effect of this market failure was that consumers paid higher airfares, other factors being the same. Since the Department's last rulemaking in 1992, the Internet has radically altered the market for air-travel information. Most fundamentally, the Internet has provided a mechanism for consumers and travel agents to verify the accuracy of information provided by different CRS providers and travel agents. Airlines cannot bias the CRSs in a manner undetectable by travel agents, and travel agents' failure to correct that bias, or their own bias, can be detected and disciplined by passengers. This enhanced ability of a majority of consumers independently to verify air-travel information calls into question whether any economic basis exists to regulate independent CRSs.

The emergence of independent CRSs also alters the market for air-travel information by removing incentives to bias information and by forcing independent

CRSs to compete on the merits for subscribers. This serves to make accurate information more available to consumers. We conclude that, at least in the case of independent CRSs, no economic justification exists for regulation barring preferential screen displays, preventing differences in booking fees, or regulating contracts between CRSs and travel agents, because the market effectively disciplines such conduct in ways that prevent harm to consumers. This conclusion is supported by an analysis of the terms and conditions negotiated in current contracts and by the data on carrier-direct bookings by travel agents.

The emergence of the Internet as an independent source of information about air travel, the increasing use of that channel by airlines bypassing travel agents and CRSs, and the increasing significance of independent CRSs all show that no individual, independent CRS has meaningful market power that should be cause for regulatory concern. This conclusion is demonstrated by understanding that this market is an information market and that relevant information is available from multiple competing providers, many of whom are not CRSs. Furthermore, the market for air-travel information is not highly concentrated.

Airlines that own CRSs are likely to act on their incentive to withdraw from or downgrade in rival, non-airline owned CRSs, reducing the quality and quantity of air-travel information, and causing consumers and travel agents to switch to the airline-owned CRSs. Such withdrawals would have a devastating effect on the competitiveness of rival, non-airline owned CRSs and would thereby reduce airline competition. Airlines also have an incentive to reduce the quality of information held by consumers as a means of reducing the price competitiveness of the market for air transportation.

Airlines that own CRSs would especially benefit by withdrawing from or downgrading their participation in other CRSs, because the owner airlines benefit from both the relative advantage created for their own CRS and the reduction in price competition engendered by poorer information. Such withdrawal would be harmful to consumers because it would balkanize information markets, create higher search costs, and act as an entry barrier to emerging airlines that may be less able to inform consumers of their presence. The Department's current mandatory participation rule has, to date, prevented this outcome from occurring. For this reason, the rule should not be eliminated as long as a significant CRS is controlled by one or more major carriers.

The paper is organized as follows. Section 2 provides background information on the supply of air-travel information. Section 3 gives an overview of the CRS rules. Market definition is discussed in Section 4, and market power is discussed in Section 5. An economic analysis of the NPRM is presented in Section 6.

2. BACKGROUND ON THE CURRENT SUPPLIERS OF AIR TRAVEL AND AIR-TRAVEL INFORMATION

In this section, we provide an overview of current suppliers of air travel and air-travel information. The objective of this section is to provide context for our economic evaluation of the proposed regulations.

2.1. Airlines

We first consider the markets for air travel between pairs of cities. U.S. air carriers generated $80.9 billion in passenger revenue in 2001, while enplaning 622 million revenue passengers (Air Transportation Association, 2002). Table 1 identifies the largest carriers serving city-pair markets in the United States, based on number of enplanements, for the twelve-month period ending June 2002.[1] On a national basis, the four largest airlines (i.e. American Airlines, Delta Airlines, United Airlines, and Southwest Airlines) account for approximately 60% of all enplanements. U.S. Airways, Northwest Airlines, and Continental Airlines have enplanement shares comparable to each other and, combined, account for an additional 26% of total enplanements nationwide. America West and other smaller airlines account for the remaining 14% of total enplanements nationwide.

Most major airlines now have one or more hubs at which many of their long-distance passengers change planes. This approach has allowed carriers to fill a larger portion of the seats on their planes and to increase the flight frequency of non-stop routes between their hubs and other airports. For travelers whose origin

Table 1. Airline Shares of U.S. Enplanements Year Ending June 2002.

Carrier	Enplanement Share (%)
American	17.9
Delta	17.4
Southwest	12.2
United	12.2
Northwest	9.3
Continental	8.7
US Airways	8.5
America West	3.1
Others	10.7
Total	100.0

Source: DOT Form 41, scheduled revenue passenger enplanements.

Table 2. Airport Shares for Selected Hub Cities.

Airport	Year	HHI	Largest Carrier		Second Largest Carrier		Third Largest Carrier	
			Name	Share (%)	Name	Share (%)	Name	Share (%)
Atlanta	2002	4,742	Delta	67.2	Airtran	13.0	American	4.7
	2000	4,256	Delta	63.4	Airtran	12.8	Continental	4.0
	1995	3,068	Delta	52.3	Airtran	13.7	Continental	6.3
Los Angeles LAX	2002	1,282	American	21.4	Southwest	17.9	United	15.0
	2000	1,442	United	24.3	Southwest	20.5	American	15.6
	1995	1,425	United	25.4	Southwest	20.4	American	11.7
Chicago O'Hare	2002	2,913	American	42.6	United	31.6	Delta	5.0
	2000	3,170	United	45.0	American	32.4	Delta	6.3
	1995	3,209	United	46.5	American	30.9	Delta	5.5
Dallas-Ft. Worth	2002	3,962	American	60.2	Delta	16.8	Northwest	3.7
	2000	3,575	American	56.6	Delta	17.3	United	4.9
	1995	4,189	American	61.6	Delta	18.6	United	3.9
Newark	2002	3,753	Continental	58.8	American	10.8	Delta	10.1
	2000	3,391	Continental	55.6	Delta	10.6	American	8.4
	1995	2,960	Continental	51.0	United	11.3	American	10.8
Detroit	2002	4,159	Northwest	62.5	Spirit	12.2	American	6.8
	2000	3,469	Northwest	57.1	Southwest	7.6	Delta	6.0
	1995	3,911	Northwest	60.8	Southwest	9.3	American	5.7
Minneapolis-St. Paul	2002	5,345	Northwest	72.5	American	5.3	Delta	5.0
	2000	4,047	Northwest	62.2	Sun Country	8.6	United	5.7
	1995	5,127	Northwest	70.7	United	7.5	American	5.2
Houston Bush	2002	5,141	Continental	70.7	American	6.7	Delta	6.1
	2000	4,757	Continental	67.9	American	6.8	Delta	5.9
	1995	4,668	Continental	66.9	American	9.4	United	6.2
Salt Lake	2002	3,444	Delta	55.0	Southwest	17.0	United	6.4
	2000	3,351	Delta	51.7	Southwest	23.6	United	8.7
	1995	3,224	Delta	46.7	Southwest	30.8	United	7.7
Cleveland	2002	3,262	Continental	53.8	Southwest	13.4	American	8.7
	2000	2,779	Continental	48.0	Southwest	16.6	US Airways	7.2
	1995	2,549	Continental	45.7	Southwest	12.7	US Airways	9.6
Memphis	2002	4,163	Northwest	61.1	Delta	18.0	American	6.7
	2000	3,320	Northwest	51.9	Delta	22.5	US Airways	5.7
	1995	3,766	Northwest	57.8	Delta	16.4	American	7.8

Source: DOT Form 41 O&D Survey.

or destination is the hub city, there is often very limited choice among airlines. This situation is documented in Table 2, which reports the enplanement shares of the three largest carriers for twelve hub cities.[2] In ten of the cities, a single carrier dominates the hub. The exceptions are Los Angeles and Chicago, which are shared by American Airlines and United Airlines. Using the Herfindahl-Hirschman Index ("HHI"), airport concentration in these locations ranges from 4,000 to 6,000; that measure can be interpreted to indicate that 1.7–2.5 equal-sized carriers serve these airports.[3] Empirical studies on airline fares have shown that the hub carrier is able to exercise market power: fares in hub city-pair markets are significantly higher than in non-hub city-pair markets (Borenstein, 1989, 1991).

In any city-pair market, each airline present in the market offers a number of daily flights and a variety of full-fare and discount tickets. As a generalization, business travelers are less price sensitive than are leisure travelers. Airlines exploit this fact by charging higher fares for tickets with characteristics valued more highly by business travelers than by leisure travelers. Business travelers, for example, often book flights without advance notice, value flexible itineraries, travel during weekdays, and value their time highly. On the other hand, leisure travelers tend to plan their travel well in advance and maintain their travel plans. As a consequence, airlines charge higher fares depending upon features such as: (1) purchase without advance notice; (2) lack of travel restrictions (e.g. a Saturday night stay); and (3) whether the ticket is fully refundable or exchangeable. Airline price discrimination has led to a plethora of fares.[4]

To illustrate the wide variety of air travel choices that confront consumers in city-pair markets generally, we selected two city-pair markets, New York (JFK)-Los Angeles and Austin-San Jose, and examined the number of flights and non-refundable, non-exchangeable fares available for a weekend trip (booked with three-weeks and with two-days advance notice). The results of our inquiry are reported in Table 3. As the portion of the table associated with the three-week advanced booking shows, we identified (on March 12, 2003) available flights departing each origin city on the morning of Friday, March 28, 2003, and returning

Table 3. Flight and Fare Choices.

Flight	Number of Airlines	Number of Fares Offered	Range of Fares Offered	Number of Flights Offered
Three-week notice[a]				
New York (JFK) to Los Angeles (LAX)	6	12	\$300 to \$621	21
Austin to San Jose	4	6	\$301 to \$321	15
Two-day notice[b]				
New York (JFK) to Los Angeles (LAX)	4	8	\$766 to \$2,478	13
Austin to San Jose	5	10	\$1,067 to \$1,698	16

[a] For a three-week advanced notice flight, departing on the morning of Friday, March 28, 2003, and returning on Sunday, March 30, 2003. The search for flights originating at JFK was completed at 4:00 p.m., March 12, 2003, and the search for flights originating in Austin was completed at 4:10 p.m. on March 12, 2003. Searches were performed using the Travelocity service at www.travelocity.com.
[b] For a two-day advanced notice flight, departing on the morning of Friday, March 14, 2003, and returning on Sunday, March 16, 2003. The search for flights originating at JFK was completed at 3:46 p.m., March 12, 2003, and the search for flights originating in Austin was completed at 3:50 p.m. on March 12, 2003. Searches were performed using the Travelocity service at www.travelocity.com.

on Sunday, March 30, 2003. In the New York-Los Angeles market, six airlines offered a total of 21 flights and 12 fares, with the fares ranging from $300 to $621. In the Austin-San Jose market, four airlines offered a total of 15 flights and 6 fares, with the fares ranging from $301 to $321. (We note that additional fares are also available without weekend-stay, advance purchase, and non-refundable, non-exchangeable restrictions.) As the second portion of Table 3 shows, the number of flight and fare options increases significantly when one takes into account differences in the amount of advance notice given.

Table 3 makes the following important point: *there is a market for information for air travel*. That is, even if travelers know when they want to leave and return, they are unlikely to know which flights are available and at what prices. Therefore, there is an opportunity for entrepreneurs to solve travelers' information problems by collecting and disseminating information, which suppliers and consumers demand and for which they are willing to pay. A similar situation arises between buyers and sellers in housing markets, between employers and employees in labor markets, and between retailers and consumers in many retail markets, such as those for groceries, office products, and automobiles. In each of these markets, the buyers' lack of information about the suppliers' products and prices creates a market for that information, which is supplied by "information suppliers." Real estate agents provide listings of houses for sale and their "asking" prices; Internet agencies like Monster.com provide résumés to prospective employers; and the Sunday newspaper provides retail price information to consumers. Some information suppliers charge the seller or the buyer, or both, for providing information; others charge the seller, the buyer, or both only when a sale is completed.

In many markets for information, a producer of information (which is often also a seller of the underlying good, such as the home, automobile, or mortgage) provides information directly to buyers, bypassing or partially bypassing independent information suppliers. Some homeowners seeking to sell their home, for example, might bypass real estate agents and seek to sell their home themselves (or offer their home themselves as well as through a broker). The same is true of airline information. Airlines may offer the information directly to passengers (e.g. on their own web sites), through independent information suppliers (e.g. travel agents using CRSs), or both.

2.2. Computer Reservation Systems

The first airline reservation system was launched in 1964 when American Airlines created the Sabre (Semi-Automated Business Research Environment) system, which allowed real-time access to flight inventory in all its offices (see, e.g.

Harrell Associates, 2002, p. 11). Prior to Sabre, inventory was managed through centralized reservation systems consisting of groups of operators in a room with physical cards that represented inventory (i.e. seats on planes). Other carriers soon followed with their own internal Airline Reservation Systems (see Declaration of R. H. Fahy, pp. 2–3). The CRS concept emerged when the various ARSs were connected to form a multi-airline reservations network that was available to all travel agents.

Today, there are four established providers of CRS services: Sabre, Galileo, Worldspan, and Amadeus. Modern CRS technology consists of four principal, functional components: (1) inventory management and display; (2) pricing and fare search engines; (3) ticket and document generation; and (4) database reporting. In addition to being the primary means by which traditional brick and mortar travel agencies obtain flight and fare data, CRSs serve as hosts for the internal reservation systems of some airlines and are the source of real-time flight and fare data for some online travel agencies. For example, Travelocity uses the Sabre system, while Expedia and Orbitz both use Worldspan. Orbitz has announced plans to connect directly with airlines, bypassing Worldspan, and has signed agreements to connect with directly ten carriers, including American, America West, Continental, Delta, Northwest, United, and U.S. Airways, which collectively account for approximately 68% of U.S. enplanements. At present, Orbitz has implemented such direct connections for American, Continental, and Northwest.

At the time the CRS rules were first adopted, all CRS systems were owned by airlines. However, airline owners to an increasing degree have divested their ownership interests in CRSs. As noted above, American Airlines originally owned Sabre, the largest system in terms of bookings. American sold 20% of its ownership interest in Sabre in 1996 and sold its remaining interest in Sabre in March 2000 (Sabre Holding Corp., 10-K for 2001, p. 2).

The Apollo CRS of United Airlines became Galileo in 1987, when ten major North American and European airlines joined with United. In 1997, Galileo became a public company, with its airline owners selling at that time 37% of the company in an initial public offering (Galileo International, Inc., 10-K for 1997, p. 10). An additional 37% of the company was sold in a second public offering, conducted in 1999 (Galileo International, Inc., 10-K for 1999, p. 47). At that time, United Airlines became the sole airline to own stock in Galileo, with a 26% ownership stake. In October 2001, Cendant Corporation (which is not affiliated with any airlines) purchased the entire company.

Worldspan was formed in 1990 through the combination of CRSs owned by TransWorld Airlines ("TWA") and Delta, and today it is entirely owned by three airlines. Delta, Northwest, and American own 40, 34, and 26% of Worldspan, respectively (Worldspan, 2001). American obtained its ownership share in

Worldspan in 2001 when it purchased TWA. Worldspan recently announced an agreement by which all airline ownership interests would be sold to private equity firms (Worldspan, 2003). The transaction, scheduled to be completed in mid-2003, is subject to financing, government, and regulatory approvals (Worldspan, 2003).

Three of the founding airline owners of Amadeus – Air France, Iberia, and Lufthansa – currently hold about 60% of the company. The ownership interest of each of the airlines is as follows: Air France (23.4%), Iberia (18.4%), and Lufthansa (18.3%) (Amadeus Global Travel Distribution, 2001, p. 151). The public owns the remainder. Continental had acquired a 13% ownership interest in Amadeus in 1995 as the result of the merger between Amadeus and System One, but that interest was sold in 1997 (see, Global Distribution Systems – Outlook for the 21st Century, 2000, p. 137).

Sabre and Amadeus report the largest number of travel agencies using their CRSs worldwide (see Amadeus Global Travel Distribution, March 12, 2003; Sabre Holding Corp., March 12, 2003). Over 60,000 travel agencies use each system worldwide. Galileo and Worldspan also report serving tens of thousands of travel agencies worldwide (see Galileo, 2003; Worldspan, 2001). Table 4 presents the bookings of each CRS provider as a percentage of total bookings made in the U.S. As shown in the table, in 1983, CRSs' combined share accounted for approximately 88% of total bookings; this combined share declined to just under 53% by 2002. Sabre's share of total bookings equaled approximately 24.6% in 2002. Table 4 shows the shares of Worldspan, Galileo, and Amadeus over the period 1983–2002.

Table 5 reports CRS providers' booking shares for total bookings made in the U.S. through CRSs, i.e. excluding all bookings that did not use a CRS. As shown in the table, Sabre's share of CRS bookings equaled approximately 45.5% in 2002. Table 5 reports the 2002 shares for Worldspan, Galileo, and Amadeus. While Sabre's share declined slightly from 1983 to 2002, Worldspan's share

Table 4. CRS Bookings as a Percentage of Total Bookings.

	1983[a]	1998	1999	2000	2001	2002
Sabre	42.8	28.7	29.0	29.5	28.2	24.6
Worldspan	12.2[b]	10.0	11.3	12.2	12.8	12.9
Galileo/Apollo	27.1	18.6	17.0	15.2	12.7	11.1
Amadeus/System One	4.1	7.1	6.0	4.6	5.1	4.3
Carrier Direct	12.0	35.5	36.6	38.6	41.3	47.1
Total	98.1	100.0	100.0	100.0	100.0	100.0

Sources: Except where noted, data source is Sabre.

[a] Source is 49 Fed. Reg. 11,649 (March 27, 1984).

[b] Represents the combined shares of DATAS II and PARS, predecessor CRSs to Worldspan.

Table 5. Bookings Shares Among CRS Providers (%).

	1983[a]	1998	1999	2000	2001	2002
Sabre	48.6	44.0	45.3	47.3	47.1	45.5
Worldspan	13.9[b]	16.6	21.2	21.2	23.4	26.3
Galileo/Apollo	30.8	27.4	23.3	23.3	20.1	19.6
Amadeus/System One	4.6	12.0	8.1	8.1	9.4	8.7
Total	97.9	100.0	100.0	100.0	100.0	100.0

Sources: Except where noted, data source is Sabre.
[a] Source: 49 Fed. Reg. 11,649 (March 27, 1984).
[b] Represents the combined shares of DATAS II and PARS, predecessor CRSs to Worldspan.

almost doubled, with much of its share gain occurring between 1998 and 2002. Galileo's share declined in the period 1983–2002, while Amadeus' share first increased, peaked in the 1990s, and has since declined.

2.3. Travel Agencies

Travel agencies provide their customers with flight and fare information, make reservations, sell tickets, and provide other ancillary services. The number of brick and mortar travel agencies in the U.S. peaked in 1994, at approximately 24,000 (National Commission to Ensure Consumer Information and Choice in the Airline Industry, 2002, p. 2; see Wilson, 2003, p. 7). During the past decade, a number of factors have affected the financial performance of these travel agencies. First, the Internet has had an impact on how consumers obtain travel information and purchase tickets. Second, airlines have eliminated base commissions paid to travel agencies and are attempting to bypass travel agents and CRSs (see, e.g. NPRM at 69,403; United Airlines, July 15, 2002; Northwest Airlines, March 19, 2002; American Airlines, March 18, 2002; Chris Isidore, March 15, 2002; Transportation Group International, July 30, 2001, p. 20. See also JetBlue Airways, 2003; see Wilson, 2003, p. 7). As a result, since 1995, the number of brick and mortar travel agencies has declined. By year-end 2001, the number had declined by 25%, from 24,000 to approximately 18,000 (American Society of Travel Agents, March 12, 2003).

The largest brick and mortar travel agencies in the U.S. in terms of volume (e.g. American Express, Navigant, and Carlson Wagonlit) focus primarily on corporate travel. In addition to providing flight and fare information and booking tickets, they assist large organizations in a variety of ways, including the development of travel policies and supplier agreements, summarizing employee

Table 6. North American Booking Shares of Top Online Agencies.

	Online Bookings as a Percent of Total Bookings (%)			Bookings Share Among Online Agencies (%)		
	2000	2001	2002	2000	2001	2002
Travelocity	2.0	2.9	3.1	41.4	32.7	28.5
Expedia	1.3	2.2	3.1	27.6	24.9	28.7
Orbitz	0.0	0.9	2.3	0.0	10.2	21.3
Other	1.5	2.9	2.3	31.0	32.2	21.5
Total	4.8	8.9	10.9	100.0	100.0	100.0

Source: Sabre. Bookings on online agencies outside the U.S. are excluded.

travel information, and providing customized reports. Medium-sized agencies often provide services to both large corporations and small businesses, while smaller agencies tend to focus on leisure travelers.

Online travel agents have achieved significant market presence since the CRS rules were last revised in 1992 (see generally Harrell Associates, 2002; Andrew Lee, 2000). These agencies are suppliers between the consumer of travel and the supplier, but they conduct business over the Internet, rather than in person or over the phone. Each online agency subscribes to one of the CRSs and provides the consumer with the same information and choices that a brick and mortar travel agency (subscribing to the same CRS) is able to provide. While most online travel agent sites have a leisure-travel focus, some are frequently used by small businesses, and some exclusively have a business travel focus. Generally, these sites offer complete trip researching and purchase capabilities, including air, hotel, and car rental. Increasingly, they sell more complex or non-traditional travel products like cruises, vacation packages, bed & breakfast stays, rental condominiums, and adventure travel. As shown in Table 6, the three largest online agencies, as measured by airline bookings, are Travelocity, Expedia, and Orbitz.

Travelocity is owned by Sabre, and its source for information regarding flight and fare data is the Sabre CRS. The Travelocity site allows the traveler to enter her travel plans, and Travelocity shows available flight options ordered by time or price, based on the user's preference. Travelocity permits the traveler to search for low fares by using alternative airports and dates, and it allows a reservation to be "held" for 24 hours where the carrier has not forbidden such a service. The website also promotes special travel and "last minute" deals.

Expedia was founded by Microsoft and is currently owned by USA Networks. Worldspan is the primary source of flight and fare information for Expedia, although Expedia has also signed separate agreements with airlines and other suppliers. Expedia offers many of the same features as Travelocity but does not offer the "reservation hold" option. Expedia has recently acquired a large, commercially-oriented travel agency to expand its presence in the corporate travel market.

Orbitz is owned by five major airlines (i.e. American, United, Northwest, Delta, and Continental) and has 37 airline associates that participate on its site.[5] Orbitz uses Worldspan for flight and fare data. Orbitz has also developed direct connections with suppliers as a means of eliminating the need for a CRS, and ten carriers have entered into direct connect arrangements (see *Aviation Daily*, 2003, p. 4). (As noted above, at least two such direct connections, with American and Northwest, have been implemented.) Combined, these ten carriers accounted for more than 77% of all U.S. enplanements in 2002. The Orbitz website allows the user the option of selecting airports within 100 miles of origin and destination as a means of finding lower fares. Orbitz uses software from ITA Associates to find and display fare information, which is the first item shown on its response screen. Passengers view prices, ranked from lowest to highest, and the number of stops on each displayed flight. The passenger then has the option of selecting a non-stop, one-stop, or multi-stop connection and may view price and schedule options for each selection. Orbitz shows fares for all major scheduled carriers except Southwest. JetBlue fares are shown on Orbitz, but the booking must be made directly with the carrier.

Each of the above online travel agencies operates as a brokerage service. They are compensated in part through commissions and promotional fees paid by travel suppliers. In some cases, they have negotiated arrangements with suppliers that allow them also to earn profit margins on air/car/hotel "package" offerings. All three major online agencies charge consumers a processing or service fee for making a reservation.

Table 7 provides information regarding the share of Sabre's total bookings contributed by the largest travel agencies using their CRS (excluding Travelocity). As shown in the table, the top ten travel agencies account for approximately 32% of Sabre's total bookings. The top 100 travel agencies account for approximately one-half of Sabre's total bookings.

Table 7. Sabre's Booking Shares by Travel Agencies.

Subscriber Travel Agency	Percentage of Sabre's Total Bookings
Top 10 total	31.6
Top 20 total	36.6
Top 100 total	49.6

Source: Sabre.

2.4. Summary

Over the last 25 years, the information suppliers in airline markets have traditionally been brick and mortar travel agencies that most often obtained their information through computer reservation systems.[6] As discussed above, however, other information suppliers have recently emerged to change this landscape. Since the CRS rules were last revised, the rapid development of the Internet has brought with it a proliferation of sources of air-travel information – namely, the various online travel agencies and the websites of the carriers themselves. The participants in the market for air-travel information continue to include such traditional sources as the four CRS operators, brick and mortar travel agencies, and the call centers of individual airlines. Joining them today, however, are web-based travel agencies like Travelocity and Expedia, which provide information directly to consumers via the Internet. In addition, every major airline, and almost every minor airline, operates a website providing schedule, fare, and ticketing information, and these have provided a means other than the telephone by which consumers can book directly with the carriers. Most recently, other sources are emerging online that seek to pool the information available through the websites of individual carriers; these new content aggregators, such as SideStep, serve consumers without relying upon a CRS.

Each of these new sources presents an alternative to the existing computer reservation systems, and each thus has the potential to discourage a CRS from increasing booking fees or from reducing the supply or quality of available information regarding air travel. An analysis of the competition faced by CRSs should therefore consider whether and to what extent the presence of these other information providers constrains the ability of a CRS to engage in anticompetitive behavior. In the sections to follow, we present an economic analysis of the current and future ability of CRS providers to charge supracompetitive prices or reduce the supply of available information, and we assess what, if any, effects the Department's proposed CRS rules will likely have in this environment.

3. OVERVIEW OF HISTORICAL AND PROPOSED CRS RULES

In this section, we briefly describe the CRS rules originally adopted in 1984, their revision in 1992, and the rules proposed in the current NPRM.

3.1. 1984 CRS Rules

The Civil Aeronautic Board's ("CAB") 1984 CRS Rules were designed to prevent "competitive abuses and consumer injury resulting from practices of those airlines that provide computer reservation services to air carriers and travel agents" (Civil Aeronautics Board, August 15, 1984, hereinafter "1984 CRS Rules"). The CAB was concerned about the actions of airlines that were vertically integrated into the CRS business because,

> [since] they are competitors in the downstream air transportation industry, they have the ability and incentive to exercise that power in ways that may interfere with air transport competition (1984 CRS Rules, Challenges to Our Basis and Purpose, I. A).

The 1984 CRS rules regulated airline-owned CRSs. The most significant regulations imposed at this time were those that: (1) prohibited display bias; (2) banned discriminatory booking fees charged to non-affiliated airlines; and (3) placed restrictions on contracts between CRSs and travel agencies ("subscriber contracts").

3.1.1. Display Bias

Airline-owned CRSs were prohibited from using any factors directly or indirectly related to airline identity when ordering information (including information regarding connecting flights) provided to travel agencies. In addition, the criteria used to order the information displayed were required to be consistent across airlines and markets. Further, airline-owned CRSs had to make available, upon request, the criteria used to order the information provided to travel agencies (see 1984 CRS Rules, § 255.4).

3.1.2. Discriminatory Booking Fees

Airline-owned CRSs were banned from discriminating among airlines with regard to fees charged for participation in the CRS. In addition, participation in the CRS could not be conditioned upon the purchase or sale of any other goods or services. Further, an airline-owned CRS had to make available, upon request, information regarding the current fee levels as well as fee arrangements with other airlines (see 1984 CRS Rules, § 255.5).

3.1.3. Subscriber Contracts

Airline-owned CRSs were banned from entering into contracts with travel agencies that exceeded five years in length. In addition, airline-owned CRSs could not directly or indirectly prohibit travel agencies from using another CRS. Further, airlines owning a CRS could not condition any commission payments to travel agencies (from the sale of tickets) on the agent's choice of CRS. Nor could an airline-owned CRS condition prices charged to travel agencies for use of the system on the identity of the airlines whose tickets were sold by the travel agency.

3.2. 1992 CRS Rules

In 1992, the DOT modified and readopted the CRS rules "because of the need to prevent the vendors from using their control of the systems to substantially reduce airline competition and to deny travel agents (and thus the traveling public) complete, accurate, and impartial information on airline services" (U.S. Department of Transportation, September 22, 1992, hereinafter "1992 CRS Rules"). The most significant modifications in the 1992 CRS Rules were: (1) the introduction of mandatory participation by airlines that own CRSs in rival CRSs; and (2) additional restrictions on subscriber contracts.

3.2.1. Mandatory Participation

Under the 1992 rules, airlines that own CRSs must participate in other CRSs as long as the other CRSs charge commercially reasonable booking fees. Booking fees are considered commercially reasonable if. (1) they do not exceed the booking fees charged by the airline-owned CRS itself or (2) they do not exceed the fees paid by the airline-owner of the CRS to another CRS (see 1992 CRS Rules, § 255.7).

3.2.2. Subscriber Contracts

Additional restrictions placed on subscriber contracts in 1992 prohibit CRSs from: (1) offering contracts longer than five years, and no longer than three years unless a contract for three years or less is offered simultaneously; (2) offering automatic contract extensions whether due to the addition/deletion of equipment or any other event; (3) requiring travel agencies to achieve a minimum volume of bookings for, or lease a minimum amount of equipment from, the CRS; and (4) restricting the use of third-party computer hardware or software in conjunction with CRS services, except as necessary to maintain CRS integrity (see 1992 CRS Rules, § 255.8).

3.3. NPRM Proposed CRS Rules

The NPRM proposes numerous changes to the 1992 CRS rules. The most significant of these proposals would: (1) expand the rules to cover independent CRSs; (2) eliminate mandatory participation by airlines that own CRSs in other CRSs; (3) eliminate the ban on discriminatory booking fees charged by CRSs to airlines; (4) impose additional restrictions on subscriber and airline contracts; and (5) impose restrictions on price advertising by airlines, CRSs, and travel agencies.

3.3.1. Expanded Coverage

The 1992 CRS rules apply only to airline-owned CRSs. The NPRM proposes to expand coverage of the rules to all CRSs (see NPRM at 69,425).

3.3.2. Additional Restrictions on Subscriber and Airline Contracts
The NPRM proposes to place additional restrictions on subscriber contracts. Specifically, CRSs are to be barred from agreeing with travel agent subscribers to contracts that would: (1) require travel agencies to pay for shortfalls in bookings upon early termination of contracts; or (2) offer prices for CRS services depending on usage levels (i.e. productivity pricing) (see NPRM at 69,427). The NPRM would also limit the ability of CRSs to require that participating carriers provide their users all their fares.

3.3.3. Restrictions on Price Advertising
The NPRM proposes that service fees charged by airlines, CRSs, or travel agencies must be listed separately from the price of air transportation until a specific itinerary is displayed (at which point the full fare must be displayed). In addition, service fees are to be considered unfair and deceptive if they: (1) exceed the greater of $20 or 10% of the fare; (2) are *ad valorem*; or (3) are not prominently displayed near the advertised fare (see NPRM at 69,428).

3.3.4. Elimination of Mandatory Participation and Discriminatory Booking Fees
The NPRM proposes to eliminate the requirement (introduced in the 1992 CRS rules) whereby all airlines that own CRSs must participate in other CRSs (see NPRM at 69,421–69,422). The NPRM also proposes to eliminate the ban on discriminatory booking fees charged by CRSs to airlines (see NPRM at 69,422).

4. MARKET DEFINITION

In this section, we define the relevant antitrust market within which we conduct our analysis of the market power issues raised in the NPRM. We begin by discussing the market definitions implicitly defined in the NPRM and then provide what we believe is the correct definition of the relevant antitrust market in this case. As discussed above, the product provided by CRSs and their competitors is information about air transportation – flights, fares, and availability.

4.1. An Analysis of the NPRM's Implicit Market Definition

The rationale for the proposals contained in the NPRM is that the CRSs have too much market power in their negotiations with airlines over booking fees. The NPRM expresses its concerns as follows:

> [T]he systems appear to have market power against airlines, because travel agencies sell 70% of all airline tickets, travel agents rely on a system for booking 90% of their domestic tickets and 80% of their international tickets, and because most travel agency offices use one system for all or almost all of their bookings.
>
> Since relatively few travel agency offices make extensive use of more than one system, most airlines have had to participate in every system in order to make their services readily saleable by the travel agents using each system. No airline can afford to lose access to a significant number of distribution outlets, as explained elsewhere in this notice. As a result, competition and market forces have not disciplined the price or quality of services offered by airline participants. The systems accordingly have established booking fees for airlines that exceed their costs of providing CRS services to the airlines (NPRM at 69,419).

Although the NPRM never defines a relevant antitrust market, this quotation suggests that the firms competing in the relevant antitrust market are limited to the four CRSs. Alternatively, the NPRM refers to CRSs as essential facilities, which necessarily is a claim that each CRS system constitutes a separate antitrust market for air-travel information. In any event, for the reasons expressed below, we do not believe that either of these two suggested markets constitutes a relevant antitrust market within which to analyze the pertinent market power issues.

The underlying assumptions in the NPRM are that consumers purchase tickets primarily from brick and mortar travel agents (and that they are unlikely to switch among channels), and that each agency is locked into a single CRS. Moreover, the quotation assumes that passengers are locked into a single travel agent and will not substitute travel agents if their travel agent provides poor information (i.e. poor service), whether because the agent receives poor information from its CRS or otherwise. As a result, the NPRM asserts CRSs are essential facilities, based on the notion that airlines have to be on every CRS or else lose access to a significant number of travel agents and, through them, to a large number of consumers. Furthermore, entry into the market for air-travel information is assumed to be difficult. Apparently based on these beliefs, the assertion is made in the NPRM that CRSs have substantial market power in establishing booking fees to airlines, which in turn increases air fares to consumers.

The NPRM generally takes the position that CRSs have substantial market power over airlines. For example, the goal in regulating subscriber contracts, as expressed in the NPRM, is to provide brick and mortar travel agent subscribers more bargaining power by permitting them to switch more easily (i.e. at low cost) between competing CRSs or to use multiple CRSs. The NPRM posits that such regulation will reduce switching costs among subscribers, thereby providing the airlines with more bargaining power. Similarly, the goal stated in the NPRM in eliminating the requirements for mandatory participation and non-discriminatory booking fees for airline-owned CRSs is to provide the airlines more bargaining power in their relationships with independent CRSs.

When travel agents and consumers have alternative means to obtain flight and fare data, the relevant antitrust market cannot be limited to CRSs. We believe, therefore, that the view of the market for air-travel information set forth in the NPRM is fundamentally flawed. We present an alternative view that recognizes that the emergence of independent CRSs and the Internet provides the market with leading competitors that lack the incentives to distort information, as had been observed in a market dominated by vertically integrated information suppliers. The Internet has allowed most consumers to bypass travel agents and their CRSs and to obtain (at very low cost) information on the flights, fares, and availability offered by airlines. We demonstrate that this alternative means of acquiring air-travel information has substantially reduced, and is likely to reduce further, any market power that the CRSs may have enjoyed previously. From a market definition perspective, this means that one cannot correctly define a relevant antitrust market for air-travel information that excludes non-CRS distribution channels.

4.2. A Theoretical Benchmark

In any city-pair market for air travel, consumers typically must choose among numerous flight and fare combinations. Price discrimination can explain the variation in fares of an individual airline, but it does not explain the variation in fares across airlines (and across time) for essentially the same product. Economists refer to variation across firms as price dispersion (see, e.g. Borenstein & Rose, 1994). The economic literature proposes a variety of models to account for price dispersion in homogenous good markets. The basic assumption of these models is that consumers lack information about prices and that it is costly for them to become informed. In some models, suppliers pay to inform consumers (via advertising) (see, e.g. Butters, 1977; McAfee, 1994; Varian, 1980). In others, consumers pay to become informed (via search costs) (see, e.g. Burdett & Judd, 1983; McAfee, 1995; Stahl, 1989, 1996).

The intuition underlying the economic models is easily grasped. If consumers are perfectly informed about products and prices, then the "law of one price" must hold. Different firms cannot charge different prices for the same product because consumers will only buy from the firm charging the lowest price. Since only firms that charge the lowest price will have any sales, all firms must charge the same price. Furthermore, that price cannot exceed marginal cost, since otherwise it will be profitable for a firm to undercut the market price slightly and capture a much larger share of the market. Thus, firms selling homogenous products in markets where consumers are perfectly informed make zero economic profits.

However, if consumers are not perfectly informed and search is costly, the competitive outcome is not achieved. If all consumers search for and obtain the lowest price, then there can be no price dispersion. But if there is no price dispersion, then consumers have no reason to search. Hence, the equilibrium in these models involves some, but not all, of the consumers searching for the lowest price and firms charging different prices above marginal cost. Firms that charge higher prices make fewer sales (i.e. they sell only to those consumers who search less). In these circumstances, the "law of one price" does not hold, and the market failure is buyers' lack of information about prices.[7]

Economic theory yields several insights relevant to airline markets. First, it explains price dispersion in airline markets. Second, it predicts that any technology that lowers search costs, such as the Internet, will lead to lower prices and more competitive airline markets. Third, the competition among airlines to sell to consumers who search (e.g. consumers with access to the Internet) lowers overall prices and benefits consumers who do not search (e.g. consumers without access to the Internet). As the portion of consumers who search increases, prices fall, and all consumers benefit. Finally, it implies that airlines have an incentive to raise consumer search costs and not to reduce them. The airlines prefer a market in which consumers are not able to compare all fares in a city-pair market. This point is particularly important to our discussion of airline-owned CRSs.

4.3. The Historical Market for Air-Travel Information

The standard model in the economic literature corresponds to airline markets in which consumers can only obtain information regarding airfares in a city-pair market by calling the airlines directly or by using the services of a travel agent to call the airlines on their behalf. The CRSs were developed by the airlines to reduce search costs for travel agents but not for consumers, since consumers did not have direct access to CRSs. This led to the market structure depicted in Fig. 1. Most consumers purchased tickets through travel agents because travel agents were the only ones that had ready access to the flight and fare information of all of the airlines. The alternative was to use the airlines' call centers, but the time costs of doing so were too high for most consumers, who would have had to call *each* airline to complete a search.

Consumers in this situation were uninformed. They had to rely upon the travel agent, and the CRS to which the agency subscribed, to select the flights that best met their needs. But the uninformed consumer gives rise to a certain "hidden action" problem, referred to by economists as the "moral hazard" problem.[8] Travel

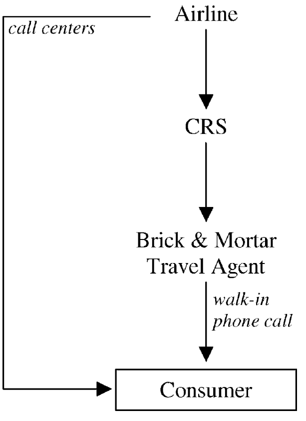

Fig. 1. Traditional Information Flow.

agents could provide less-than-best advice on flights and fares to consumers, and consumers would not be able to verify easily the quality of the advice.

The payment flows shown in Fig. 2 imply that travel agents and airline-owned CRSs had financial incentives to be less than diligent. The travel agency's revenue was derived almost exclusively from commissions paid by airlines. That revenue might include supplemental incentive payments (also referred to as "override commissions"), which airlines paid to those agents who demonstrated they could move traffic to increase their share on a particular route. Thus, travel agency compensation from a booking could vary depending upon which airline obtained the booking. Airline-owned CRSs had an obvious incentive to structure displays and booking incentives so that the travel agents gave the owner's flights and fares

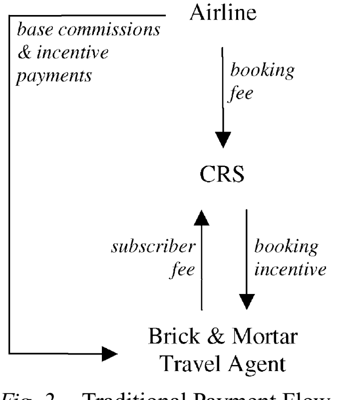

Fig. 2. Traditional Payment Flow.

preferential treatment. In fact, because the travel agencies were being paid by the CRS and airlines, they were primarily or exclusively agents for the airlines, and not for consumers.

A striking feature of Fig. 2 is that consumers did not pay directly for the information services provided by the CRS and travel agent. That is, the price of the airline ticket was the same whether the consumer purchased it directly from the airline or indirectly through the travel agent. In this sense, the consumer's cost of acquiring air-travel information was bundled into the cost of the airline ticket. Since a travel agency could more easily check the flights and fares offered by the different airlines, it is not surprising that most consumers booked their tickets through a travel agency.

In theory, the CRSs could have eliminated the search costs for consumers. In practice, they did not. One reason is that the CRSs were owned by airlines. Consistent with the predictions of the theoretical model, airlines did not want to cross-list their flight and fare information on each other's CRS such that travel agents could identify the best fare and flight combination for their customers. The Department had to force the airlines to participate on each other's CRS by imposing the mandatory participation rule of the 1992 CRS Rules.

The second reason is that, even with complete information from CRSs, travel agents have typically acted as agents for airlines rather than agents for the consumers. The Department has essentially recognized that this is so. Indeed, neither the Department nor the CAB have ever identified a travel agent's failure to provide passengers with complete information on competing alternative flights and fares, or the failure to disclose the existence of override commissions, to be unfair methods of competition or deceptive trade practices.[9] The buyers' lack of information about flights and fares continues to be the primary source of market failure in the market for air-travel information.

In sum, CRS providers were the major suppliers of air-travel information in the early- to mid-1980s. As shown in Table 8, approximately 88% of bookings during that period were made using CRSs. However, as discussed in the next section of our report, that situation has changed dramatically, with the share of total bookings accounted for by CRSs now approaching 50% and expected to continue to fall. The fundamental causes of this decline have important implications for the definition of the relevant antitrust market for air-travel information, as described in the next section.

4.4. The Current Market for Air-Travel Information

In many information markets, the Internet has largely eliminated the danger that an uninformed consumer will be deprived of the value of needed information, by

Table 8. Ticket Distribution Channel Shares (%).

North America	1983[a]	1987[b]	1998	1999	2000	2001	2002
Travel agency breakdown							
Online	0.0	0.0	0.7	2.7	4.8	8.9	10.9
Corporate	NA	NA	0.0	0.1	0.4	1.0	1.6
Brick and mortar	NA	NA	63.8	60.5	56.2	48.8	40.4
Total agency bookings	88.0	87.4	64.5	63.4	61.4	58.8	52.9
Carrier direct breakdown							
Offline/Call center	12.0	12.6	NA	34.1	33.0	31.3	31.9
Online	0.0	0.0	NA	2.5	5.6	9.9	14.0
Total carrier direct bookings	12.0	12.6	35.5	36.6	38.6	41.3	47.1

Source: Except where noted, data source is Sabre (2002 is forecast).
[a] Source is 49 Fed. Reg. 11,649 (Mar. 27, 1984).
[b] Source is 57 Fed. Reg. 43,782 (Sept. 22, 1992).

dramatically reducing the costs of acquiring and transmitting information. Instead of calling the supplier for price quotations, the buyer can obtain the supplier's list of products and prices directly from its website. The Internet has also given rise to a different kind of information supplier, the "online" travel agent. Buyers may now shop online and view lists of prices charged by *different* suppliers for products that range from hardware and software (e.g. at Shopper.com) to mortgages (e.g. at Mortgagequotes.com) (Baye & Morgan, 2001). In fact, in information markets with many brick and mortar agents, there is a market for information regarding the brick and mortar agents themselves. For example, in real estate, online agents such as Realty.com and Realtor.com provide buyers with information about real estate agents and property listings. Individual buyers who do not themselves take advantage of information on the Internet largely benefit from its existence, since it is difficult for brick and mortar agents to know whether their customer is checking up on them.

The market for air-travel information has seen similar developments. Figure 3 describes the structure of the information (and booking) flows in the market today. Consumers can, with a click of the mouse, be informed about the flights and fares of many airlines at essentially zero cost by accessing online travel agencies, or by accessing carrier websites directly, or through content aggregators such as SideStep. They can use this information to bypass the brick and mortar travel agents and book with an online agency, or to bypass the travel agents and CRSs by booking online with a carrier at its website.[10] Consumers can also use the Internet to monitor the information they receive from their travel agents.

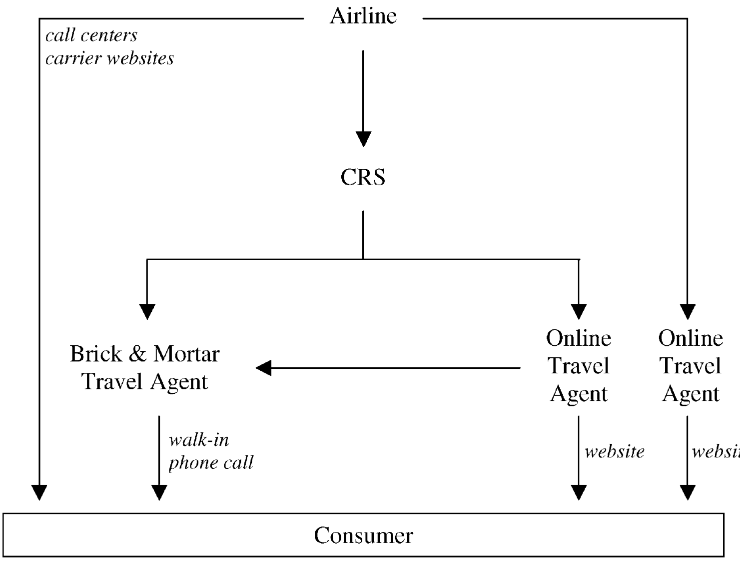

Fig. 3. Modern Information Flows.

The Internet has become an integral part of almost every travel agency.[11] According to American Society of Travel Agents ("ASTA"), no less than 98% of agencies surveyed have Internet access at their offices, up from 24% in 1995 (American Society of Travel Agents, 2002) (hereinafter "ASTA Survey"). Eighty percent of travel agencies provide Internet access for every staff member at his or her workstation (ASTA Survey, p. 3). Moreover, brick and mortar agencies increasingly use the Internet to gather travel information, with 94% of all travel agencies reporting that they have conducted research online (ASTA Survey, p. 3). Internet bookings by travel agencies are growing, with nearly 56% of ASTA agencies reporting the use of the Internet to book tickets (ASTA Survey, p. 3). Of course, not all travel agents and consumers need to access and use the Internet for this alternative to limit effectively the exercise of market power by CRSs. Competition for the marginal customer confers competitive benefits to all consumers, including those who lack access to the Internet as a travel information source.

As Fig. 3 makes clear, the Internet also works to eliminate the partially informed, less than diligent, travel agent. Travel agents can use the Internet to access online agents of competing CRSs and websites of carriers that do not participate on any CRS. Thus, travel agents are no longer locked into a single CRS, and there is no reason why they cannot find the lowest fare meeting the needs of a customer. Travel agents that fail to do so will tend to lose customers to those who do.

Table 9. Percentage of Revenues Booked Online (January 2002 to June 2002).

Airline	Percentage of Total Revenues Booked Online
Southwest	46
Delta	16
American	13
US Airways	24
United	11
Northwest	16
Continental	14
America West	43
Alaska	28

Source: PhoCusWright (2003).

The impact of the Internet on booking flows is documented in Table 8. Carrier direct ticketing has grown substantially, from only 12% of total bookings in 1983 to an estimated 47% in 2002. Some of the growth is explained by the growth of low-cost carriers such as Southwest that rely heavily on call centers. But much of the increase (probably the larger part of the increase) over the past five years is due to consumers' use of carriers' websites. Table 9 provides the share of revenues booked online for the different carriers and demonstrates that, even for carriers such as Southwest, websites are replacing call centers. Online travel agencies did not exist ten years ago, but they now account for nearly 11% of all bookings. Brick and mortar travel agents have seen their share of bookings decline from 88% in 1983 to slightly more than 40% in 2002. The trend toward online booking does not appear to be slowing. In fact, it is likely to continue as carriers increasingly use "web fares," boarding passes, and frequent flyer miles to make their websites more attractive to consumers.

The travel agents, of course, may not earn as much by booking on a competing CRS or a carrier website. Indeed, in the traditional market structure, they earned nothing. Therefore, it is not surprising to find that compensation for travel agents has changed with the advent of the Internet (see Fig. 4). Airlines no longer pay base commissions to travel agents, and, as discussed more fully below, travel agents' subscriber fees to CRSs are often more than offset by the incentive payments paid to them. The travel agencies' main sources of income from the sale of airline tickets are the service fees paid by consumers and the booking incentives that CRSs pay to agents as an incentive to book through them whenever feasible. Competitive pressure from informed consumers has forced travel agents to act as their agents rather than as agents for the CRS or airlines, and to be paid accordingly.

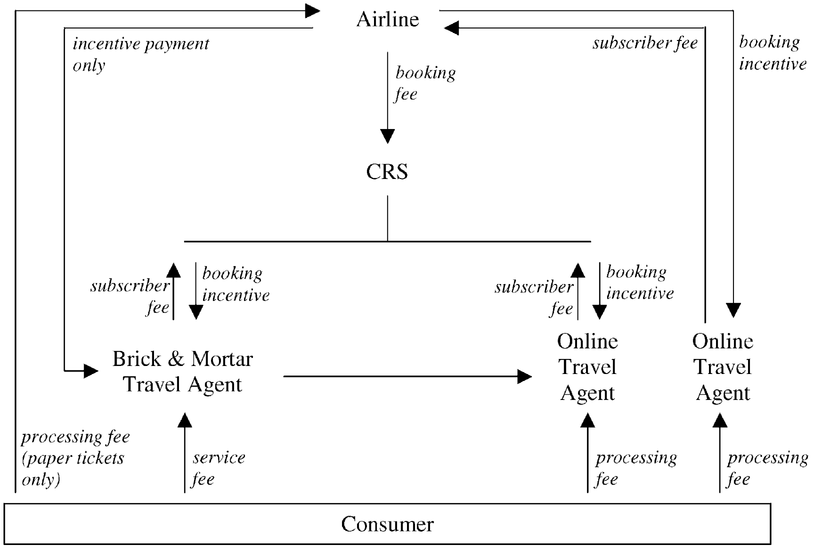

Fig. 4. Modern Payment Flows.

The Internet has also dramatically changed the way in which CRSs compete with each other. In the traditional market, CRSs competed for travel agents. In the modern market, although CRSs do not sell directly to the traveling public, they have established or supported online travel agencies to assure access to consumers directly. If Sabre hosts more flights and fares than Worldspan, then Travelocity is offering a higher quality product than is Expedia, all else constant, and *all* consumers should switch to Travelocity. Assuming other characteristics of the service offerings are the same, there is no reason for an informed consumer to click on Expedia if Travelocity contains information relating not only to the flights and fares on Expedia but also to flights and fares of other airlines. The same basic logic applies to brick and mortar travel agencies. Travel agents of agencies that subscribe to Worldspan would have to check Travelocity and book online if the carrier offering the best flight-time-fare combination for the customer is not a participant in Worldspan. If this hypothetical situation continued, the agencies would eventually subscribe to Sabre.

Thus, contrary to the view expressed in the NPRM, the evidence suggests that: (1) consumers no longer purchase tickets blindly from brick and mortar agents, but increasingly bypass travel agents (and CRSs) by checking alternatives or by booking online; and (2) travel agencies with Internet access are not locked into a single CRS, since they can query and book on carrier websites and competing

CRSs via their online agencies. Airlines do not have to be on every CRS to gain access to consumers and their agents. At most, they need to be on a single CRS with an online agency. We conclude, therefore, that CRSs are not essential facilities.[12]

Southwest and JetBlue are examples that support our analysis. Southwest, an airline that has grown and successfully entered many city-pair markets, uses Sabre as its only CRS (at a lower level of functionality) and increasingly sells its tickets directly on its own website (NPRM at 69,379). Southwest does not rely on Travelocity since its flights cannot be booked through that online agency. JetBlue is also on only one of the CRSs. Apparently, these airlines believe that a single CRS with an online agency, in combination with their own websites and call centers, is sufficient to access consumers.

Internet sources such as airline websites and online travel agencies provide alternative sources of information regarding airline flights and fares and the ability to book tickets. Therefore, they must be considered substitutes to the traditional CRS/travel agency channel. Indeed, the discussion above demonstrates that they are particularly important substitutes, in that their emergence has significantly changed the market for air-travel information. These new information sources (i.e. airline websites and online travel agents) provide a significant competitive constraint on travel agents and CRSs. The view implicit in the NPRM is that the relevant antitrust market is limited to the traditional CRS/travel agency channel. This view is wrong. An antitrust market defined to include only CRSs, or only an individual CRS, is not economically meaningful, because it ignores the presence and effect of substitute sources of air-travel information that have gained widespread use.

In this regard, it is worth recalling how the U.S. Department of Justice and Federal Trade Commission's "Horizontal Merger Guidelines" define relevant antitrust markets (see, U.S. Department of Justice and Federal Trade Commission, HORIZONTAL MERGER GUIDELINES (revised April 8, 1997) (hereinafter "Merger Guidelines")). The Merger Guidelines state: "Market definition focuses solely on demand substitution factors – i.e. possible consumer responses" (Merger Guidelines, at § 1.0). Thus, the Guidelines define an antitrust market as:

> a product or group of products and a geographic area in which it is produced or sold such that a hypothetical profit-maximizing firm, not subject to price regulation, that was the only present and future producer or seller of those products in that area likely would impose at least a "small but significant and non-transitory" increase in price, assuming the terms of sale of all other products are held constant. A relevant market is a group of products and geographic area that is no bigger than necessary to satisfy this test (Merger Guidelines, at § 1.0).

For the reasons discussed above, we conclude that the relevant antitrust market is "air-travel information."

5. MARKET STRUCTURE

As discussed in the Merger Guidelines, having defined the relevant antitrust market, the next step is to identify the firms that compete in that market, to determine the competitive constraints on the firm asserted to have market power. Participants in this information market include: CRS providers and their travel agency subscribers (both brick and mortar and online), online travel agencies not subscribing to CRSs, the websites and call centers of individual airlines, and content aggregators like SideStep. Travel agencies and consumers view each of these alternative sources of air-travel information as reasonably interchangeable in use. As demonstrated above, the share of total bookings made via CRS systems has declined considerably since the early 1980s, such that CRSs now account for only about one-half of total bookings.

Table 10 reports concentration in the market for air-travel information using the HHI. As discussed above, the providers of air-travel information include CRS providers and their travel agencies (both brick and mortar and online),

Table 10. Market for Air-Travel Information Herfindahl-Hirschman Index (2002).

Provider	Share of Total US Bookings	Square Share
CRS/Travel agency channel[a]		
Sabre	24.6	605.2
Worldspan	12.9	166.4
Galileo	11.1	123.2
Amadeus	4.3	18.5
Carrier direct channel[b]		
American	8.4	71.1
Delta	8.2	67.2
Southwest	5.7	33.0
United	5.7	33.0
Northwest	4.4	19.2
Continental	44.1	16.8
U.S. airways	4.0	16.0
America west	1.5	2.1
Others	5.0	25.4
HHI		1,197

[a] See Table 4.

[b] As shown in Table 4, the carrier-direct channel accounted for 47.1% of U.S. bookings in 2002. Bookings shares for individual carriers are assigned using airline shares of U.S. enplanements (see Table 1).

online travel agencies not subscribing to CRSs, and the websites and call centers of individual airlines. We assume the travel agency channel, which accounts for approximately 53% of total U.S. bookings, is served by the four CRSs (i.e. we adopt a conservative approach and ignore online travel agencies that bypass CRSs). Unfortunately, information is not available for the carrier direct bookings of individual airlines. Therefore, we estimate these bookings shares based on the assumption that the relative bookings shares of individual carriers can be approximated by their relative shares of U.S. enplanements. Based on this assumption, the HHI in the market for air-travel information equals approximately 1,197, or the equivalent of 8.4 equal-size firms.[13] Within the defined market, Sabre's share is approximately 24.6%, which does not represent a predominant share of the market. These statistics demonstrate that the relevant market is only moderately concentrated, according to the criteria in the Merger Guidelines.

An additional structural characteristic of the air-travel information market is the ability of new firms to enter. Strong evidence here shows that entry barriers are low. Recall that Orbitz has announced plans to connect directly with airlines, bypassing Worldspan, and has signed agreements to connect directly with ten carriers, including American, America West, Continental, Delta, Northwest, United, and U.S. Airways, which collectively account for approximately 68% of U.S. enplanements. At present, Orbitz has implemented such direct connections for American and Northwest. The ability of Orbitz to create a new source of air-travel information, completely bypassing existing CRSs and yet at the same time aggregating the flight and fare information of numerous air carriers, demonstrates the lack of entry barriers into this market. The existence of low barriers to entry is a further structural characteristic of the market that demonstrates its competitive nature.

The NPRM asserts that CRSs have been able to maintain "high" booking fees (and therefore have market power). The NPRM's apparent justifications for the belief that booking fees are "high" are its views that "participation in each system is necessary" (NPRM at 69,370) and that "the decline in computer-related costs suggests that the system's costs of serving the airlines could be increasing at a rate lower than the general inflation rate."[14] While the assertion in the NPRM is that "systems usually increase their fees annually," it fails to consider the extent to which the costs of CRS providers have also risen.

In discussing the costs imposed by system practices, the observation in the NPRM is that the "fees charged by airlines have not been effectively disciplined by competition and may well exceed system costs by a significant amount" (NPRM at 69,382). But the support in the NPRM for this statement is a March 1991 study. Of course, such a study, even if correct at the time, pre-dates the widespread use of the Internet, which has provided a bypass alternative to CRSs, and pre-dates the emergence of independent CRSs. The presence of the Internet permits the airlines to exert pressure on the CRSs to keep booking fees low. Since the netback price to the airline equals the ticket price less booking fees, it is profitable for an airline to post special "web fares" on its website that are lower than the fares it provides to the CRS but higher than its netback price (i.e. the price of a ticket sold using the CRS less booking fees). Web fares induce consumers to check the airline's website and encourage them to book direct. Although web fares typically account for only 2% of bookings, the presence of web fares has certainly contributed to the growing use of the Internet by consumers.

The effect of web fares on booking fees is demonstrated by the booking fee reductions proposed by Sabre and Galileo. In particular, Sabre's concern that its travel agency clients will lose bookings to airline-owned websites or to Orbitz resulted in its proposal to reduce booking fees on all flights by 10% (and to freeze booking fees at this level for three years) in exchange for the carrier's agreement to provide all of its web fares to Sabre and its travel agency clients and to provide other protections to those Sabre users.[15] U.S. Airways and other several smaller carriers have accepted Sabre's offer. United Airlines and U.S. Airways have accepted a similar offer made by Galileo.

The NPRM conjectures that CRS costs should be falling because of an unspecified "decline in computer-related costs." While the cost of computer processing of a single bit of data has indeed fallen over time, total computer costs of CRS providers have in fact increased. This increase in cost is attributable to the same market developments that have made CRSs face new competition. Between 1993 and 2002, Sabre's data processing cost per message declined. However, during this same period, the number of messages Sabre processed per booking increased by more than 119% (Wilson, 2003, p. 14). The increase in messages is derived from consumers' frequent querying of on-line travel agencies to search for lower fares, and our traditional travel agents increasing their queries to seek discount fares for their clients. As a result, Sabre's data processing cost per booking increased between 1993 and 2002, despite the reduction in data processing cost per message.

Another important component of Sabre's variable expenses – incentive payments by Sabre to travel agencies less subscriber charges paid by travel agencies to Sabre – has also increased dramatically. Prior to 1996, Sabre subscriber fees exceeded the incentive payments made to travel agencies. However, beginning in the mid-1990s, incentive payments to travel agencies began to exceed subscriber fees. As Galileo told the National Commission, travel agent incentives now exceed $1 per booking. Sabre's experience has been similar (see Wilson, 2003, pp. 16–17).

Taking the above cost factors into account (i.e. the decline in data processing costs, the increase in messages per booking, and the increase in net travel agency incentive payments per booking), Sabre's variable expenses per booking increased by at least 76% from 1983 to 2002, or at least 9% per year on average.

Thus, Sabre's variable expenses have increased more rapidly than its booking fees over the past five years. This finding refutes the claim that Sabre has substantial market power, as well as the NPRM's reliance on high or increasing booking fees as evidence of CRS market power.

6. ECONOMIC ANALYSIS OF THE NPRM

In this section, we provide our economic analysis of the CRS rules proposed in the NPRM. We specifically assess the rationale expressed in the NPRM regarding: (1) the continued regulation of subscriber contracts and CRS displays; and (2) the elimination of the mandatory participation and non-discrimination rules on airline-owned CRSs.

The threshold question that needs to be asked in considering whether regulation is necessary or advisable here is: What are the market failures that the rules in the NPRM are trying to correct? This question is salient for two reasons. First, like most economists, we believe that regulation can improve market outcomes only if the conditions for a competitive market fail to be present, since competitive markets allocate resources efficiently. Therefore, the presence of a market failure is a necessary condition for regulation. However, it may not be a sufficient condition. Regulation is costly and creates its own distortions.[16] Suppliers in regulated markets typically have poor incentives to reduce costs and to invest in innovation. They may also be required by regulation to adopt inefficient technologies. For example, when the markets for air travel were regulated, airlines were effectively compelled to adopt networks that failed to take advantage of the economies of density of hub-and-spoke networks. Therefore, the second reason for identifying the market failures that the rules proposed in the NPRM seek to address is to ensure that these rules are targeting problems, not symptoms of regulation itself, and are not making matters worse.

We observe that the Internet largely solves the market failures that motivate many of the existing and proposed CRS rules. The Internet enables most consumers to be perfectly informed buyers of air travel services at relatively low cost. Informed consumers will force travel agents and CRSs to be diligent and honest. As noted above, not all consumers have the capacity or the ability to take advantage of the Internet. However, the interests of these consumers are effectively protected by the ability of most consumers to verify independently air-travel information.

The economic theory described above predicts that overall airline fares and profits will decline as use of the Internet grows. The number of travel agents and their profits will decline, since many consumers will act as his or her own travel agent. Finally, increased pressure will be placed upon CRS profit margins, from below by travel agents demanding payment to book through the CRS rather than via the Internet, and from above by airlines whose cost of not participating on a CRS has fallen.

6.1. Analysis and Policy Recommendations Regarding Rules Governing Subscriber Contracts and Display Bias

In this section, we examine the specific rules on subscriber contracts and display bias proposed by NPRM. The regulations proposed in the NPRM are largely superfluous because of changes in market conditions that have already occurred. The principal regulation that should be retained, as long as a significant CRS is controlled by major airlines, is mandatory participation. Unfortunately, the NPRM proposes to revoke that regulation, which continues to be needed to the extent that any CRS is owned or controlled by one or more major airlines and any CRS rules exist.

6.1.1. Subscriber Contracts

Traditional subscriber contracts between CRSs and brick and mortar travel agencies contained provisions governing subscriber fees and incentive payments, exclusivity, minimum booking requirements, equipment leasing, and early termination penalties. We discuss, in turn, the changes in these contract terms that have occurred in recent years.

6.1.1.1. Subscription fees and incentive payments. Subscription fees have been substantially reduced relative to the incentive payments provided to travel agencies. Since 1996, Sabre subscribers, on average, have received incentive payments that exceed their subscription fees. Sabre provides travel agents per-booking incentive payments as well as substantial up-front payments to travel agencies at the beginning of their contract term.

Other changes in contract terms are best understood with reference to the type of contracts Sabre is currently offering: the Optimal Earnings Plan (“OEP”) and the Simplicity Plan. The OEP is tailored to the needs of larger travel agencies (agencies with more than 10,000 annual bookings), while the Simplicity Plan is tailored to smaller agencies. Currently, 39% of Sabre’s subscriber contracts are of the new types, a percentage that is expected to rise to 67% by the end of 2004 and to 100% by 2006.[17] Sabre’s largest subscriber agencies tend to use multiple CRSs and have individually negotiated arrangements with Sabre.

6.1.1.2. Minimum booking and exclusivity requirements. Contracts with minimum booking requirements (also referred to as productivity pricing) provide travel agencies with discounts for system charges and equipment rental if the agency meets a threshold minimum booking level for each terminal. Sabre's Simplicity Plan offers an incentive payment on all bookings if the agency achieves 1,000 bookings annually (Sabre Holding Corp., January 24, 2003, p. 10). If an agency appears unable to meet the 1,000-booking requirement, the agent is permitted to become a member of the Nexion collection of travel agents and avoid any penalty shortfalls.[18] There is no minimum-booking requirement in Sabre's OEP contract (Sabre Holding Corp., January 24, 2003, p. 5).

The ASTA survey indicates that, across all four CRS providers, minimum booking requirements for incentive payments have fallen significantly over time. Minimum segment booking requirements for Galileo subscribers (per terminal per month) has fallen from 348 segment bookings in 1998 to 217 segment bookings 2002, a decline of approximately 37% (ASTA Survey, p. 38). During the same time period, minimum segment booking requirements on Sabre, Amadeus, and Worldspan declined by approximately 31, 18, and 13%, respectively (ASTA Survey, p. 38).

The ASTA survey finds that productivity pricing in travel agencies' contracts has declined sharply from 1998 to 2002. According to ASTA, 90.7% of all agencies utilized this pricing option in 1998, but this figure declined to 55.8% in 2002 (ASTA Survey p. 36). As noted by ASTA, this decrease has been matched by the rise in the number of agencies opting for a fixed monthly payment. In 1998, approximately 7% of the agencies surveyed operated under a fixed payment plan as compared to 22% today (ASTA Survey, p. 36). According to ASTA, the surge in Internet booking sites with reservation capabilities and the airline commission cuts both contributed to the agency's decision to select the fixed-payment option.

With respect to exclusivity provisions, Sabre's Simplicity Plan requires that all CRS booking must be made on Sabre; however, the plan permits agencies to use the Internet, as does the OEP contract (Sabre, Jan. 24, 2003, p. 4). Previous Sabre contracts did not permit the travel agent to use a terminal provided by Sabre to access other CRSs or the Internet. While there are such provisions in the older Sabre contracts, we understand that currently these provisions are no longer enforced. Thus, Sabre subscribers can obtain flight and fare information through Sabre but then book directly with an airline via the Internet. In this scenario, Sabre would not earn a booking fee.

Currently, each of Sabre's ten largest agencies (defined by bookings) has access to multiple CRSs. These agencies account for 32% of Sabre's total bookings. Fifty-four percent of Sabre's 100 largest agencies (accounting for 42% of Sabre's total bookings) have access to multiple CRSs.[19]

The view expressed in the NPRM is that minimum booking provisions may be anticompetitive because they discourage travel agencies from using multiple

CRSs or other databases for bookings (see NPRM at 69,408). The NPRM states that CRSs "set the booking quota high enough that the agency as a practical matter cannot afford to make substantial use of another system or database" (NPRM at 69,408). Minimum booking requirements are essentially volume discounts. While minimum use provisions may encourage a travel agency to use a single CRS, this is not anticompetitive in and of itself. In arguing that minimum booking clauses (i.e. volume discounts) are anticompetitive, the views expressed in the NPRM ignore the competition among CRSs for subscriber contracts and the impact of the Internet. Travel agents, who themselves must compete for passengers, are unlikely to agree to restrictive minimum booking requirements that would prevent them from serving their customers' best interests. The empirical evidence presented above supports this conclusion, since minimum booking requirements have become less restrictive over time. Moreover, in addition to the cost of regulation, banning volume discounts could also prevent more efficient market outcomes (see, e.g. Varian, 1985).

A concern is expressed in the NPRM regarding contract provisions that "limit the ability of most travel agencies to use multiple systems and other means of obtaining airline information and booking airline seats" (i.e. exclusivity clauses) (NPRM at 69,406). Once again, if exclusivity clauses prevent travel agents from serving their customers, the agents are unlikely to agree to such provisions. In fact, as noted above, Sabre does not currently enforce exclusivity clauses for use of its hardware in its older contracts, and its Optimal Earning Plan contracts do not contain exclusivity clauses. Moreover, exclusivity provisions have the potential to promote economic efficiency by preventing incentive conflicts that can arise when a travel agency represents more than one CRS (see, e.g. Bernheim & Whinston, 1998). A CRS may choose not to undertake an investment in a travel agency if that investment would benefit a rival CRS, even when the investment would otherwise enhance economic efficiency.

6.1.1.3. Contract duration. With respect to contract duration, the OEP provides agencies with a choice of contract durations ranging from one to five years. The average contract length for OEP subscribers is four years, with half of the OEP contracts having a three-year duration. The Simplicity Plan has a three-year duration (Sabre, Jan. 24, 2003, p. 5).

The term of Sabre's new contracts are consistent with the findings on contract terms reported in a recent ASTA survey. According to the survey, from 1998 to 2002, the fraction of travel agents with five-year contracts declined from 84.7 to 47.2% while the fraction of agents with three-year contracts increased from 9.3 to 39.2% (ASTA Survey, p. 35). In addition, contracts for "other" durations (largely contracts shorter than three years) increased from 5.9 to 13.6% over the same time period (see Table 11).

Table 11. CRS Contract Length Reported by ASTA Agencies.

Contract Length	% of Responding Agencies				
	1998	1999	2000	2001	2002
3 Years	9.3	10.7	26.4	39.8	39.2
5 Years	84.7	81.7	64.9	51.5	47.2
Other[a]	5.9	7.9	8.7	8.7	13.6

Note: An examination of the expiration dates of Sabre's subscriber contracts reveals that, as of December 2002, approximately 18% of Sabre's subscriber contracts were due to expire within one year. In addition, approximately 23% of Sabre's subscriber contracts were due to expire between one to two years. Thus, as of December 2002, approximately 41% of Sabre's subscriber contracts were due to expire within two years. (Source: Sabre.)

Source: ASTA, Agency Automation 2002, p. 35 (October 2002).

[a] Virtually all respondents choosing the "other" option reported contract lengths of less than three years.

In the NPRM, the DOT states that long-term contracts can harm travel agencies because such contracts may prevent travel agencies from switching between CRSs (see NPRM at 69,407). As discussed below, however, not all contracts have the same effective dates or durations. A substantial portion of Sabre's subscriber contracts expire each year. If, as is likely, a significant fraction of travel agencies are not locked into a CRS at any given time (because of contract expirations), then it is unclear how consumers can be harmed by long-term contracts. We note also that, in a market with informed consumers and competition, travel agents are unlikely to agree to contract durations that are not in the best interest of their customers. Travel agents that fail to serve customers well are eventually driven from the market. The evidence presented in Table 11 supports this conclusion. On the other hand, regulating contract duration does have undesirable costs. In addition to the cost of regulation, as noted by the DOT in the NPRM, contracts can provide economic benefits by reducing uncertainty, helping to spread risk, and reducing contract negotiation costs (see NPRM at 69,407).

6.1.1.4. Equipment leasing. With respect to equipment leasing provisions, prior CRS contracts were structured such that when a travel agency added a terminal, it was required to sign a new contract with the CRS. However, the addition of a terminal to a travel agency location does not trigger an increase in the duration of Sabre's new contracts. While there are such provisions in the older Sabre contracts, we understand that currently these provisions are not enforced.

Although Sabre continues to lease equipment to travel agencies with OEP contracts, Sabre encourages the agencies to purchase their own hardware. For example, if a subscriber breaks the equipment lease, the subscriber must pay a fee to Sabre. However, the fee is waived if the leased equipment is replaced with subscriber-owned equipment. Sabre also provides a "technology fund" to the agents in the Simplicity Plan contracts that subsidizes an agency's purchases of its own equipment. In any event, Sabre currently provides less than 35% of the hardware its subscribers use, so there is no possible danger of this large segment of Sabre-using agencies being "locked out" of the Internet or other systems.

6.1.1.5. Early termination penalties. Finally, contracts with early termination provisions require the terminating subscriber to compensate the CRS for lost booking fees. Sabre's OEP contracts do not include liquidated damages or penalties for early termination.[20] Sabre's Simplicity Plan members can terminate their contracts without penalty if they become part of Nexion, a collective involving multiple CRSs.

The views expressed in the NPRM indicate a concern regarding the use of early termination penalties (i.e. liquidated damages clauses) because they "deter travel agencies from switching systems and make the travel agency liable for the booking fees lost by the system when the agency no longer uses it" (NPRM at 69,407). If consumers are informed and there is competition among CRSs, then travel agents will not accept liquidated damages clauses in subscriber contracts that restrict their behavior. In addition, clauses stipulating liquidated damages have the potential to promote efficiency by protecting relationship-specific investments (see, e.g. Williamson, 1985). Specifically, the ability to recoup some investment upon early contract termination will tend to encourage CRSs to offer up-front cash payments, technology funds, and the like, thereby increasing competition among CRSs for travel agents. The proposed regulation thus would have the opposite effect from the one apparently intended in the NPRM; it will reduce, rather than increase, innovation and competition among CRSs for travel agents.

6.1.1.6. Subscriber switching. According to ASTA, there is competition among CRSs for subscriber contracts, with nearly 76% of travel agencies surveyed planning to seek competing bids once their contracts expire (see Tables 12 and 13).

Of course, not all of a CRS's subscriber contracts expire at the same time because not all contracts have the same effective date or duration. Thus, some fraction of a CRS's subscriber contracts may be expected to expire in any give time period. If, as is likely, a significant fraction of each CRS's subscriber contracts expires each year, then a significant portion of that market is open to bid in each period. ASTA reports that approximately 61% of agents have not decided to renew their contracts once they expire (ASTA Survey at 5). Price and contract length are the top two factors the agents say they will consider in reviewing competitive bids.

Table 12. Percent of Travel Agencies Surveyed Planning to Seek Competing Bids Once Contract Expires.

	Will Seek Competing Bid (%)	Will Not Seek Competing Bid (%)
Galileo	78.6	21.4
Sabre	72.7	27.3
Amadeus	54.2	45.8
Worldspan	90.7	9.3
Overall	75.6	24.4

Source: ASTA, Agency Automation 2002, p. 49 (October 2002).

In sum, the ability of consumers of air-travel information to bypass CRSs, and the emergence of independent CRSs, has forced those systems to compete vigorously for travel agencies. The resulting competition has led to contracts between CRSs and travel agencies that already have the characteristics that the NPRM seeks to enforce through regulation. Thus, market forces have largely eliminated any economic rationale for the regulations. The evidence presented above indicates that there is substantial competition at the time contracts are renewed, and the large percentage of travel agencies switching between CRSs belies any lock-in effect. Competition for contracts eliminates the need to regulate the contract provisions. Competition among CRS for travel agents and the availability of the Internet as a bypass option implies those travel agents seeking to maximize "override payments" by misinforming consumers will lose customers to those that act with the interest of the consumer in mind.

Table 13. Sabre's Booking Fees.

Year	Average Booking Fees ($ 1993)[a]
1993	1.00
1994	1.04
1995	1.08
1996	1.10
1997	1.14
1998	1.21
1999	1.23
2000	1.25
2001	1.35
2002	1.35

Sources: Sabre Holding Corporation and Consumer Price Index – All Urban Consumers, Series Id. CUUR0000SA0, Bureau of Labor Statistics, United States Department of Labor.

[a] Average booking fee equals annual airline booking revenues divided by annual airline bookings.

6.1.2. Display Bias

CRSs are required to provide neutral screens to brick and mortar travel agencies. They are prohibited from using any factors relating to airline identity in ordering flight and fare information, and they must also make available upon request the criteria used to order the information. However, online travel agents can and do present flight and fare information in ways that feature certain airlines. Presumably, the view expressed in the NPRM is that online consumers do not need to be protected from preferential displays by online travel agencies because these consumers are not misled by the display or, if they are deceived, the DOT can use its authority under Section 411 to stop deceptive displays. But if the brick and mortar travel agent is acting on behalf of the consumer, then the same logic should apply to these agencies. Therefore, in our view, regulations regarding display bias are no longer economically justified.

6.2. Analysis and Policy Recommendations Regarding Mandatory Participation and Non-Discriminatory Booking Fees

As noted in the previous sections, the proliferation of Internet-based sources and the recent emergence of multiple independent CRSs have together led to the development of a competitive market for air-travel information. As we demonstrate below, however, the presence of online information sources is not by itself sufficient to ensure the continued competitiveness of these markets. Certain protections are still needed.

The NPRM expresses the view that removal of the mandatory participation requirement and non-discriminatory booking fees is necessary to limit the market power of the independent CRSs over airlines. In this section, contrary to the view expressed in the NPRM, we present evidence that the Internet has already limited the market power of CRSs. We also argue that, if the proposals in the NPRM were adopted, CRSs owned by airlines are likely to become dominant, to the detriment of consumers. This is because airlines that own CRSs will have a strong incentive to withdraw information from independent CRSs. This conduct would harm consumers because it would serve to balkanize information markets, create higher search costs for consumers, and may act as an entry barrier to emerging airlines that may be less able to inform consumers of their presence.

6.2.1. Implications of Eliminating Mandatory Participation and Non-Discriminatory Booking Fees

The rationale given in the NPRM for eliminating the mandatory and non-discrimination rules is that it will limit the market power of the CRSs and lower booking fees:

> Our proposed ending of the mandatory participation requirement and the prohibition against discriminatory booking fees may enable some airlines at least to bargain for better terms for system participation. These changes may also enable the systems to offer better terms to airlines that might otherwise choose not to participate (or choose to participate only at a low level), like some new-entrant airlines (NPRM at 69,422).

Our main concern with this proposal is that it gives airline owners of CRSs too much market power, both in the market for air-travel information and in the product markets that it serves, the markets for air-travel services. If airlines that control CRSs can withdraw from independent CRSs (or threaten to do so and demand discriminatorily low booking fees, compared to other airlines, in exchange for participating in independent CRSs), independent CRSs may have to reintegrate with airlines to compete effectively. And, in the absence of robust competition from independent CRSs, the airline-owned CRSs are likely to deter entry of new-entrant airlines by charging them excessive booking fees.

The mandatory participation rule was introduced in the 1992 CRS Rules because the DOT recognized that airlines that own CRSs have an incentive to withhold their flight information from rival CRSs. By withdrawing from a rival CRS, an airline could both degrade the utility of competing systems and make its affiliated CRS more valuable to subscribers, particularly in the airline’s hub cities where it was essential for travel agencies to have access to the airline’s flights and fares. Although the airline would lose bookings on the rival CRS, the loss in bookings could be outweighed by the gain in subscribers experienced by the airline’s affiliated CRS (which in turn would increase the airline’s bookings, at least in its hub markets).

The incentive for airlines who own CRSs to withdraw their flight information from rival CRSs is much greater today than it was in 1992. At that time, an airline would lose a significant number of bookings if it de-listed from a CRS. Most travel agencies using that CRS would simply book customers on the other airlines participating in the system. In 2003, the losses are likely to be much smaller because consumers are no longer dependent upon travel agents for their bookings, and because travel agents are no longer locked into their CRS. Online customers can access the airline’s flight information by checking the carrier’s website or the online travel agent of the airline’s affiliated CRS, and travel agents can do the same. In other words, the airline’s delisting from a rival CRS is unlikely to change the information that consumers and travel agents have about flights and fares. But, if this is the case, then consumers and travel agents will continue to make the same choices, and the airline will not lose any bookings.[21]

On the other hand, the airline will enjoy substantial revenue gains from the delisting. First, it saves on booking fees by requiring consumers and travel agents to book their flights on its affiliated CRS rather than on the rival CRS. Second, it devalues the product offered by the rival CRS and enhances that of its affiliated CRS. As a result, more consumers are likely to use the airline's affiliated CRS, thereby increasing its share of all bookings. Over time, the affiliated CRS is also likely to increase its share of travel agencies and possibly gain the market power it needs to raise its booking fees to unaffiliated airlines.

To illustrate this point further, assume that every airline listed on Worldspan is also on Sabre and available to the CRS's respective online travel agency subscribers, so online consumers are indifferent between using Expedia or Travelocity. Now suppose that the owners of Worldspan decide to withdraw from Sabre. Online consumers will surely switch from using Travelocity to Expedia since Expedia is offering more comprehensive coverage of flights and fares than is Travelocity. Travel agents that subscribe to Sabre will also have to check with Expedia and book with the owners of Worldspan if they offer better flights. Thus, even though airline bookings are not affected, Worldspan's share of bookings has increased dramatically at Sabre's expense.

The above analysis suggests that eliminating the mandatory participation rule could take the "independence" out of independent CRSs. Sabre and Galileo would have to reintegrate with airlines to protect themselves against an airline-owned CRS like Worldspan. With airline owners, Sabre and Galileo could then threaten to withdraw flights of their owners from Worldspan if the owners of Worldspan try to withdraw their flights from Sabre. If bookings shares of the owners of the different airline-owned CRSs are roughly equal, these threats would offset each other. However, independent CRSs have no such leverage.

How are consumers harmed if every CRS is owned by airlines? First, airlines prefer to sell their services in a market in which consumers are not fully informed about prices and products. This is one of the fundamental insights of the search models discussed in an earlier section of this report. Airlines can charge higher fares and earn higher profits if consumers are not fully informed about flights and fares and search is costly. Competition may force airlines to cross-list their flights on each other's CRSs, thereby providing comprehensive coverage of flights and fares. But another possible outcome is the balkanization of the information market in which airlines participate only in their own CRS and not in any of the rival CRSs. This outcome would increase search costs to consumers and travel agents: since they would have to check multiple websites instead of just one.

Second, if the market includes only airline-owned CRSs *and* the CRSs are allowed to price discriminate, then the market returns to the pre-1984 state. The 1984 CRS Rules banned discriminatory booking fees to restrain airline-owned CRSs from providing their airline owners with a competitive advantage over rival airlines by charging non-affiliated airlines higher booking fees, thereby raising the non-affiliated rivals' costs. As noted by Civil Aeronautics Board:

> Before the Board prohibited discriminatory booking fees, vendors compelled the least-favored carriers to pay as much as $3 per booking while other carriers paid as little as thirty cents – and the disfavored carriers usually received the worst service, since their flights were subject to the most display bias . . .. The carriers paying the highest fees and suffering the most display bias tended to be the vendor's major competitors (1992 CRS Rules, Booking Fees, IV.B (internal citations omitted)).

At the time, the CAB chose not to regulate the level of booking fees because it felt that, although CRSs had the power to impose excessive fees on smaller airlines, the bargaining power of the larger airlines combined with the ban on discriminatory booking fees would be sufficient to prevent CRSs from charging excessive booking fees.

We believe that, to some extent, the logic of the 1984 CRS Rulings still applies. Contrary to the view expressed in the NPRM, small airlines and new-entrant airlines are unlikely to win "better terms" from airline-owned CRSs. The airline-owned CRSs have no incentive to list an emerging airline that diverts bookings away from owners. Entry costs are lower than they were in 1984 because the Internet has reduced the search costs for consumers and travel agents, but they are not zero. The reduced competition in airline markets implies marginally higher fares and, perhaps, fewer choices.

The analysis changes dramatically when the market for air-travel information includes an independent CRS. The reason is that the independent CRS and consumers share a common interest in making sure that the CRS provides the most comprehensive coverage of flights possible. Consumers want a system that offers comprehensive coverage because it allows them to find the best product with only one click of the mouse. An independent CRS wants comprehensive coverage because more flights means more bookings, and booking fees are its main source of revenue, not airline tickets. Independent CRSs are indifferent to ticket price, as their compensation is on a flat booking fee basis. Therefore, the independent CRS has a strong incentive to list new-entrant airlines onto its system and to maximize volume (not price) of airline tickets.

The non-discrimination rule eliminates charging different booking fees for the same service level but it does not prohibit charging different booking fees for different service levels. Currently, the CRSs have gained some flexibility in their negotiations with the airlines by offering a lower booking fee for a lower level of service. The number of days of seat inventories stored, the speed of access the CRS gives to the airlines' reservations computers, the management information the CRS generates for the airline, and the geographical coverage the CRS offers all vary according to the airline's contract with CRS. For example, Worldspan recently obtained JetBlue's flight and fare information under the condition that flights are booked through JetBlue and not through agents subscribing to

Worldspan. Similarly, Southwest negotiated a lower booking fee from Sabre in exchange for a lower level of service. By tailoring the functionality of the system to the airline's needs, CRSs are able to adjust the booking fees. The elimination of the non-discrimination rule would give the CRSs and airlines more flexibility to negotiate a mutually beneficial agreement, one that could provide higher service levels to the consumer.

Competition among the CRSs will ensure that an airline-owned CRS will vigorously pursue the new-entrant airlines as well, or risk losing consumers and bookings to the independent CRS. Hence, if the market includes an independent CRS, then eliminating the non-discrimination rule can, on the margin, be pro-competitive.

6.2.1.1. Policy recommendation regarding mandatory participation. In sum, so long as any major CRS is owned or controlled by one or more major carrier, contrary to position set forth in the NPRM, we believe that no clear benefits are to be derived from eliminating the mandatory participation rules, yet the costs of so doing may be substantial. Therefore, our policy recommendation is that the current rules on mandatory participation be maintained, along with the associated rules on "commercially reasonable" booking fees.

6.2.1.2. Policy recommendation regarding non-discrimination. We conclude that there may be a benefit from removing the non-discrimination rule if: (1) the mandatory participation rule is kept; and (2) the market includes one or more significant, independent CRS providers.

NOTES

1. Enplanements represent the number of passengers boarding planes.
2. An airline's enplanement share at an airport includes all passengers changing planes at that airport and not just originating passengers.
3. The HHI is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. For example, for a market consisting of three firms with shares of 20, 30, and 40%, the HHI is equal to 2,900 (i.e. $20^2 + 30^2 + 40^2$). The HHI takes into account the relative size and distribution of firms in the market and approaches zero when a market consists of a large number of firms of relatively equal size. The HHI increases both as the number of firms in the market decreases and as the disparity in size between firms increases. An HHI of 10,000, which results from squaring a single share of 100%, thus represents a monopoly.
4. The multiplicity of airline fares and ticket restrictions is well recognized in the literature of marketing and economics. For example, a 1994 study on U.S. airline competition found "considerable dispersion in airline prices" and observed that "variation

in fares is substantial." Indeed, the study discovered that, for direct coach class travel in the largest direct service U.S. domestic markets, the "expected difference in prices paid by two passengers selected at random on a route is about 36% of the airline's mean ticket price on the route." The authors of this study concluded, moreover, that airline "price dispersion cannot easily be explained by cost differences alone" (Borenstein & Rose, 1994). Case studies prepared by the Harvard Business School have similarly documented the prevalence of price discrimination among airlines (Michael & Silk, 1994a, b).

5. See Orbitz (March 12, 2003). Together, the 42 airline partners are called "charter associates." Charter associates are required to provide Orbitz with any of their fares posted on their own or third-party websites. They are also required to provide Orbitz with marketing support, including advertising and publicity, in relation to their sales on the site. This support may take the form of exclusive web fares.

6. Before the advent of CRSs, and to some extent even after, travel agents obtained information from Official Airlines Guides, IATA fare manuals, and from the individual airlines directly by telephone.

7. A "market failure" is an imperfection in a price system that prevents an efficient allocation of resources. See, e.g. Samuelson and Nordhaus (1992, p. 741). Natural monopoly, imperfect competition, asymmetry of information, and externalities are all examples of possible market failure.

8. "Moral hazard" refers to any situation where one side has an incentive to change the terms of exchange, unobserved by the other side. See Church and Ware (1999, p. 191).

9. See 49 C.F.R. § 399.80 (enumerating travel agent practices deemed false and misleading).

10. According to R. J. Fahy, recently the Executive Director of the National Commission to Ensure Consumer Information and Choice in the Airline Industry ("NCECIC"), 75% of U.S. adults use computers, and 66% access the Internet. Of the Internet-using population, 66% researched travel information online, and 42% purchased or reserved travel via the computer (spending an estimated $18.7 billion in 2001). Mr. Fahy also cites the results of a 2001 Plog survey of air travelers with an email address, which reported that nearly 78% of the sample had used the Internet to purchase travel. See Declaration of R. J. Fahy, Jr., p. 6.

11. With regard to travel agencies, R. J. Fahy notes that nearly all (94%) employ the Internet to gather travel information and that more than half (56%) have purchased directly from online supplier sources. See Declaration of R. J. Fahy, Jr., p. 6 (citing American Society of Travel Agents, 2002). According to Mr. Fahy, airlines such as Northwest and Delta have also launched websites specifically designed for travel agent use. *Id*. at p. 7.

12. Although the term "essential facilities" has no rigorous definition in economics, the term generally refers to a facility to which rivals require access in order to compete profitably. In the current matter, there can be no dispute that CRSs are not essential facilities given the large number of customers who obtain air-travel information without accessing a CRS.

13. We performed a second HHI calculation in which we adopt an alternative procedure for estimating the carrier-direct bookings of individual airlines. In particular, using information reported in PhoCusWright's ONLINE TRAVEL OVERVIEW: MARKET SIZE AND FORECASTS 2002–2005, we estimate the revenue each airline obtained from its carrier-direct bookings. We then estimate bookings shares based on the assumption that the relative bookings shares of individual carriers can be approximated by their relative shares of carrier-direct revenues, rather than enplanements. Using this approach, the HHI of the market for air-travel equals approximately 1,215.

We use the following procedure to estimate carrier-direct revenue for individual airlines. For each airline, PhoCusWright (2003) reports: (1) total airline revenue for the period January through June 2002; (2) the percentage of revenue booked on the Internet during that period; and (3) the percentage of Internet revenues obtained from carrier websites. Using these data, we first derive airline revenues obtained from their own websites. We then estimate the revenue carriers obtain from their call centers by assuming each carrier books approximately 40% of its total revenue through brick and mortar travel agencies (i.e. the average percentage level of bookings through brick and mortar travel agencies for all carriers, see Table 8). This allows us to calculate, as a residual, the revenues carriers obtain from their call centers (i.e. call center revenue equals: (1) total revenue minus; (2) revenue booked through the Internet minus; and (3) revenue booked through brick and mortar travel agencies). We then add carrier website and call center revenues to determine total carrier-direct revenue. Finally, we estimate booking shares based on the assumption that the relative booking shares of individual carriers can be approximated by their relative shares of carrier direct revenues.

14. NPRM at 69,400. The NPRM acknowledges that "we have made no finding that each system's booking fees exceed the system's costs of providing services to airlines." (*Ibid*.).

15. *Source:* Sabre Holding Corp. Sabre's offer also requires the carrier to make a three-year commitment to remain at the highest level of participation and not to deny Sabre users other facilities for the sale of their flights, such as the ability of consumers booked through Sabre to check in via the carrier's web site if that facility is offered to consumers generally.

16. Antitrust is often distinguished from ongoing regulation, in that antitrust seeks to correct market failures and then allow market forces to establish actual price and output outcomes, rather than to specify outcomes. See Scherer and Ross (1990, pp. 11–14).

17. *Source:* Sabre Holding Corp.

18. Nexion is a network of multiple CRSs. See, e.g. Sabre, March 9, 2003.

19. *Source:* Sabre Holding Corp.

20. *Source:* Sabre Holding Corp.

21. This assumes that travel agents act in the best interests of their customers. They cannot behave as if the airline no longer exists simply because it is not on their CRS. Elsewhere we have argued that the informed consumer disciplines this behavior. Travel agents that are less than diligent will soon lose customers to travel agencies that are diligent.

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WHICH INDUSTRIES USE THE INTERNET?

Chris Forman, Avi Goldfarb and Shane Greenstein

ABSTRACT

Our study provides an industrial census of the dispersion of Internet technology to commercial establishments in the United States. We distinguish between participation, that is, use of the Internet because it is necessary for all business (e.g. email and browsing) and enhancement, that is, adoption of Internet technology to enhance computing processes for competitive advantage (e.g. electronic commerce).

We find that participation and enhancement display contrasting patterns of dispersion. In a majority of industries, participation has approached saturation levels, while enhancement occurs at lower rates with dispersion reflecting long standing industrial differences in use of computing. In general, lead adopters were drawn from a variety of industries, including many of the same industries that lead adoption of other generations of information technologies; however, the appearance of water transportation and warehousing as leading industries in Internet adoption shows that the Internet influenced establishments where logistical processes played a key role. We find large differences across industries and we caution against inferring too much from the experience in manufacturing despite the widespread availability of data in that sector.

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INTRODUCTION

The commercialization of the Internet in the 1990s brought about a complementary surge in hardware and software spending. Commercial firms undertook most of this investment. In 2000, for example, total business investment in IT goods and services was almost triple the level for personal consumption of similar goods.[1]

We view the diffusion of the Internet to business in the context of observations about technological convergence (Ames & Rosenberg, 1984), which is the increasing use of a small number of technological functions for many different purposes. Bresnahan and Trajtenberg (1995) develop this further in their discussion of General Purpose Technologies (GPTs), which they define as capabilities whose adaptation raises the marginal returns to inventive activity in a wide variety of circumstances. GPTs involve high fixed costs in invention and low marginal costs in reproduction. A GPT is adapted for any new use, and this adaptation takes time, additional expense and further invention. Following the literature, we label these as *co-invention expenses*. Studies have found that co-invention influences computing and Internet technology investments by business users (Bresnahan & Greenstein, 1997; Forman, 2002).

Almost by definition, GPTs have a big impact if and when they diffuse widely, that is, if they raise the marginal productivity of a disparate set of activities in the economy. As a practical matter, "disparate" means a great number of applications and industries, performed in a great number of locations. What stands in the way of achieving wide and disparate diffusion? Barriers arise as a result of users facing different economic circumstances, such as differences in local output market conditions, quality of local infrastructure, labor market talent levels, quality of firm assets or competitive conditions in output markets. Simply put, these barriers are different co-invention expenses.

By 2000, the level of investment flows associated with the Internet was immense and so was the variance across industries. In some industries, the Internet has been adopted across all facets of economic activity, while in other industries adoption has not been widespread. This variance offers valuable clues about where and how the Internet brings value.[2] In this study, we provide a census of commercial Internet use. We offer evidence about the dispersion of the Internet across industries and other factors that shape co-invention expenses at the industrial level. Moreover, we investigate whether industry-level adoption propensity affects regional variation in adoption.

Specifically, we investigate data from a private survey of 86,879 establishments with over 100 employees, updated to the end of 2000. These establishments undertake the vast majority of investment in information infrastructure in the U.S.

Harte Hanks Market Intelligence, a commercial market research firm that tracks use of Internet technology in business, undertook the survey. We employ the County Business Patterns data from the Census and routine statistical methods to generalize our results to cover all medium and large commercial establishments in the United States, the type of location employing approximately two-thirds of the workforce.

We analyze the adoption of the Internet in two distinct layers. In one layer – hereafter termed *participation* – adoption of Internet technology enables participation in the Internet network. Participation is affiliated with basic communications, such as email use, browsing and passive document sharing. It also represents our measure of "table stakes," namely, the minimal Internet investment required to do business (Porter, 2001). In the second layer – hereafter termed *enhancement* – adoption of Internet technology enhances business processes. Enhancement uses Internet technologies to change existing internal operations or to implement new services. It represents our measure of investment aimed at competitive advantage.

The results can be summarized into three main points:

- First, our results emphasize the presence of widespread dispersion and considerable heterogeneity in the use of Internet technology across industries. In a majority of industries participation has approached saturation levels. Enhancement is similarly widespread, but at lower rates. We find large differences in behavior between establishments in different industries, particularly for enhancement. While industry adoption rates in each layer are correlated, the overall diffusion patterns are distinct. Therefore we caution against inferring too much from the experience in any given industry, such as manufacturing, where there happens to be widespread availability of data.
- Second, dispersion of enhancement reflects long standing industrial differences in use of computing. In general, lead adopters were drawn from a variety of industries, including many of the same industries that were on the technical frontier during the evolution of previous generations of information technologies. However, the appearance of new leading industries such as such as water transportation and warehousing shows that the Internet influenced establishments where logistical processes played a key role.
- Third, similarities between establishments from the same industry suggest the possibility that the pre-existing industrial composition of a region will explain regional variation in adoption propensities. In particular, our results raise the possibilities that the type of industry found in major cities plays a key role in explaining the variance of adoption rates between cities, or between cities and low-density regions.

BACKGROUND

Our framework builds on micro-studies of Internet investment in commercial establishments and organizations.[3] It is motivated by the user-oriented emphasis in the literature on GPTs.[4]

General Purpose Technologies and the Commercialization of the Internet

There is no preset pattern for the dispersion of GPTs. They can diffuse in layers or waves (e.g. Lipsey, Becker & Carlaw, 1998). Below we argue that analysis of the dispersion of the Internet to commercial business requires analysis of distinct layers. We hypothesize that the co-invention costs of certain types of Internet investment were low, whereas other bottlenecks persistently produced high co-invention costs. When costs for some activities were low, adoption of these aspects of Internet technology became required to be in business. When the costs were higher and the benefits variable for other aspects, firms were more circumspect, investing only when it provided competitive advantage.

We ignore differences across applications and intensities of use within an establishment. We focus on two layers that vary across location and industry. We label these layers as *participation* and *enhancement*. Both layers of activity are important for economic advance, but each has distinct effects on industrial growth. We do not necessarily presume that the two are closely related, but intend to measure the correlation between them.

The first layer, participation, is a key policy variable. As noted, it represents a measure of "table stakes," the basic requirements for being at the table for medium and large businesses. By 2000, participation was regarded as a routine matter.[5]

The second layer, enhancement, is linked to the productive advance of firms and the economic growth of the regions in which these firms reside. It usually arrives as part of other intermediate goods, such as software, computing hardware, networking equipment or consulting services.[6]

Implementation of participation was rather straightforward by the late 1990s. It involved a PC, a modem, a contract with an Internet Service Provider and some appropriate software. Investment in enhancement, in contrast, was anything but routine during the latter half of the 1990s. Enhancement included technical challenges beyond the Internet's core technologies, such as security, privacy, and dynamic communication between browsers and servers. Organizational procedures usually also changed.[7] Benefits accrue to the business organization employing enhancement through the addition of competitive advantage, but the co-invention costs and delays vary widely.

Why do Industries Differ?

Our thesis emphasizes the commonalities of investment behavior across industries, and how these differences between industries persist over time. It draws upon theories of general purpose technologies and co-invention, and is complemented by the work of computer industry historian, James Cortada (2003).

First, innovative IT rarely diffuses into an organization *tabula rasa*. Users face idiosyncratic co-invention costs based on variations in the installed base of hardware and software applications across firms and industries (Bresnahan & Greenstein, 1997). These variations shape the short run demand for innovative IT, as users rarely, if ever build IT infrastructure from scratch. Thus, adopters are incremental in their approach to investment, compromising between the benefits of frontier and the costs of keeping an existing process, picking and choosing among those new possibilities that make the most sense for their business. In particular, Forman (2002) showed that installed base of hardware and software applications played a major role in shaping organizations' early decisions to invest in the Internet.

Second, most innovative IT is directed toward automating functional activity or business processes within an organization, such as accounts receivable, inventory replenishment or point of sale tracking.[8] The activities that are essential for operating an organization have not changed over decades, even though the identities of firms have. In the language of economics, the list of functions that receive attention from one decade to the next is similar, whether or not the motive for adoption is "technology push" or "demand pull," and whether or not the same decision makers appear. Thus, if there is stability of the types of economic activity going on within organizations across different industries, then this stability shapes the demand for innovative IT, enhancing the same activities decade after decade.

Third, such investments have competitive consequences. Many models of diffusion and technology investment forecast there may be strong incentives to emulate rivals. This may be due either to competitive pressure (e.g. Porter, 2001), or knowledge spillovers within industries (e.g. Irwin & Klenow, 1994). Hence, most organizations examine other firms with functions similar to their own and enhance their own processes in similar manner. Both forms of benchmarking increase the incentives of lead firms to emulate other organizations in the same industry, either close competitors or those with similar supply chains.

This conceptual framing leads to two key implications. First, throughout several decades of change most investment is incremental. Both suppliers and vendors understand the conceptual problems and opportunities for augmentation in much the same terms. Each firm determines its priorities across activities, but firms in the same industry tend to come to similar conclusions about their priorities – because they employ the same processes, face the same range of costs, and because they compete with each other.

Second, innovation in IT is likely to lead to non-incremental change only when it involves "radical" change in products or production processes. In Cortada's view only three innovations have spurred such investments: the UPC code, EDI and the Internet. Cortada singles out the Internet because it altered the applications for many functions simultaneously, and consequently contained the possibility for dramatic re-coordination of multiple activities within an organization. He argued that this rearrangement of functions could lead to reorganization of supply chains in many specific markets.

More to the point, whether its effect is radical or incremental, pre-existing investment in IT should predict use of the Internet except where the Internet has devalued completely pre-existing activities. Firms that have invested in augmenting activities with IT in the past will continue to do so when the Internet becomes available. Large investors in the past will persist as large investors over time. Related, the emergence of lead users from industries that did not previously contain any lead users will also be indicative of radical departures from the past.

DATA AND METHOD

We will measure the dispersion of Internet technology across industries. Since there is no single way to measure dispersion, we will modify our analysis to the data available. Our research strategy involves identifying leaders and laggards, and comparing their features. Given that this study is the first to examine such data, our primary goal is to document and rank. Because we are interested in measuring the dispersion of Internet use across establishments from different industries rather than its evolution across time, an analysis of the cross-section data is sufficient for our purposes.

The data we use for this study come from the Harte Hanks Market Intelligence CI Technology database (hereafter CI database).[9] The CI database contains establishment-level data on: (1) establishment characteristics, such as number of employees, industry and location; (2) use of technology hardware and software, such as computers, networking equipment, printers and other office equipment;

and (3) use of Internet applications and other networking services. Harte Hanks Market Intelligence (hereafter HH) collects this information to resell as a tool for the marketing divisions at technology companies. Interview teams survey establishments throughout the calendar year; our sample contains the most current information as of December 2000.

HH tracks over 300,000 establishments in the United States. Since we focus on commercial Internet use, we exclude government establishments, military establishments and non-profit establishments, mostly in higher education. Our sample contains all commercial establishments from the CI database that contain over 100 employees, 115,671 establishments in all;[10] and HH provides one observation per establishment. We will use 86,879 of the observations with complete data generated between June 1998 and December 2000. We adopt a strategy of utilizing as many observations as possible, because we need many observations for thinly populated areas.[11] This necessitates routine adjustments of the data for the timing and type of the survey given by HH.

Data Description and Sample Construction

To obtain a representative sample, we compared the number of firms in our database to the number of firms in the Census. We calculated the total number of firms with more than 50 employees in the Census Bureau's 1999 County Business Patterns data and the number of firms in our database for each two-digit NAICS code in each location. We then calculated the total number in each location. This provides the basis for our weighting. The weight for a given NAICS in a given location is

$$\frac{\text{Total \# of census establishments in location} - \text{NAICS}}{\text{Total \# of census establishments in location}} \times \frac{\text{Total \# of establishments in our data location}}{\text{Total \# of establishments in our data in location} - \text{NAICS}}$$

Therefore, each location-NAICS is given its weighting from its actual frequency in the census. In other words, if our data under-samples a given two-digit NAICS at a location relative to the census then each observation in that NAICS-location is given more importance.

Using two survey forms, HH surveyed establishments at different times. To adjust for differences in survey time and type, we econometrically estimate the relationship between an establishment's decision to participate or enhance as a function of its industry, location, timing of survey and form of survey. We then calculate predicted probabilities of adoption for each establishment *as if it were surveyed in the second half of 2000 and were given the long survey*. Once we weight by the true frequency of establishments in the population, we have information about establishments related to two-thirds of the U.S. workforce. The more observations we have for a given region or industry the more statistical confidence we have in the estimate.

Definitions of Behavior

Identifying participation was simple compared to identifying enhancement. We identify participation as behavior in which an establishment has basic Internet access or has made any type of frontier investment. Because the survey gives plenty of information on such activities, identifying participation was straightforward. In contrast, identifying the proper margin for complex enhancement activity was more difficult. We look for indications that an establishment must have made investments that involved frontier technologies or substantial co-invention. Thus, we identify enhancement from substantial investments in electronic commerce or "e-business" applications. We look for commitment to two or more of the following projects: Internet-based enterprise resource planning or TCP/IP-based applications in customer service, education, extranet, publications, purchasing or technical support.

In Table 1 we show the results of these definitions. Participation by establishments within the sample is at 80.7% (see Unweighted Average in Table 1). The sample under-represents adopters. Our estimate of the economy-wide distribution, using the true distribution of establishments from the Census, is 88.6% (see Weighted Average in Table 1). Enhancement has been undertaken by 11.2% of our sample and 12.6% of the true distribution. We also can estimate the rate of adoption by "experimenters," that is, those establishments with some indication of use, but not much. As one would expect for a technology still in the midst of diffusion, the proportion for experimenters (combined with enhancement) is considerably higher than for enhancement alone, reaching 18.1% for the unweighted average and 23.2% for the weighted average. We have explored this latter definition and

Table 1. National Internet Adoption Rates (In Percentages).

	Weighted Average (%)	Unweighted Average (%)	Northeast (%)	Midwest (%)	South (%)	West (%)
Participation	88.6	80.7	88.0	88.7	89.0	85.7
Enhancement	12.6	11.2	12.7	12.7	12.4	12.5
Enhancement & experimenting with enhancement	23.2	18.1	24.0	23.1	22.7	23.3

found that it tracks the enhancement definition we use below, so it provides no additional insight about the dispersion of use. We do not analyze it further.

LEADING INDUSTRIES

In Tables 2 and 3 we list the estimates for participation and enhancement organized by two-digit NAICS industry; we list industries in the order of highest to lowest adoption rates. We first show the results for all two-digit NAICS industries in the left half columns, and then break them into their three-digit NAICS industries in the right half columns. We identify leading and laggard industries. We also list the standard errors and number of observations.

Participation

Our first finding is quite apparent in Table 2 – participation is high in every industry, reaching over 92% – near saturation – in a majority of them. Of course, this is not a surprise after Table 1, since the average rate of participation was 88%. The striking feature in Table 2 is the skew of these results. Establishments in all but four two-digit NAICS industries are at 90% or higher. With rare exception, the Internet reaches everywhere. Participation clearly represents a low cost "table stakes."

The two major low outliers are the two components of retail trade, each at 80% adoption rates. Looking more closely at the NAICS three-digit industries in retail trade, we see there are a few outliers. These are (more narrowly) NAICS 452, general merchandising stores (69%); NAICS 447, gasoline stations (75%); NAICS 444, building materials and garden equipment and supply dealers (73.7%); and NAICS 445, food and beverage stores (72.1%), all of which contribute many observations to their respective NAICS two-digit category. NAICS 452 has some apparent non-response bias, so we believe these estimates are a lower bound.[12]

We conclude that participation is virtually ubiquitous in all establishments excepting – at worst – a few industries. This dispersion is consistent with the popular perception that: (1) adoption costs were low; (2) the Internet was available almost everywhere; (3) nearly every business experienced some benefit from adoption; (4) this diffusion saturated potential adopters sometime before the decline in Internet technology spending in 2001; and (5) the Internet became a necessity for U.S. business by the end of the millennium.

This is remarkable for a technology that is less than a decade old. To our knowledge, no major historical technology diffused this fast to such a disparate set of industries right after introduction – not electricity, telephony, the steam

Table 2. Participation by Industry.

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
51- Media, Telecommunications, & data processing	99.1	0.1	3181	511-Publishing industries	99.3	0.2	1475
				512-Motion picture & sound recording industries	90.3	1.0	129
				513-Broadcasting & telecommunications	99.2	0.2	1076
				514-Information & data processing services	98.0	0.4	501
22-Utilities	99.0	0.2	680	221-Utilities	99.0	0.2	680
54- Professional, scientific, & technical services	98.9	0.1	4556	541-Professional, scientific & technical services	98.9	0.1	4556
52- Finance & insurance	97.8	0.2	3933	522-Credit intermediation & related activities	96.9	0.4	1369
				523-Security, commodity contracts, etc.	96.3	0.4	503
				524-Insurance carriers & related activities	98.4	0.2	1707
				525-Funds, trusts, & other financial vehicles	86.1	0.6	74
33- Manuf. 3: metals, machinery, computers & electronics, appliances, transportation equipment, furniture, & other manufacturing	97.8	0.1	12679	331-Primary metal mfg	96.7	0.4	1019
				332-Fabricated metal product mfg	97.2	0.3	2257
				333-Machinery mfg	98.4	0.2	2575
				334-Computer & electronic product mfg	99.0	0.2	2026
				335-Electrical equip, appliance & component mfg	97.4	0.4	962
				336-Transportation equipment mfg	97.8	0.3	1825
				337-Furniture & related product mfg	94.3	0.6	912
				339-Miscellaneous mfg	97.8	0.3	1103
55- Mngmt of companies & enterprises	97.2	0.5	291	551-Management of companies & enterprises	97.2	0.5	291
32- Manuf. 2: wood, paper, printing, petroleum, chemical, plastics & rubber, non-metallic minerals	97.0	0.2	7161	321-Wood product mfg	94.6	0.5	964
				322-Paper mfg	96.5	0.4	1243
				323-Printing & related support activities	97.6	0.3	1030
				324-Petroleum & coal products mfg	92.7	0.8	213
				325-Chemical mfg	98.1	0.3	1440
				326-Plastics & rubber products mfg	97.0	0.3	1513
				327-Nonmetallic mineral product mfg	94.8	0.6	758

23-Construction	95.9	0.3	2518	233-Building, developing & general contracting	95.8	0.6	703
				234-Heavy construction	96.2	0.5	652
				235-Special trade contractors	94.7	0.5	1163
42- Wholesale trade	95.8	0.3	5197	421-Wholesale trade, durable goods	96.7	0.3	2814
				422-Wholesale trade, non-durable goods	94.7	0.4	2383
21-Mining	95.6	0.6	529	211-Oil & gas extraction	88.6	0.7	63
				212-Mining (except oil & gas)	92.7	1.0	269
				213-Mining support activities	96.5	0.9	197
62- Health care & social assistance	94.1	0.3	14506	621-Ambulatory health care services	96.5	0.3	2129
				622-Hospitals	97.5	0.2	4406
				623-Nursing & residential care facilities	91.1	0.4	6516
				624-Social assistance	93.7	0.5	1455
49- Transportation & warehousing2: couriers & warehousing	93.6	1.0	283	492-Couriers & messengers	92.9	1.2	127
				493-Warehousing & storage	94.0	1.3	156
71- Arts, entertainment, & recreation	93.6	0.5	1363	711-Performing arts, spectator sports, etc.	95.8	0.7	260
				713-Amusement, gambling & recreation industries	92.6	0.6	1103
56- Administrative & support & waste management & remediation services	92.9	0.5	2303	561-Administrative & support services	93.0	0.5	2078
				562-Waste management & remediation services	91.1	1.3	225
31- Manufacturing 1: food & textiles	92.7	0.4	4400	311-Food mfg	92.6	0.5	1983
				312-Beverage & tobacco product mfg	93.7	0.9	415
				313-Textile mills	91.6	0.8	612
				314-Textile product mills	93.8	0.8	368
				315-Apparel manufacturing	90.8	0.8	873
				316-Leather & allied product mfg	85.3	1.8	149
53- Real estate & rental & leasing	92.3	1.0	467	531-Real estate	94.8	0.7	480
				532-Rental & leasing services	86.1	1.3	256
				533-Lessors of other non-financial intangible assets	47.4	3.2	11
48- Transportation & warehousing1: transportation	92.0	0.5	2273	481-Air transportation	90.5	1.0	152
				482-Rail transportation	88.6	2.2	137
				483-Water transportation	76.8	1.1	40
				484-Truck transportation	90.2	0.9	856
				485-Transit & ground passenger transportation	86.7	1.2	509

Table 2. (*Continued*)

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
				486-Pipeline transportation	81.4	2.0	40
				487-Scenic & sightseeing transportation	75.8	0.6	28
				488-Transportation support activities	94.7	0.7	511
81- Other services (except public administration)	90.5	0.8	791	811-Repair & maintenance	92.3	0.9	321
				812-Personal & laundry services	87.3	1.2	470
72- Accommodation & food services	90.4	0.5	4775	721-Accommodation	97.0	0.2	3066
				722-Food services & drinking places	79.4	1.1	1709
44- Retail trade1: durables	80.1	0.7	9069	441-Motor vehicle & parts dealers	96.5	0.3	1892
				442-Furniture & home furnishing stores	88.6	1.5	184
				443-Electronics & appliance stores	96.0	0.6	421
				444-Bldg material & garden equip & supp dealers	73.7	1.7	675
				445-Food & beverage stores	72.1	0.9	5319
				446-Health & personal care stores	86.1	2.0	140
				447-Gasoline stations	75.0	3.3	109
				448-Clothing & clothing accessories stores	90.1	1.2	329
11-Agriculture, forestry, fishing & hunting	80.0	1.5	145	113-Forestry & logging	68.5	1.4	22
				114-Fishing, hunting & trapping	55.3	3.5	7
				115-Agriculture & forestry support activities	80.4	1.8	116
45- Retail trade2: non-durables	72.1	0.9	5767	451-Sporting goods, hobby, book & music stores	84.6	1.2	172
				452-General merchandise stores	69.0	1.0	5083
				453-Miscellaneous store retailers	90.0	1.2	278
				454-Nonstore retailers	88.9	1.1	234
61- Educational services	29.0	0.9	12	611-Educational services	29.0	0.9	12

Table 3. Enhancement by Industry.

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
55- Mngmt of companies & enterprises	27.9	2.7	291	551-Management of companies & enterprises	27.9	2.7	291
51- Media, telecommunications, & data processing	26.8	0.9	3181	511-Publishing industries	28.5	1.3	1475
				512-Motion picture & sound recording industries	24.6	3.7	129
				513-Broadcasting & telecommunications	21.7	1.3	1076
				514-Information & data processing services	33.0	2.2	501
22-Utilities	21.1	1.7	680	221-Utilities	21.1	1.7	680
52- Finance & insurance	19.9	0.7	3933	522-Credit intermediation & related activities	20.5	1.2	1369
				523-Security, commodity contracts, etc.	25.7	2.0	503
				524-Insurance carriers & related activities	18.8	1.0	1707
				525-Funds, trusts, & other financial vehicles	11.2	3.6	74
54- Professional, scientific, & technical Services	19.6	0.7	4556	541-Professional, scientific & technical services	19.6	0.7	4556
42- Wholesale trade	17.2	0.6	5197	421-Wholesale trade, durable goods	18.5	0.8	2814
				422-Wholesale trade, non-durable goods	15.5	0.8	2383
33- Manuf. 3: metals, machinery, computers & electronics, appliances, transportation equipment, furniture, & other manufacturing	15.7	0.4	12679	331-Primary metal mfg	16.0	1.2	1019
				332-Fabricated metal product mfg	13.6	0.8	2257
				333-Machinery mfg	13.9	0.8	2575
				334-Computer & electronic product mfg	23.5	1.0	2026
				335-Electrical equip, appliance & component mfg	15.6	1.3	962
				336-Transportation equipment mfg	14.4	0.9	1825
				337-Furniture & related product mfg	11.0	1.1	912
				339-Miscellaneous mfg	14.0	1.1	1103
53- Real estate & rental & leasing	15.6	1.8	467	531-Real estate	13.9	1.6	480
				532-Rental & leasing services	15.9	2.3	256
				533-Lessors of other non-financial intangible assets	14.4	6.9	11
49- Transportation & warehousing2: couriers & warehousing	15.5	2.2	283	492-Couriers & messengers	15.8	3.1	127
				493-Warehousing & storage	13.7	2.7	156

Table 3. (*Continued*)

Two-Digit NAICS	Two-Digit NAICS Adoption Rate (%)	Standard Error (%)	Two-Digit # Obs.	Three-Digit NAICS	Three-Digit NAICS Adoption Rate (%)	Standard Error (%)	Three-Digit # Obs.
32- Manuf. 2: wood, paper, printing, petroleum, chemical, plastics & rubber, non-metallic minerals	14.4	0.5	7161	321-Wood product mfg	11.6	1.1	964
				322-Paper mfg	15.8	1.1	1243
				323-Printing & related support activities	18.0	1.3	1030
				324-Petroleum & coal products mfg	16.0	2.5	213
				325-Chemical mfg	16.3	1.1	1440
				326-Plastics & rubber products mfg	12.0	0.9	1513
				327-Nonmetallic mineral product mfg	10.9	1.2	758
21-Mining	12.4	1.5	529	211-Oil & gas extraction	18.4	4.8	63
				212-Mining (except oil & gas)	9.9	1.9	269
				213-Mining support activities	12.6	2.5	197
48- Transportation & warehousing1: transportation	12.0	0.7	2273	481-Air transportation	12.4	2.7	152
				482-Rail transportation	12.4	3.0	137
				483-Water transportation	23.6	5.9	40
				484-Truck transportation	11.8	1.2	856
				485-Transit & ground passenger transportation	4.7	1.0	509
				486-Pipeline transportation	21.4	6.0	40
				487-Scenic & sightseeing transportation	12.2	5.5	28
				488-Transportation support activities	16.2	1.7	511
31- Manufacturing 1: food & textiles	11.5	0.6	4400	311-Food mfg	11.2	0.8	1983
				312-Beverage & tobacco product mfg	13.5	1.8	415
				313-Textile mills	8.1	1.2	612
				314-Textile product mills	12.1	1.8	368
				315-Apparel manufacturing	12.6	1.2	873
				316-Leather & allied product mfg	12.4	2.8	149
72- Accommodation & food services	11.2	0.5	4775	721-Accommodation	14.4	0.7	3066
				722-Food services & drinking places	5.6	0.6	1709
11-Agriculture, forestry, fishing & hunting	11.1	2.6	145	113-Forestry & logging	14.1	6.1	22
				114-Fishing, hunting & trapping	0.0	0.0	7
				115-Agriculture & forestry support activities	10.2	2.8	116

81- Other services (except public administration)	10.7	1.2	791	811-Repair & maintenance	14.1	2.0	321
				812-Personal & laundry services	8.2	1.4	470
56- Administrative & support & waste management & remediation services	10.6	0.7	2303	561-Administrative & support services	11.0	0.8	2078
				562-Waste management & remediation services	6.7	1.8	225
62- Health care & social assistance	9.8	0.3	14506	621-Ambulatory health care services	10.8	0.8	2129
				622-Hospitals	10.1	0.5	4406
				623-Nursing & residential care facilities	10.1	0.5	6516
				624-Social assistance	5.9	0.7	1455
44- Retail trade1 – durables	9.7	0.4	9069	441-Motor vehicle & parts dealers	20.5	1.1	1892
				442-Furniture & home furnishing stores	15.9	2.8	184
				443-Electronics & appliance stores	25.6	2.2	421
				444-Bldg material & garden equip & supp dealers	5.1	0.9	675
				445-Food & beverage stores	4.6	0.4	5319
				446-Health & personal care stores	10.7	2.7	140
				447-Gasoline stations	4.3	2.0	109
				448-Clothing & clothing accessories stores	16.2	2.1	329
71- Arts, entertainment, & recreation	9.6	0.9	1363	711-Performing arts, spectator sports, etc.	15.7	2.4	260
				713-Amusement, gambling & recreation industries	8.1	0.9	1103
23-Construction	9.4	0.6	2518	233-Building, developing & general contracting	8.7	1.1	703
				234-Heavy construction	12.8	1.4	652
				235-Special trade contractors	7.9	0.9	1163
45- Retail trade2 – non-durables	7.0	0.4	5767	451-Sporting goods, hobby, book & music stores	20.4	3.0	172
				452-General merchandise stores	5.3	0.4	5083
				453-Miscellaneous store retailers	14.6	2.2	278
				454-Nonstore retailers	21.2	2.7	234
61- Educational services	6.2	3.6	12	611-Educational services	6.2	3.6	12

engine, the automobile, or the calculator (Helpman, 1998; Rogers, 1995).[13] Only the modern fax machine comes close to having a parallel pattern, but that only occurred after decades of refinement of standards and other infrastructure, and multiple attempts to diffuse such a capability (Schmidt & Werle, 1998, Chap. 8).

More narrowly, the history of computing does offer some insight into why participation was rapid. To be sure, no previous major generations of IT hardware innovation diffused to business users this rapidly – not mainframes, general purpose mini-computers, or even PCs.[14] The closest historical analogue lies in software applications, which industry wisdom suggests diffuse quickly when installation costs are low and benefits high. More formally, this can be interpreted as applications with large benefits but without large *initial* co-invention costs. In this sense, the diffusion of email and the browser are similar to the diffusion of the spread sheet (i.e. Visicalc and Lotus 1–2–3), second-generation word-processing (i.e. Word Perfect), electronic financial planning (i.e. Quicken), and many other office software applications.

The emphasis on *initial* co-invention costs is important, because many historical IT innovations came in waves, with one generation of innovation building on the adoption decisions of a previous wave (see Bresnahan & Greenstein, 2000, for one such view). Further modifications of basic Internet use – such as e-commerce – may require coordinating multiple users within the same establishment or across establishments. These co-invention costs can be high if the organizations involved have complex processes or idiosyncratic needs.

In our sample, investments in such innovations are likely to appear in our measurement of enhancement. We expect, therefore, that the adoption of enhancement will not be as widespread as participation, but positively correlated.

Enhancement

In Table 3, we provide the estimates for adoption of enhancement. The lead adopters exceed adoption rates of 25%. These are NAICS 55, management of companies and enterprises (27.9%), and NAICS 51, media, telecommunications and data processing (26.8%). These two industries are not statistically different from each other, but they are statistically higher than all other NAICS 2 industries.

These first two lead user industries are very different. NAICS 55 represents the financial side of the Internet revolution. It includes corporate headquarters for multidivisional firms, securities firms and financial holding companies. NAICS 51 includes publishing firms, thus representing the change the Internet brings to media. It also includes information and data processing services (NAICS 514), an industry that includes firms like America Online and other Internet access providers. This variety at the top is not a surprise, as the business press has largely described the wide impact of this technology's diffusion. The Internet has been used in a variety of industries to create competitive advantage. However, our results confirm the varied impact of the diffusion of Internet technology – a theme that we will repeat as we look further down the table.

The second tier of lead users again includes a wide mix from two-digit industries, such as finance and insurance, professional and scientific services, utilities, and wholesale trade. These latter two industries include heavy users of sophisticated applications combining database software with communication technologies. The third tier of enhancement adopters includes NAICS 32 and 33, which together cover over 80% of manufacturing. Within this group a few notable lead industries at the NAICS three-digit level are NAICS 334, computer and electronic manufacturing (23.5%), NAICS 323, printing and related support activities (18.%), and NAICS 211, oil and gas extraction (18.4%). These are all long-time lead users in computing, but for very different reasons. Other lead users at the three-digit level include NAICS 483, water transportation (23.6%); NAICS 486, pipelines (21.4%); NAICS 441, motor vehicle and parts dealers (20.5%); NAICS 443, electronics and appliance stores (25.6%); NAICS 451, sporting goods (20.4%); and NAICS 454, non-store retailers (21.2%). These last four are leaders in consumer e-commerce.

Low adopters (under 6% adoption) at the NAICS three-digit level do not surprise us, nor should it surprise any long-time observer of computing. These include transit and ground passenger transportation (NAICS 485, 4.7%), food services and drinking places (NAICS 722, 5.6%), social assistance (NAICS 624, 5.9%), and amusement (NAICS 713, 8.1%).

Industry and Location

Table 4 shows that MSAs with more than one million people are nearly 50% more likely to adopt enhancement than MSAs with less than 250,000 people. We argue that industry composition is one possible explanation for this disparity. For a variety of reasons, industries tend to cluster in the same locations (e.g. Krugman, 1991; Marshall, 1920). The substantial differences across industries in the propensity to adopt frontier Internet technologies suggests that geographic variation in the propensity to adopt may simply be a function of pre-existing industrial composition.

Table 4 shows that large MSAs have a larger percentage of establishments in leading industries, and they have a relatively low proportion of retailers, a laggard industry. Table 5 provides further evidence for this. For large, medium, and small MSAs, the ten leading MSAs for enhancement adoption have a much

Table 4. Percentage of Establishments in Top Quartile Industry for Enhancement, by Size of MSA.

Population	Average Enhancement (%)	Percentage of Establishments in Top Quartile Industries (%)	Percentage of Establishments in Top Quartile of Non-retail Adopters (%)	Percentage of Establishments that are Retailing (%)	No. of Areas
>1 Million	14.7	27.5	32.1	14.3	57
250,000–1 Million	11.2	19.5	23.5	16.7	116
<250,000	9.9	19.0	23.3	18.3	143

larger percentage of establishment in leading industries than do the bottom ten MSAs.

These results suggest that industrial composition plays a role in regional variation in adoption propensity. In Forman, Goldfarb and Greenstein (2003), we provide more conclusive evidence of the relative importance of industry and location, relying on estimates of marginal effects. Nevertheless, the average effects presented in Tables 4 and 5 strongly suggest that industrial composition plays an important role in regional variation.

Comparison with Others' Findings

We compared our findings against two other recent studies of Internet technology use and against a summary of historical adoption.

First, we compared our estimates with Census estimates for 1999 on the use of networking by manufacturing plants, as reported in Atrostic and Gates (2001). This data was compiled from 40,000 surveys of large and small plants. The large plants in their samples and ours largely overlap; but their sample contains

Table 5. Leading Adopters of Enhancement Among MSAs With Over One Million in Population.

MSA	Adoption Rate (%)	% Establishments in Top Quartile
Average of top ten large MSAs	16.5	26.6
Average of bottom ten large MSAs	10.7	21.7
Average of top ten medium MSAs	17.9	24.4
Average of bottom ten medium MSAs	4.4	16.3
Average of top ten small MSAs	18.0	16.4
Average of bottom ten small MSAs	2.1	11.1

plants with fewer than 100 employees and ours does not. Atrostic and Gates focus primarily on three measures of networking and business process adoption: percentage of firms that use networks; percentage of employees that use networks; and percentage of plants with fully integrated enterprise software.

We find that our data and theirs give a similar picture, though not an identical one. Despite differences in sampling frame, our estimate of enhancement is close to theirs for adoption of networking and enterprise software (correlation coefficients for NAICS three-digit manufacturing industries is 0.40 and 0.48). Not surprisingly, their question about employee use of networking is less correlated with our estimate (0.18). We conclude that our measure partially overlaps with the Census results because we both measure similar phenomena. But we also conclude that our measure captures something distinct beyond just networking.

Second, we also compared our estimates with Bureau of Economic Analysis (BEA) data on communications and capital service flows per industry, as used by Stiroh (2002b). Although the BEA data uses Standard Industrial Classification (SIC) codes rather than NAICS codes, we were able to match forty-three industry categories. We found that investment in computers and communication is positively but weakly correlated with both participation ($\rho = 0.121$) and enhancement ($\rho = 0.080$). This weak correlation is not surprising since the two series use different units, which are not very comparable. Our estimates measure enhancement adoption per establishment in an industry, whereas the BEA numbers measure dollars for all firms in an industry.

The Spearman Rank Coefficient eliminates this mismatch of unit scale and, accordingly, is much higher and statistically significant for both participation and enhancement (respectively 0.37 and 0.34). In other words, Internet technology-intensive industries tend to be those where a high fraction of establishments are adopting the Internet for enhancement, but one should take care in translating industry leadership into dollar differences in investment. Information technology investment involves a wide array of activities, not just the Internet. A ranking of extensive involvement of many establishments in Internet technology, which is what we measure, need not correlate perfectly with a ranking of dollar investment in all information technology, which is what BEA measures.[15]

Finally, we compared our list of lead industries with similar lists from more than two decades ago.[16] The list of "leading" computer users in the late 1970s to early 1980s remains on our list of medium to large adopters. Cortada (1996) lists lead industries as banking and finance, utilities, electronic equipment, insurance, motor vehicles, petroleum refining, petroleum pipeline transport, printing and publishing, pulp and paper, railroads, steel, telephone communications and tires. We find that these are lead industries in our data too.

However, wholesale trade is a low user, so too is water transportation. How did these industries change status in two decades? In short, these industries include many establishments that use communications to enhance logistical operations, which was difficult to do electronically more than two decades ago. Aside from this exception, his list of laggards also corresponds with our list.

We conclude that the industrial identities of the leading and lagging users of the new economy are a lot like leading and lagging users in the old computing economy, even if the names of the firms in the lead role has changed. This also opens questions about why the costs and benefits of innovative information technology have not changed much in decades.

Industry Investment in Broader Perspective

Our findings lead us to four broad lessons. First, we find Internet technology use is widespread, both at simple and complex levels of investment. We find that Internet technology producers (as well as their distributors) are frequent adopters. This echoes a finding that information technology and electronics manufacturers are intensive users of computing and communications as inputs (e.g. Stiroh, 2002a). However, there are two differences: Manufacturers and *distributors* of electronics both are lead adopters. Moreover, these establishments are far from being the *only* lead adopters. They are two among a crowd. Consequently, we warn strongly against the conclusion that principal benefits to the large investment in IT in the late 1990s largely accrued to only IT-producing industries.

Second, the composition of this distribution has old as well as new information to investigate. There are the familiar lead industries from information service industries, scientific and technical industries, and finance, insurance and real estate. The flip side of the coin is similar: Most laggard industries (i.e. infrequent computing and computer adopters two decades ago) did not suddenly become Internet-intensive. The exceptions are informative about the nature of building competitive advantage using Internet technologies. The appearance of water transportation and warehousing as lead industries shows that the Internet influenced establishments where logistical processes played a key role.[17] At the same time, it confirms our hypothesis that there is durability in the factors shaping the dispersion of innovation information technology across industry.

Third, our findings warn against inferring too much from the experience in manufacturing. The Census collected a lot of detail about manufacturing, but its establishments are medium to high adopters, neither leaders nor laggards. Establishments in other industries are outside this picture. Finance and media have many more lead adopters – as a fraction of total establishments within each sector – and possibly a very different set of applications.

Fourth and finally, these estimates foreshadow further findings about the geographic distribution of enhancement (Forman, Goldfarb & Greenstein, 2003). First, participation is almost at saturation, so the same will have to be true across most locations – simply for the sake of statistical consistency. It is also well known that some lead industries in enhancement, such as corporate headquarters and financial firms, disproportionately locate establishments in dense urban settings. That said, there are many industries from disparate settings that are close to these leaders. If the location of establishments from these industries does not overlap much (and they will not), then adoption will disperse widely across locations.

CONCLUSIONS

The diffusion of the Internet to commercial establishments did not occur in one layer. Adoption patterns for participation and enhancement are distinct. Adoption of participation approached saturation levels by the end of 2000, while enhancement was adopted much less frequently. For participation, and especially for enhancement, there is wide variation in the propensity to adopt across industries. Leading industries are similar to previous information technology leaders with the addition of fields with high logistical demands such as pipelines and warehousing. This variation influences the variation in average adoption propensities across geographic areas.

Distinguishing between different layers of Internet technology is essential to understanding the diffusion process. While participation diffused widely and rapidly, enhancement did not. Adoption of the two technologies is only weakly correlated across industries.

Participation and enhancement each provide distinct strategic and productivity benefits to private firms, and each should be the focus of distinct economic policies. The economic transactions associated with participation diffused quickly. As of late 2000 there was not much room left for growth. Its diffusion both took advantage of existing capital and motivated additional expenditure on software, hardware and networking service. In addition, the dispersion associated with participation became table stakes for most firms, a necessity for doing business. We conclude that if there was an economic benefit to GDP as a result of participation, it was a one-time benefit affiliated with outfitting establishments with the equipment to support participating in email and browsing.

Enhancement diffused less widely and its diffusion may be far from over. As opposed to participation, enhancement was optional – motivated by the development of competitive advantage – and it had variable benefits and co-invention costs. There are strong hints in our results that the incidence of these costs and benefits fell primarily on traditionally intensive users of computers. If there is an economic benefit to GDP as a result of enhancement, these benefits were widely dispersed, but dependent on industry. There is still a large possibility that the economic gains will occur in the future. This conclusion also varies with standard approaches to measuring productivity from investment in information technology, where prevailing research makes no allowance for the composition of capital, nor its motivation.

Finally, while we found GPT theory useful for formulating our measurement framework, we relied on the principle that dispersion should reflect economic constraints that foster different behavior across industry and location. These constraints are necessarily localized in contemporary experience. Therefore, we speculate that historical comparisons of the dispersion of the Internet with the dispersion of other GPTs are apt to be badly posed unless the comparisons are heavily qualified. It is misleading to compare the diffusion of the Internet with agricultural improvements, the railroad, electrical networks, telegraph, telephone or PC without accounting for the unique factors that shape co-invention costs and produce dispersion in each episode. Although aspects of similar economic issues arise in historical cases, the Internet's combination of economic motives, speeds, and environments has no precise historical precedent.

The high adoption propensities in some regions are not necessarily a consequence of region-specific spillovers and benefits to adoption. We have shown that they are partly a consequence of pre-existing industrial composition. The speed of the diffusion of the Internet means that firms did not have time to relocate in response to the new technology. The high levels of enhancement in some industries such as computer manufacturing, imply that regions with a large number of establishments in these industries such as Silicon Valley, will have high levels of adoption. In Forman, Goldfarb and Greenstein (2003) we separately identify the relative importance of industry and location through analysis of marginal effects.

In this study we focus on aggregate trends in the dispersion of Internet technology. But this represents only the beginning of uses for such data. Our conclusion begs the question of why some industries use Internet technology more intensively. We show that the identities of leading industries tended to be the same over decades, and we did offer the outline an explanation for this phenomenon. But our explanation begs further questions. What does the persistence of IT use within an industry say about the strategic benefits to using the Internet and the co-inventive expenses during this GPT's diffusion in comparison to those of the past?

We also did not address questions about the distribution of costs and benefits within an industry. To do so, we would need information about the micro-determinants of adoption among the medium- to large-scale firms in our sample. Do co-invention costs differ between single- and multi-establishment organizations? Between different applications of enhancement? What part of co-invention costs are attributable to local economic factors and what parts are attributable to costs imposed by competition between establishments from similar industries? Forman (2002) offers a framework for addressing these questions using microlevel data, which is a step in the right direction.

We also did not measure a third of all employment, namely, small commercial establishments of less than 100 employees. We conjecture that these establishments follow similar patterns in participation and different patterns in enhancement, but this is an open question.

Finally, our study also raises questions about the regional distribution of the economic impact from the use of the Internet. How did local and industrial applications influence the intensity of use of information technology? To what extent can state and local development policies foster a positive environment for lowering these costs? There is room for much economic research applying the estimates in our study to models of regional growth.

NOTES

1. For 2000 estimated personal consumption of IT goods and services was $165 billion. For business it was $466 billion. See Henry and Dalton (2002).
2. For example, see Oliner and Sichel (2000), Brynjolfsson and Hitt (2000), Baily and Lawrence (2001), Litan and Rivlin (2001), Henry and Dalton (2002), and the brief survey in Jalava and Pohjola (2002).
3. See e.g. Forman (2002), Jones, Kato and Pliskin (2002), Gertner and Stillman (2001), Carlton and Chevalier (2001), Tan and Teo (1998).
4. See e.g. Bresnahan and Trajtenberg (1995), Bresnahan and Greenstein (2000), Helpman (1998).
5. Examples of participation include browsing and posting text-based web pages, advertising on the World Wide Web (WWW), WWW browsing, and a basic intranet.
6. Careful readers will notice that this varies from the definitions employed by Porter (2001). This is due to a difference in research goals. Throughout his article, Porter discusses the determinants of, and shifting boundaries between, investments that provided table stakes and those that complement a firm's strategy and enhance competitive advantage. He argues that these levels vary by industry and differ from firm to firm. This is the proper variance to emphasize when advising managers about their firm's strategic investment. However, when *measuring* this variance for purposes of formulating policy advice it is useful to shift focus. Our measurement goals require both a standardized definition (of something of interest for policy, but consistent with the spirit of strategy research) and a consistent application across industries and locations.
7. See for example, Malone, Yates and Benjamin (1987), Hubbard (2000), Hitt and Brynjolfsson (1997), or Bresnahan, Brynjolfsson and Hitt (2002).

8. The investor in IT seeks the same process at lower cost or the same process at the same cost and with improved features – such as lower error rates, more timely supply of inventory, or better real-time decision support for firms in rapidly changing market environments. For our purposes it is not relevant whether this conceptual framing resembles economic models of labor saving or capital deepening/augmenting innovation. In any case, Cortada (2003) argues that the appropriate model varies between industries and even within industries over different eras.

9. This section provides an overview of our methodology. For a more detailed discussion, see Forman, Goldfarb and Greenstein (2002).

10. Previous studies (Census, 2002; Charles, Ives & Leduc, 2002) have shown that Internet participation varies with business size, and that very small establishments rarely make Internet investments for enhancement. Thus, our sampling methodology enables us to track the relevant margin in investments for enhancement, while our participation estimates may overstate participation relative to the population of all business establishments.

11. If we were only interested in the features of the most populated regions of the country, then we could easily rely solely on the most recent data from the latter half of 2000, about 40% of the data. However, using only this data would result in very small number of observations for most regions with under one million in population.

12. This was particularly apparent in underreporting of IT usage by Walmart. That said, this non-response bias cannot fully explain why retailing is lower than other industries. For example, if all of Walmart's establishments answered in the affirmative to participating in the Internet, then the estimate for general merchandising would increase from 36 to 60%.

13. Speed is usually associated with an incremental technical advance aimed at a narrow set of adopters, such as the replacement of iron by steel rails, of steam by diesel engines, of black and white by color broadcasting, and so on. Even so, these canonical innovations did not diffuse to all potential adopters in less than a decade.

14. The PC comes closest. The commercial PC began gestating in the early mid-1970s and did not diffuse to a majority of businesses until well into the mid-1980s. The commercial Internet became available around 1992 and was nearly ubiquitous by 2000, the time of our survey.

15. We also experimented with separating communications and computing, following Stiroh (2002a, b). The results are qualitatively similar. The rank correlation between communications and enhancement is mildly lower. There is a high rank correlation between computing and participation that is mildly higher.

16. Our estimates cannot be directly compared against another historical study of lead users, Bresnahan and Greenstein (1997). That study examines the diffusion of client-server technology to former mainframe users in the early 1990s. First, the Bresnahan and Greenstein study concerns mainframe users, and it over-samples some industries relative to this population. Second, the results highlight the role of co-invention costs, which overwhelmed the benefits of adjusting at many traditional information-intensive users. This prevented or slowed down adoption of new technology on a large scale in many industries, except those with scientific or engineering users. In contrast, after several years of the diffusion of the Internet, the benefits were large enough to induce new investment activity in virtually every industry. See Forman (2002) for a discussion of co-invention costs in Internet technology when it first diffused.

17. Their appearance is also echoed in recent surveys of IT capital investment across industries. See, for example, Triplett and Bosworth (2003).

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VALUING INTERNET RETAILERS: AMAZON AND BARNES AND NOBLE

Judith A. Chevalier and Austan Goolsbee

ABSTRACT

Many Internet retailers must raise margins in the future if they are to survive. This raises the important issues of whether they will be able to raise margins as well as how valuation estimates made today should evaluate projected changes to margins in the future. In this paper, we describe retail strategies of pricing for market share in growing markets and show how measures of the price elasticity of demand facing retailers in the current year can be combined with standard accounting variables to inform calculations about future margins. Our analysis suggests that the capital market projects greater future margin improvements for Amazon.com than for BN.com and that this may be due to Amazon benefiting from network effects.

1. INTRODUCTION

In this paper, we show that measuring the elasticity of demand facing a company can provide important insights into each company's expected future profitability and that this information is not completely captured in standard accounting approaches. In our empirical example, we examine the future prospects of Amazon.com and BN.com and we do so using only publicly available data. While publicly available, these data have not been incorporated into previous valuation strategies.

Many researchers and analysts have considered the question of how to value companies for which current financials are poor indicators of future prospects

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(see Damodaran, 2000; Schwartz & Moon, 2000), as is likely to be true for any successful Internet company. All of these methods, however, have to face the same basic problem. It is difficult to forecast whether a firm that has low margins today will truly be able to earn get higher margins in the future. Without any concrete information on that topic, the valuations rely heavily on the untestable assumptions and from the start, Internet commerce has generated wildly differing estimates of future profitability.

Many economists and media observers predicted Internet retailers would quickly become close to perfectly competitive.[1] The Internet reduces search costs directly and shopbots/comparison sites likely reduce such costs even further. Others suggested that the profitability of Internet retailers would eventually resemble the profitability of brick and mortar retailers (for example, Damodaran, 2000) or even higher. At the peak of Internet stock prices, many investors and analysts were forecasting levels of future profitability far above those observed for brick and mortar retailers.

While these historical observations suggest different predictions for the future of Internet retailing *in general*, it is clear that market valuations must also reflect the particular prospects of specific companies and this is even harder to establish. In this paper, we consider the specific cases of Amazon.com and BN.com. Recall that BN.com is the online Barnes and Noble bookstore (ticker BNBN) and is partially owned by, but legally distinct from, the brick and mortar Barnes and Noble stores (ticker BKS).

Table 1 shows the 2002 accounting data for BN.com and Amazon.com, as well as their market valuations as of February, 2003. Total sales by Amazon.com are about nine times higher than the total sales of BN.com and gross profits are about 10 times higher. The gross margins at present, then, are similar across the two

Table 1. Valuation and Accounting Data.

	12-Feb-2003	2002			
	Market Cap	Net Sales	Gross Profit	SG&A	Total Op Ex
AMZN	7,683,000	3,932,936	992,618	812,516	928,494
BMDV		1,873,291	527,542		
Non-BMDV		2,059,645	465,076		
BNBN	172,727	422,827	95,569	167,304	170,841
AMZN/BNBN	44.48	9.30	10.39	4.86	5.43

Notes: Numbers in 000s. SG&A are sales, general and administrative expenses. BNBN is BN.com, AMZN is Amazon.com. BMDV denotes the books, music, DVD and video segment of Amazon.com. The last row shows the Amazon data divided by the BN.com data.

sites. The accounting data do suggest that there might be economies of scale in this industry: Amazon's sales, general, and administrative expenses, as well as total operating expenses were only five times larger than BN.com's. However, while the accounting data might suggest that Amazon might be worth 10 times BN.com, it's actual market value at the time of this writing was more than 50 times greater.

There are four distinct potential explanations for this discrepancy. The first is that markets are irrational and the securities are mispriced relative to one another. Perhaps, as espoused by the "BNBN bulls" on Internet stock bulletin boards such as Ragingbull.com, it is just that Amazon is more well-known and newsworthy.

The second is that the market is forecasting that Amazon will grow faster, and that economies of scale are important in this industry so their profitability will rise faster. Certainly, Amazon's current growth rate of sales exceeds that of BNBN. Amazon's 2002 sales increased 26% relative to 2001 vs. only 4% for BN.com. But the historical data show erratic relationships between SG&A and sales and between total operating expenses and sales so it is impossible to estimate the fixed and variable components of those expenses. Furthermore, some of these expenses might represent one-time expenses that will not be repeated annually, such as expenses related to developing the user interface or how much BN.com may be able to leverage the scale economies arising from sharing facilities (such as warehouse fulfillment) with the brick and mortar Barnes and Noble stores.

A third possibility is that the market believes Amazon's currently non-profitable ventures outside of core retailing will become profitable in the future. For example, Amazon effectively "rents" space on its site to small retailers through its z-shops, as well as to larger retailers such as Target and Eddie Bauer. While currently only Amazon's Books, Music, and DVD and Video segment (BMDV) is profitable, these other segments might one day increase margins.

Finally, it is possible that the market rationally forecasts that Amazon is well-positioned to raise margins on its core BMDV business in the future and that BN.com is poorly positioned to do so. In this paper, we will explore the validity of this fourth explanation. To do this, we detail analytical tools for theoretically and empirically considering a firm's ability to raise margins in the future. The tools we describe are applicable for companies that are using low current prices as a means of investing in future market share. The pricing for market share strategy is often articulated as being important in consumer industries, particularly for young firms but it can occur in any industry in which consumers who buy from a particular company today have an extra propensity to buy from that same company in the future. Klemperer (1987) provides several formal models of pricing for market share.

In this paper, we sketch out a theory of pricing for market share, based on Klemperer (1987) and Chevalier and Scharfstein (1996) and then turn to an empirical application, specifically measuring the extent to which Amazon and/or BN.com are following such a strategy.

To do this we estimate the demand elasticities faced by each retailer, following the methodology in Chevalier and Goolsbee (2003). While measuring only current prices and margins does not directly inform us about the potential for retailers to raise prices in the future, if, as we show below, a retailer today is pricing on the inelastic part of the demand curve, this suggests they may be able to raise prices in the future.

Typically measuring the demand elasticity facing a firm is difficult because the companies generally do not separately provide data on prices and quantities. Using the data provided by Amazon.com and BN.com on their shopping pages about sales ranks of books, however, coupled with some simple distributional assumptions, we can get around the problem. We will do this using a sample of some 20,000 books sold at both sites and then use these elasticity measures to inform valuation comparisons for Amazon and BN.com.

The paper proceeds as follows. Section 2 reviews the theoretical literature on pricing for market share. Section 3 briefly describes the methodology presented in Chevalier and Goolsbee (2003), which translates sales ranks into sales quantities and provides evidence on the demand elasticities. Section 4 discusses valuation implications, discussing how valuations might be predicted to change in response to new information about competition. Section 5 concludes.

2. PRICING FOR MARKET SHARE

The incentives to price for market share depend critically on the growth of the market and the elasticities of demand. To fix ideas, consider the example of pricing at a local supermarket. When a new consumer moves to town, that consumer may evaluate which local supermarket has the best prices and selection. During that initial investigation, the consumer is price sensitive, but after that, may not do much comparison shopping. In this case, the supermarket has to consider the effect that its prices will have on the decisions of the new shoppers, as well as on the decisions of existing shoppers.

The supermarket would like to charge high prices to harvest profits from the less price-sensitive existing customers, but also has an incentive to charge low prices in order to capture the newcomer. The incentive to price low to attract newcomers will be more important in a town which is growing rapidly (i.e. new customers are relatively numerous). The supermarket may price low, even perhaps below marginal cost, because by doing so they invest in locked-in oldtimers that can be harvested profitably in the future. Notice that this strategy can be profitable even absent significant economies of scale (though, obviously, more profitable if scale economies exist). A more formal model of this process for the supermarket context can be found in Chevalier and Scharfstein (1996).

Extending the analogy to Internet retailers, it is clear that this is an industry where new and future customers are quite important and so might be particularly amenable to pricing for market share. Amazon.com has explicitly articulated this idea. During its October 2002 webcast of quarterly results, Amazon reported: "We will continue $25 free super saver shipper at least through the holidays, . . . and will continue to offer the best value proposition for our customers through lower prices. . . . Each of these investments is expensive, and will negatively impact profits in the near term. However, unit growth is critical to driving significant increases in future cash flows and therefore, as we have been doing throughout the years, we are willing to forego some current profits to invest for the long term benefit of our shareholders."

Now consider the difficulties in assessing the financial data provided by a company pricing for market share. They are making an investment for future sales quite similar to a standard capital expenditure but this will not appear in accounting data as an investment expenditure. Instead, operating margins will be lower due to the lower prices. Put differently, the prospects of the company are not identified in the accounting data. Two firms with identical revenues, costs of good sold, and operating margins could have extremely different future prospects. So what to do?

One way to contrast future prospects is to compare the elasticities of demand at the two firms. If we find two firms with similar accounting margins but very different valuations, it would be interesting to see if the elasticities of demand differ substantially. In the extreme, if a firm is on the inelastic part of the demand curve, they may well be pricing for market share (since their prices are lower than they could be). A normal, static profit-maximizing firm should price on the elastic part of the demand curve (i.e. profits are maximized by choosing prices such that $\in_D < -1$).

3. DEMAND ELASTICITY METHODOLOGY

In Chevalier and Goolsbee (2003), we use the publicly available price and sales rank data from Amazon.com and BN.com to measure demand elasticities. It is important to remember that demand elasticities cannot be inferred solely from prices. Financial analysts have suggested that, because Amazon.com sometimes charges relatively high prices for some books, this must reflect consumer price insensitivity. However, this argument misses the possibility that consumers are avoiding those books for which Amazon.com is relatively expensive. In order to correctly examine consumer price elasticities, one must also look at quantities sold.

To measure quantities sold, we use the information available on the websites. A customer visiting one of the sites and looking for a book would typically face a screen giving the price of the book, the relative sales ranking at the site, information on the shipping time/availability, a brief description of the book, customer reviews of the book and a listing of other books and authors that are popular among people interested in the book, and the price for a used version of the book (if available).

In Chevalier and Goolsbee (2003), we collected data during three different weeks in 2001 on about 18,000 different books from the websites of Amazon and BN.com. Our three samples were taken during the weeks of April, June and August of 2001. During this period there were major price changes by both sellers.

Our basic approach is to translate the observed sales ranking of each book into a measure of quantity. To do so, we need to know the probability distribution of book sales so we employ a standard distributional assumption for this type of rank data, the Pareto distribution (i.e. a power law).[2] This methodology allows us to fit a simple relationship between ranks a sales.

$$\ln(\text{Rank} - 1) = c - \theta \ln(\text{Sales}). \tag{1}$$

The constant c is a function of θ, k, and the total number of books for sale. We constrain θ to be the same for both Amazon and BN.com, but we will not constrain c to be the same across sites.

We obtained estimates of θ using data from a single publisher who was monitoring the sales of their own books and competitor's books on Amazon. We also conducted our own purchasing experiments. We use 1.2 as the basic estimate of θ.

Our main estimating equation is given below:

$$\begin{aligned}(r_{bt}^{s} - r_{bt-1}^{s}) = \phi_{bt} + \theta(\beta^{s})(p_{bt}^{s} - p_{bt-1}^{s}) - \theta(\alpha^{s})(p_{bt}^{-s} - p_{bt-1}^{-s}) \\ + \theta\Gamma(x_{bt}^{s} - x_{bt-1}^{s}) + \omega_{bt}.\end{aligned} \tag{2}$$

Where r_{bt}^{s} denotes the log rank at site s for book b at time period t, p_{bt}^{s} denotes the log price for book b at time period t at site s, and p_{bt}^{-s} is the log price for book b at time period t at the other site. β^{s} and α^{s} are the own price elasticity of demand and cross price elasticity of demand for site s, respectively. In other words, estimating the equations using log ranks, r, rather than actual quantities, yields the correct elasticity but scaled by the Pareto shape parameter, θ, which we estimated above.

We estimate this using pairs of time periods for each site. One reason to do this is that we can then use trimmed LAD estimation to allow for the censoring of sales ranks in the Barnes and Noble data.[3]

Table 2. Two Period Panel Estimates of Online Book Demand System.

Dep Var.: ln(Rank)	(1) t_2, t_1	(2) t_3, t_2	(3) t_3, t_1
BN.com (trimmed LAD)			
ln (P_{own})	4.396 (0.182)	2.985 (0.128)	2.894 (0.128)
ln (P_{cross})	−3.825 (0.181)	−2.403 (0.128)	−2.696 (0.114)
n	24738	24738	24738
Shipping dummies	Yes	Yes	Yes
Time × age dummies	Yes	Yes	Yes
ISBN dummies	Yes	Yes	Yes
Amazon (OLS)			
ln (P_{own})	0.262 (0.032)	0.256 (0.048)	0.371 (0.050)
ln (P_{cross})	−0.047 (0.090)	−0.131 (0.081)	−0.189 (0.073)
n	24738	24738	24738
R-squared	0.97	0.97	0.96
Shipping dummies	Yes	Yes	Yes
Time × age dummies	Yes	Yes	Yes
ISBN dummies	Yes	Yes	Yes

Notes: The dependent variable is the log of the sales rank. This is censored as described in the text. Standard errors are in parentheses. The cross price is the price for the same book at the competitor's site. *t*1 denotes April 14, 2001. *t*2 denotes June 23, 2001. *t*3 denotes August 3, 2001.
Source: Chevalier and Goolsbee (2003).

Table 2 shows these results from Chevalier and Goolsbee (2003). Interestingly, the sum of the own price elasticity at each site plus the cross-price elasticity at the other site do approximately equal the same value (as assumed in our specification of Eq. (3)). However, this conceals an extreme difference in the source of the relative price sensitivity across the two sites. BN.com has a large own price elasticity with a small cross-price from Amazon. Amazon has the reverse. With the Pareto parameter of 1.2, BN.com's own-price elasticity of demand is around −3.5. At Amazon, on the other hand, it is actually less than one in absolute value, at −0.45.

There are two important issues about the results. First, the elasticity measures for Amazon are much lower than for BN.com, suggesting that Amazon has more "room" to raise prices that BN.com at the same marginal cost. Furthermore, the elasticity estimates for Amazon are extremely small. As discussed above, of course, standard calculations for static imperfectly competitive markets suggest that a firm should choose prices such that the elasticity of demand exceeds 1 in absolute value. This is consistent with Amazon.com's claims about its strategy, as well as speculation in the popular price as to whether Amazon's prices are sustainable or are artificially low (see, for example, Hansell, 2001). When Amazon's growth stops, we may see prices rise substantially.

4. IMPACT OF FUTURE MARGINS ON VALUATION

While the elasticity data do provide insights into valuation, they do not translate directly into projections for future margins. They do suggest that future margin growth for Amazon is likely to be higher than for BN.com if customer behavior does not change drastically.

To get a sense of the importance of future margins for the valuation of these companies, consider the valuation model proposed by Damodaran (2000). Damodaran provides a web site in which users can input current accounting data, projections about future growth rates of revenues, and projections about the steady-state margins that the firm will enjoy. For illustration, we input Compustat end-of-year 2001 accounting data for Amazon.com and BN.com into Damodaran's spreadsheets. Table 9 reports per-share values of Amazon.com and BN.com on March 1, 2002, around the time the annual financial figures for Amazon.com and BN.com for 2001 would be fully available.

In order to obtain valuation figures, we have to make a number of assumptions. First, for both firms, we assume a variety of growth rates in revenues over the next 10 years, with revenues reaching a steady-state growth rate of 5% per year beginning in the 11th year. We assume that each firm will maintain a constant level of sales to capital of three.[4] For assumptions other than the growth rate of revenues and the level of margins, we adopt the default assumptions in Damodaran (2000). In order to highlight the role of margins, we use the actual 2001 accounting data for each of the two firms, and make common assumptions for the two firms about the equity premium, firm beta, expected cost of debt, and the like and ignore the effects on valuation of any outstanding options. The other values are available from the authors on request.

The results are reported in Table 3. The first thing to note is how wildly sensitive valuation estimates are to the sales margin input. At the time these accounting data were released, on March 1, 2002, Amazon.com had a per-share price of \$15.39, while BN.com has a per share price of \$1.44. Assuming growth rates of revenues of 10% per year for the first 10 years, one cannot get the \$1.44 BN.com share price without pushing the steady-state margins below 5%. Of course, as the assumed margin gets lower, the valuation estimate becomes increasingly insensitive to the revenue growth rate chosen. For Amazon.com, assuming growth rates in revenues compounding 10% per year for the first 10 years, Amazon's per-share value of \$15.39 can only be reached by assuming that profit margins approach 15%, some three times higher than BN's.

While, a priori, we might expect two Internet retailers selling very similar products to face similarly elastic customers, there are several reasons why these customers may differ, consistent with Brynjolfsson and Smith's (2000) finding

Table 3. Valuation Estimates for Amazon.com and Barnesnoble.com as of FY Ending 2001 Accounting Data.

Steady State Margin	Growth Rate of Revenues for First 10 Years		
	10%	15%	20%
AMZN per share valuation[a]			
5%	$2.32	$3.53	$5.29
10%	$9.44	$13.87	$20.31
15%	$16.49	$24.20	$35.85
20%	$23.54	$34.52	$50.42
BNBN per share valuation[b]			
5%	$1.55	$1.81	$2.20
10%	$3.40	$4.50	$6.00
15%	$5.22	$7.15	$9.96
20%	$7.03	$9.80	$13.82

Note: Valuation methodology uses FY 2001 accounting data and spreadsheets from Damodaran (2000). Assumptions inputting the valuation are described in the text. The margin is the profit margin on goods sold that the firm will eventually earn. The growth rate in revenues describes how fast the company is assumed to grow per year for the next ten years.

[a] AMAZON ACTUAL SHARE PRICE 3/1/02: $15.39.

[b] BN.COM ACTUAL SHARE PRICE 3/1/02: $1.44.

that customers at dealtime.com, an Internet shopbot have a significant propensity to click through to Amazon after conducting a price search, even when Amazon did not offer the lowest prices to the search. First, Amazon has made significant investments in trying to improve customer loyalty, such as sending customized book recommendations to past customers and pioneering one-click shopping. Second, Amazon may have a good reputation for service quality, for which consumers are willing to pay a premium. Finally, Amazon may reap some network advantages as a function of being the first and largest Internet book retailer. Indeed, Amazon articulated its early strategy as "GBF," "get big fast," on the theory that scale would be, in and of itself beneficial.[5] For example, time pressured or novice users might go to Amazon without bothering to check prices elsewhere. Further, much of Amazon's technology investments focused on collaborative filtering technologies for the site; customers would benefit from (and be stimulated to purchase more) if they are given information about the purchases of other customers who bought this book, or information about other customers' likes or dislikes and the quality of such information rises with the number of customers.

Unfortunately, our data do not allow us to test all of these myriad and non-mutually exclusive hypotheses. However, we do have some information to allow a preliminary probe of one part of the network effects hypothesis. We examine here the differential propensity of Amazon and Barnes and Noble.com customers to purchase books as a function of the extent to which they have been reviewed by other customers on the site. Both Amazon and Barnes and Noble offer site visitors the opportunity to post reviews for books. Due to the higher traffic at Amazon, Amazon has more reviews for most books. For example, for our sample taken in April 2001, 30 customer reviews per book, while BN.com had on average 3.5 reviews per book. Given the fact that consumers can free ride on the information provided by either site (reading reviews on one site and purchasing at the other), we might be surprised to find that this difference in the "depth" of reviews provides any advantages for Amazon. Nonetheless, a regression analysis suggests that depth of reviews does impact purchases at the site. Table 4 shows two regression specifications for the April 2001 period. The dependent variable is log of sales rank minus one. There is one observation for each site for each book. Each specification includes ISBN dummies, so the coefficients capture differences between the two sites. Control variables include an Amazon fixed effect, the prices at each site, and dummy variables to capture differences in the promised shipping time between the two sites. In the first column, we include as explanatory variables the natural log of the number of customer reviews for that book at that site. This variable is set equal to zero if there are no reviews. We also include a dummy variable if the number of reviews equals zero. Since ISBN dummies are included, these coefficients only capture differences across sites in the depth of reviews for a given book.

The results are shown in Table 4. The coefficient for the natural log of reviews is negative and significant at the 1% confidence level. This means that ranks are improving (getting lower) as the number of reviews increases. Consider a situation in which Amazon had 10 reviews for a book and BN had 10, and the book was

Table 4. Relationship Between Review Depth and Sales Ranks.

	(1)	(2)
ln(price)	2.340 (0.064)	2.490 (0.066)
(ln price − mean(ln price)) × ln reviews		−0.077 (0.008)
ln(number of reviews)	−0.110 (0.008)	−0.115 (0.008)
Zero reviews dummy	0.170 (0.018)	0.148 (0.018)
R-squared	0.899	0.900
Number of books	11535	11535
Includes ISBN dummies?	Yes	Yes
Includes shipping dummies?	Yes	Yes
Includes site dummy?	Yes	Yes

Notes: Dependent variable equals ln(sales rank – 1). Included in specifications but not reported: ISBN dummies, a dummy for Amazon sales, dummies to capture differences in promised shipping times across books and sites.

ranked number 500 on both sites. If Amazon's reviews increased to 20, holding BN's constant, the expected rank would fall to 463 at Amazon. The coefficient for the no reviews dummy is positive and significant, suggesting that relative sales are depressed if a book is not reviewed on one site, but has reviews on the other. Column 2 considers the interaction between price elasticity and the log of reviews. We construct a variable that equals the log of price (minus the mean log of price in the sample) time the log of the number of reviews. The coefficient for the log of price not interacted remains positive, indicating that relative sales fall when relative prices rise. However, the interaction term is negative, suggesting a lower price elasticity the more reviews there are. More detailed analyses of the relationship between reviews and sales behavior can be found in Chevalier and Mayzlin (2003).

5. CONCLUSION

Using an applied valuation technique from Damodaran (2000), we illustrate that differing assumptions about the future margins to be earned by Amazon.com and BN.com are likely factors in the widely different valuations of the two firms implied by the market. The analysis here and in Chevalier and Goolsbee (2003) suggests that differences in the demand elasticities faced by each site may contribute to the valuation differences observed in the market. Preliminary analysis suggests that network effects may play a role in stimulating demand at Amazon.

NOTES

1. See, for example, Kuttner (1998).
2. For discussions on the use of power law distributions to describe rank data, see Pareto (1897), Quandt (1964), and Mandelbrot (1988). It should be noted that the well-known "Zipf's law" (Zipf, 1949) is a special case of Pareto's law. More details on the Pareto and its application can be found in Johnson and Kotz (1970) or Goolsbee (1999).
3. Trimmed LAD estimation panel procedures for data sets with more than two time periods are not well-developed. The survey of Chay and Powell (2001), for example, present trimmed LAD results only for pairs of time periods rather than for the entire panel.
4. This choice is arbitrary, and could be important, as pointed out in Damodaran (2000).
5. See Brooker (2000) for details.

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THE EVOLUTION OF PRICE DISPERSION IN INTERNET RETAIL MARKETS

Xing Pan, Brian T. Ratchford and Venkatesh Shankar

ABSTRACT

We investigate how online price dispersion has evolved since the bursting of the Internet bubble by comparing price dispersion levels in years 2000, 2001, and 2003 and between multi-channel and pure play e-tailers. The results show that although online price dispersion declined between 2000 and 2001 when there was a shakeout in Internet retailing, it increased from 2001 to 2003, the post bubble period, in particular, for desktop computers, laptop computers, PDAs, electronics and software. The proportion of items for which price dispersion at multi-channel retailers was higher than that at pure play e-tailers, increased steadily during 2000–2003. These findings suggest that online price dispersion is persistent even as Internet markets mature.

1. INTRODUCTION

Price dispersion on the Internet has been the subject of a growing body of research (e.g. Baye & Morgan, 2001; Brown & Goolsbee, 2002; Brynjolfsson & Smith, 2000; Clay et al., 2001, 2002; Ellison & Ellison, 2001; Morgan, Orzen & Sefton, 2001; Morton, Zettelmeyer & Silva-Risso, 20001; Pan, Ratchford & Shankar, 2002,

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2003; Scholten & Smith, 2002; Smith & Brynjolfsson, 2001). A consistent finding is that online price dispersion is persistent and large. As online markets have grown in size and maturity over the years, some recent studies have focused on whether online price dispersion has increased or decreased or remained the same after the initial Internet years (e.g. Baye, Morgan & Sholten, 2001; Ratchford, Pan & Shankar 2003). How has online price dispersion evolved over time, in particular, since the bursting of the Internet bubble? That is the focus of this study.

In the years following the arrival of Internet retail markets, online price dispersion has not vanished. Baye, Morgan and Scholten (2001) found that over time average price range was about 40% and the average difference between the two lowest prices remained stable at around 5%. In a study of dispersion in e-tailer prices during 2000 and 2001, Ratchford, Pan and Shankar (2003) showed that although price dispersion decreased substantially, it was still significant.

Online price dispersion is substantial due to various reasons. First, differences among e-tailer service quality may drive online price dispersion (Brynjolfsson & Smith, 2000; Pan, Ratchford & Shankar, 2002). Second, market and product factors are significant causes of online price dispersion (Pan, Ratchford & Shankar, 2003). Third, Internet markets were inefficient during the initial years of the Internet, so the presence of online price dispersion in most empirical studies covering those years was only natural.

Although we know about some of the sources of online price dispersion, we do not know much about online price dispersion levels since the bursting of the Internet bubble. A better understanding of this issue could help retailer pricing as Internet markets mature. The research objective of this study is thus to extend prior research by focusing on changes in online price dispersion during the post-bubble period and as Internet markets mature.

In the next section, we review the related literature. In Section 3, we explain the data and the measurement. In Section 4, we present our empirical analysis. In the fifth section, we present and discuss the results. In the final section, we offer our conclusions and discuss the limitations and directions for future research.

2. RELATED LITERATURE

Two streams of research are relevant to this paper. One stream is focused on online price dispersion in general and the other is comparison of prices and price dispersion at multi-channel retailers and pure play e-tailers. Theoretical research on online price dispersion (Baye & Morgan, 2001; Chen & Hitt, 2003) shows that online price dispersion is an equilibrium outcome of price competition on the Internet. Therefore, it is likely to be persistent.

Empirical research on online price dispersion offers a lot of evidence for continued price dispersion. Clay et al. (2002), Clemons et al. (2002) and Erevelles et al. (2001), all found that online price dispersion is greater than offline dispersion. Brynjolfsson and Smith (2000) show that price dispersion on the Internet is at least as high as dispersion in traditional channels, before weighting for market shares of the retailers, but the opposite when prices were weighted for market shares of the retailers. Two studies, Brown and Goolsbee (2002) and Morton, Zettelmeyer and Risso (2001), however, found that price dispersion was lower online than it was offline. Pan et al. (2002) show that online price dispersion is large and is partially explained by e-tailer service quality and Pan et al. (2003) show that the large online price dispersion is primarily explained by non-e-tailer characteristics.

Ratchford et al. (2003) compared price dispersion among e-tailers for eight product categories in November 2000 and November 2001. They found that price dispersion declined during this period, but was still persistent. In a study of 1,000 best-selling electronic items at price comparison site Shopper.com over an eight-month period, Baye, Morgan and Scholten (2001) found that average price range was about 40% and the average difference between the two lowest prices remained stable at around 5%. These studies show that online price dispersion was still persistent at or before the bursting of the Internet bubble. Scholten and Smith (2002) found that price dispersion in 2,000 was comparable to that in 1976 for both online and offline retailers.

Our first research question is: What happened to online price dispersion after the bursting of the Internet bubble? A number of e-tailers exit the market after the bursting of the bubble, so one expectation is that online price dispersion would have reduced. However, what really happened in the post bubble period is an empirical question.

The second stream of research of interest is the one comparing price dispersion at multi-channel and pure play e-tailers. Multi-channel retailing is emerging as a growing trend in retailing and therefore it is important to examine price dispersion at multi-channel retailers over time. It has been found that a growing number of bricks-and-mortar stores are having online presence and turning themselves into bricks-and-clicks retailers (Zettelmeyer, 2000).

In a study of DVDs, Tang and Xing (2001) found that price dispersion was higher for multi-channel retailers than it was for pure play e-tailers. In a study of books and CD markets in Milan Italy during 2002, Ancarani and Shankar (2003) found that when price dispersion is measured by standard deviation, it is higher at multi-channel retailers than it is at pure play e-tailers or traditional retailers. This finding was consistent regardless of whether prices included shipping costs or not. They found, however, that when price dispersion is measured by price range, the result is diametrically opposite – pure play e-tailers have higher dispersion than do multi-channel retailers.

Therefore our second research question is: How has dispersion at pure play e-tailers and multi-channel retailers evolved as the Internet markets mature? The answer to this question is related to our first research question because the first research question covers both the type of retailers.

3. DATA

We gathered three data sets with comparable product items from different time periods, November 2000, November 2001 and February 2003. The data comprise product categories in which entirely homogeneous product items can be identified and their prices compared. This allows us to eliminate the potential problem of price difference due to product heterogeneity. The eight product categories we study, namely, books, CDs, DVDs, desktop computer, laptop computer, PDA (personal digital assistant), computer software and consumer electronics, allow us to compare homogeneous product items. Product items in the same product line that have different model numbers and slight differences are treated as different products so that we keep the price comparison to the same product. We also selected these product categories because they cover product item prices ranging from a few dollars to thousands of dollars. This allows for greater generalizability of the results.

We used BizRate.com as the starting point to search for the e-tailers who sell the same product items. BizRate searches e-tailers' prices twice a day and publishes them on BizRate.com. We also used other price comparison engines (e.g. MySimon.com, PriceScan.com, and Shopper.com) to search e-tailer prices and compare with BizRate's list. We found that BizRate has the most complete retailer price list among all the price comparison engines. We also searched for the well-known retailers' Web sites individually, if we suspected that they might carry certain product item but they did not appear in the list generated by those search engines. Although in a few cases, some additional e-tailers were added to the seller list, we found that in general, the search engine-generated list is rather complete. This careful seller selection process allows us to avoid a sample selection bias.

We collected product prices without shipping and handling charges. The shipping and handling cost depends on a consumer's basket size and the consumer's geographic location. To include shipping and handling charge, a strict assumption on a consumer's basket size and location has to be made. Since our research focus is on e-tailers' posted prices to general consumers rather than prices to individual consumers in one-to-one marketing, it is appropriate to avoid making such assumptions. Further, as reported by Smith and Brynjolfsson (2001), consumers evaluate product price, shipping and handling charge, and tax differently and they are very sensitive to how the total price is allocated among these components. That also suggests directly adding the shipping and handling charge and tax to product price may not be appropriate. Scholten and Smith (2002) compared online price dispersion with and without adjusting shipping cost and found that adjusting for shipping cost only slightly reduces the price dispersion by 1%, but the results are fairly similar. All these imply that using product price directly is generally not problematic.

4. ANALYSIS OF PRICE AND E-TAILER SERVICE HETEROGENEITY

Previous empirical analyses on price dispersion have examined prices with and without adjustment for retailer service. Most studies compared retailer prices directly and found substantial amount of price dispersion online (e.g. Baye, Morgan & Scholten, 2001; Brynjolfsson & Smith, 2000; Clay, Krishnan & Wolff, 2001). Theoretically, the observed price dispersion could be merely a result of retailer differentiation on retail service rather than be an indicator of market inefficiency (Pan, Ratchford & Shankar, 2002). However, using a hedonic regression approach, Pan et al. (2002) showed that price dispersion remains significant even after correcting product prices for differences in e-tailer service quality. Pan, Ratchford and Shankar (2003) further showed that e-tailer characteristics only explain a small amount of price dispersion, even after controlling for non-service attributes such as consumer awareness and trust. Ratchford et al. (2003) compared price dispersion between 2000 and 2001 using both e-tailer service adjusted and unadjusted price data and found similar results. To understand whether the relationship between e-tailer price and service has changed in 2003, we conduct a hedonic price regression similar to that of Pan et al. (2002) and Ratchford et al. (2003) as shown in the following equation.[1]

$$\frac{p_{mr}}{\bar{p}_m} - 1 = \sum_{k=1}^{k} b_k (S_{mrk} - \bar{S}_{mk}) + v_{mr} \qquad (1)$$

In the above equation, p is product price, S is e-tailer service, m is product item, r is e-tailer, k is attribute of e-tailer service ($k = 1, \ldots, K$), b is coefficient of e-tailer service on price, and v is an error term. The prices of each product are deflated by the average price of that product across all e-tailers, so we have a measure of price that is comparable across all product items since it is independent of a product's absolute price level. Measuring all effects as deviations from item means eliminates item effects due to generally high or low levels of service attributes for sellers of that item. It has the same general effect as including a set of item dummy variables, and creates a zero intercept. We run the regression for each product category separately given drastic heterogeneity across categories.

We adopt Bizrate.com's ratings to measure e-tailer services. The Bizrate ratings have been widely used by consumers, e-tailers, shopbots, and other organizations such as *Consumer Report* to measure e-tailer service quality. Specifically, nine service attributes are measured by surveying the online shoppers with a ten-point scale. Because of high correlations among these measures, we first factor analyze them to obtain orthogonal variables of e-tailer service that can be used to estimate Eq. (1).

The results of the factor analysis for the three years appear in Table 1. The rotated component matrix suggests there exist three fundamental dimensions of e-tailer service, namely, reliability of fulfillment, shopping convenience, and shipping and handling, consistent with Ratchford et al. (2003).[2] The three factors capture over 94% of the original variance so we can simplify the hedonic regression analysis without loss of information.

Factor scores from the above analysis are then employed as independent variables to estimate Eq. (1). As Table 2 shows that although the e-tailer service attributes are significantly related to prices, the coefficients have mixed signs across categories, similar to other hedonic regression studies (e.g. Betancourt & Gautschi, 1993; Pan, Ratchford & Shankar, 2002, 2003; Ratchford, Pan & Shankar, 2003). Pakes (2003) showed that this is quite likely to happen when information and competition are imperfect, because services that are costly to produce and are positively valued by consumers may have negative signs in the equilibrium hedonic regression. More important, the R squares of these models are very low, ranging from 1.6 to 7.3%. Since the nine attributes we examined capture a comprehensive set of important e-tailer service dimensions, the results indicate a very weak relationship between e-tailer services and prices. This is very consistent with the findings of Pan et al. (2002) and Ratchford et al. (2003), who examined such relationship using data for 2000 and 2001. Thus, all the evidence suggests that measured differences in e-tailer services have little relation to e-tailer prices. Therefore, adjusting for e-tailer services does not substantively affect price dispersion analyses. Our subsequent analyses are hence based on unadjusted e-tailer prices.

4.1. Price Dispersion Analysis

Although theoretical arguments predict narrower price dispersion online than offline (Bakos, 1997; Brynjolfsson & Smith, 2000), empirical evidence does

Table 1. Factor Analysis of e-Tailer Services: Rotated Component Matrix.

Variable	Component		
	1	2	3
2000 sample			
Ease of ordering	0.14	**0.91**	0.22
Product selection	0.17	**0.82**	0.21
Product information	0.35	**0.72**	−0.31
Web site navigation	0.15	**0.87**	0.23
On-time delivery	**0.93**	0.12	0.10
Product representation	**0.89**	0.30	0.08
Customer support	**0.91**	0.18	0.22
Tracking	**0.89**	0.17	0.12
Shipping and handling	0.35	0.33	**0.79**
Factor name	Reliability	Shopping convenience	Shipping and handling
2001 sample			
Ease of ordering	0.24	**0.90**	0.22
Product selection	0.29	**0.88**	0.05
Product information	0.40	**0.61**	0.37
Web site navigation	0.17	**0.93**	0.20
On-time delivery	**0.87**	0.34	0.25
Product representation	**0.91**	0.15	0.07
Customer support	**0.85**	0.27	0.39
Tracking	**0.85**	0.34	0.31
Shipping and handling	0.39	0.28	**0.85**
Factor name	Reliability	Shopping convenience	Shipping and handling
2003 sample			
Ease of ordering	**0.88**	0.33	0.22
Product selection	**0.92**	0.24	0.15
Product information	**0.85**	0.35	0.23
Web site navigation	**0.88**	0.35	0.20
On-time delivery	0.34	**0.90**	0.17
Product representation	0.50	**0.78**	0.20
Customer support	0.25	**0.91**	0.25
Tracking	0.28	**0.91**	0.17
Shipping and handling	0.39	0.39	**0.83**
Factor name	Shopping convenience	Reliability	Shipping and handling

Note: Extraction: Principal components. Rotation: Varimax with Kaiser normalization. Percentage of variance explained by the three factors (2000 sample: 85%, 2001 sample: 89%; 2003 sample: 94%). High scores in bold.

Table 2. Results of Hedonic Regressions of Normalized Prices on e-Tailer Service Attributes by Product Category.

Category	Parameter	Independent Variable			R^2	N
		Reliability	Shopping Convenience	Shipping & Handling		
Book	Estimate	0.018*	0.057*	0.037*	0.017	715
	t Value	2.76	2.61	2.93		
CD	Estimate	−0.014*	0.054*	0.004	0.054	628
	t Value	−3.53	3.22	0.56		
DVD	Estimate	−0.012*	0.013*	−0.034*	0.057	991
	t Value	−4.29	03.30	−7.00		
Desktop	Estimate	0.014	−0.028	0.003	0.016	288
	t Value	1.26	−1.50	0.42		
Laptop	Estimate	0.015*	0.001	0.018*	0.059	1,023
	t Value	4.01	0.37	6.59		
PDA	Estimate	0.001	−0.008	0.018*	0.017	722
	t Value	0.10	−0.72	2.89		
Electronics	Estimate	0.008	−0.036*	0.018*	0.073	775
	t Value	1.48	−4.06	4.49		
Software	Estimate	0.002	−0.067*	−0.010*	0.057	1,877
	t Value	0.39	−10.54	−3.59		

*Significant at the 0.01 level.

not support it. In studies of books, CDs, software, vitamins, airline tickets and electronics sold online, Bailey (1998), Brynjolfsson and Smith (2000), Clay, Krishnan and Wolff (2001), Clemons et al. (2002), Erevelles et al. (2001), and Scholten and Smith (2002) all found that online price dispersion is no narrower than that in conventional markets. Brown and Goolsbee (2002) and Morton et al. (2001), however, found that price dispersion is somewhat narrower online than offline. Regardless of whether price dispersion is higher or lower online than offline, online price dispersion appears to be persistent over time (Baye, Morgan & Scholten, 2001; Brynjolfsson & Smith, 2000; Clay, Krishnan & Wolff, 2001; Smith, Bailey & Brynjolfsson, 2000). However, the time periods analyzed in these studies have been limited to several months and all data examined were prior to March 2001. Ratchford, Pan and Shankar (2003) compared online price dispersion between November 2000 and November 2001 and found that average price dispersion measured by percentage of price difference (price range relative to mean) dropped significantly (from 39 to 29%), but remained substantial. Given the rapid growth and high volatility of the e-tail markets, it is interesting to know whether and how price dispersion in e-tail markets has changed since 2001. This

Table 3. Comparison of Price Dispersion.

Variable	Mean & Std. Dev. (2000)	Mean & Std. Dev. (2001)	Mean & Std. Dev. (2003)
Price coefficient of variation	11.72 (6.21)	9.78 (6.23)	10.38 (6.32)
Price percentage difference[a]	38.50 (20.97)	28.73 (18.71)	28.81 (18.38)
Price level	651.99 (995.01)	748.75 (1,476.1)	672.99 (1,259.10)
Number of sellers for an item	11.60 (3.33)	8.17 (2.27)	9.13 (5.96)

Note: Number of observations: 581 (2000), 826 (2001), and 769 (2003).
[a] Price range relative to average price instead of minimum price.

understanding will contribute to a deeper understanding of the impact of the Internet on price competition when markets become more mature.

We calculate two relative price dispersion measures, namely, the coefficient of variation (standard deviation of price relative to the average price) and the percentage difference (range of price relative to the average price) for a variety of homogeneous products from the following eight product categories: books, CDs, DVDs, desktop computer, laptop computer, PDAs, software, and consumer electronics. We calculate the price dispersion of every homogeneous product and compare the average price dispersion of all product items at each time period. As shown in Table 3, the products in the three samples are comparable and their average prices are not statistically different (the F statistic of test of equal price across the three samples is 1.16).

Price dispersion drops significantly from 2000 to 2003. For coefficient of variation, the t statistics are -5.71 (between 2000 and 2001) and -3.88 (between 2000 and 2003). For percentage price difference, the t statistics are -9.38 (between 2000 and 2001) and -9.17 (between 2000 and 2003). All of them are significant at the 0.01 level. However, price dispersion did not decrease further since November 2001. The t-test shows that the averages of percentage price difference are nearly the same in November 2001 and February 2003 (the t statistic is 0.08 and insignificant), and the average of coefficient of variation in price was slightly higher in February 2003 (the t statistic is 1.92 and marginally significant at the 0.1 level). Figure 1 (a and b) illustrate the changes in price dispersion.

We compare our results with those of Baye, Morgan and Scholten, who monitor online prices using automatic data collection software. They compare the prices and price dispersion of electronics and computer related products listed at Shopper.com everyday.[3] As shown in Fig. 2 (a and b), they found that the coefficient of variation increased from year 2000 to 2003. Although the percentage difference does not appear to increase as much as the coefficient of variation does, it increases since August 2002 and dispersion in 2003 is larger than that in 2000.

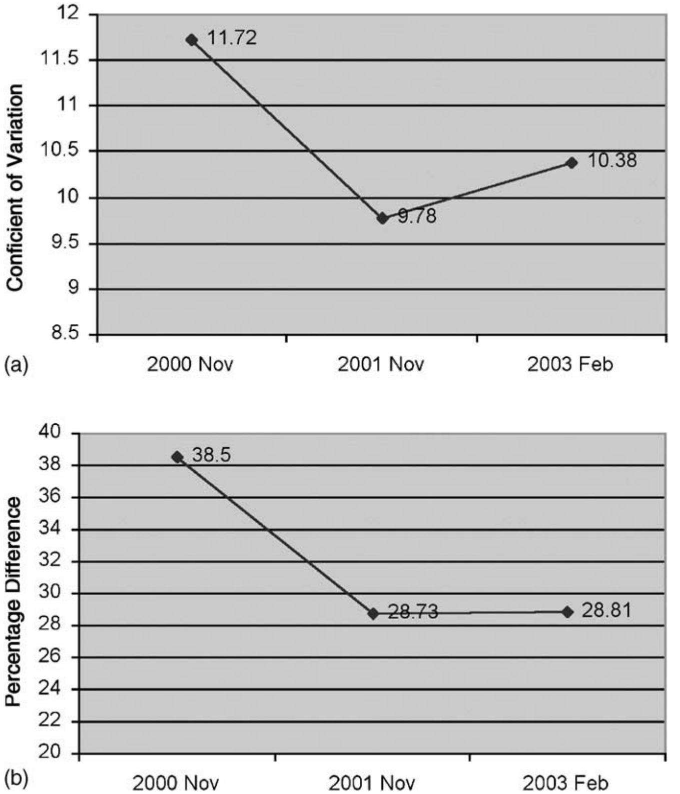
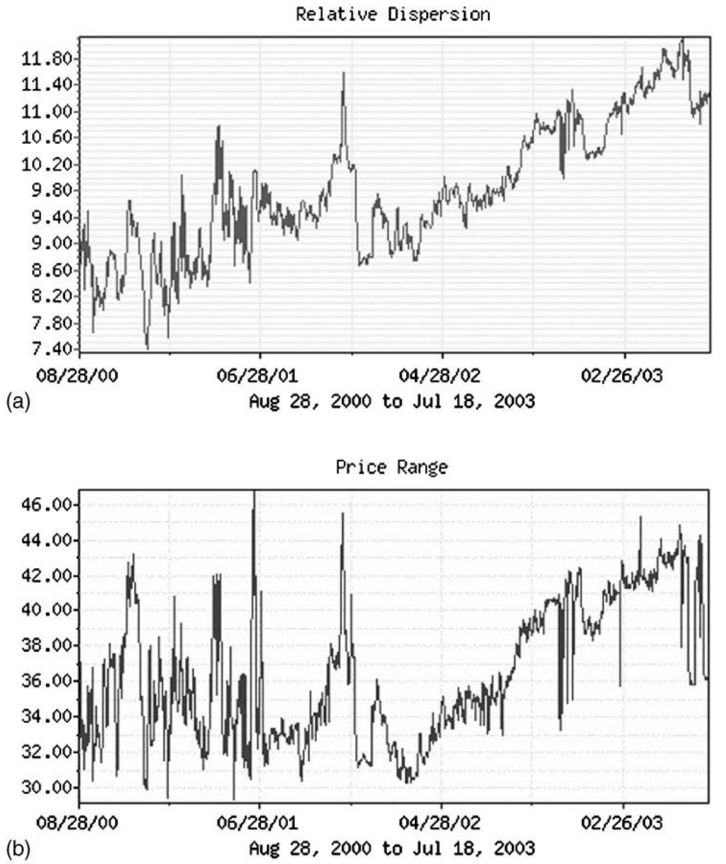


Fig. 1. Comparison of Price Dispersion. (a) Coefficient of Variation; (b) Percentage Difference.

These findings are consistent with ours in that online price dispersion is significant and persistent from 2000 to 2003 and that the Internet retail markets have not become more efficient, even after market restructuring in 2001. These results are different from ours in that while they found that price dispersion actually increased, we find that price dispersion increased for desktop computers, laptop computers, PDAs, electronics and software. However, for books and DVDs, price dispersion decreased from 2001 to 2003. Thus, the differences in the results of these two studies result from differences in the product mix studied. Our samples include low price items such as books, CDs, and DVDs, in addition to consumer electronics and computer related products that were investigated by Baye et al. (2001, 2003).



Price range is the price range relative to the minimum price.

Fig. 2. Changes in Price Dispersion. (a) Coefficient of Variation (Relative Dispersion is the Coefficient of Variation in Prices); (b) Percentage Difference (Price Range is the Price Range Relative to the Minimum Price). *Source:* http://www.Nash-Equilibrium.com

Next, we examine price dispersion within each product category as shown in Table 4. Books consistently emerges as one of the categories with the highest level of price dispersion, even after a significant drop in the 2003 sample. This suggests that books may be a special category that is somewhat atypical (Pan, Ratchford & Shankar, 2003). Chen and Hitt (2003) observed that only 6% of online book buyers use price comparison engine and 80% consumers only visit one bookseller's Web site. The limited consumer search may explain the persistently high price dispersion

Table 4. Changes of Price Dispersion by Product Category.

Category	November 2000		November 2001		February 2003	
	Mean & Std. Dev.	*N*	Mean & Std. Dev.	*N*	Mean & Std. Dev.	*N*
Coefficient of variation in price						
Book	15.29 (3.92)	105	16.63 (4.44)	134	14.21 (6.35)	141
CD	15.46 (5.14)	43	13.02 (5.63)	120	8.79 (4.67)	108
DVD	13.05 (6.26)	96	10.22 (6.02)	103	10.31 (4.85)	110
Desktop	10.78 (7.58)	105	5.46 (4.04)	107	7.03 (5.36)	41
Laptop	7.55 (4.15)	78	6.11 (5.44)	96	7.32 (6.26)	110
PDA	10.49 (6.59)	37	9.86 (5.33)	52	14.13 (8.54)	49
Software	10.55 (6.99)	51	6.51 (3.71)	120	9.22 (5.05)	100
Consumer electronics	9.65 (3.17)	66	8.22 (4.63)	94	10.83 (6.03)	110
Percentage difference in price						
Book	48.90 (13.78)	105	48.08 (13.02)	134	33.32 (14.89)	141
CD	51.04 (18.41)	43	39.30 (17.68)	120	22.21 (11.67)	108
DVD	43.67 (16.69)	96	32.29 (18.49)	103	30.69 (16.10)	110
Desktop	34.39 (27.12)	105	15.01 (10.65)	107	17.73 (13.67)	41
Laptop	25.70 (13.91)	78	17.87 (16.08)	96	20.66 (17.22)	110
PDA	37.10 (24.43)	37	30.26 (16.96)	52	45.68 (29.68)	49
Software	35.58 (25.89)	51	18.95 (10.52)	120	32.91 (18.89)	100
Consumer electronics	30.99 (11.67)	66	22.12 (13.83)	94	28.65 (17.21)	110

for books. Table 4 further show that although price dispersion declined from November 2000 to February 2003 for books, CDs and DVDs, there were mixed changes to price dispersion in the other categories that are also in Baye, Morgan and Scholten's sample. In particular, price dispersion for PDAs increased substantially from 2001 to 2003. This is consistent with the finding of increased price dispersion for consumer electronics and computer products by Baye, Morgan and Scholten.

To analyze the differences in price dispersion among the three samples and across the product categories in greater depth, we run the following random effects regression model.

$$\begin{aligned} \mathrm{PD}_{mjt} = {} & \alpha_0 + \alpha_1 \bar{p}_{mjt} + \alpha_2 \mathrm{Sellers}_{mjt} + \alpha_3 \mathrm{Sellers}^2_{mjt} + \alpha_4 \mathrm{Year2001}_t \\ & + \alpha_5 \mathrm{Year2003}_t + \mu_j + \varepsilon_{mjt} \end{aligned} \quad (2)$$

where PD is the price dispersion, $\bar{p}$ is the average price, Sellers is the number of e-tailers, Year2001 and Year2003 are dummy variables for the 2001 and 2003 samples, m is product item, j is product category, t is time period, μ is a random disturbance characterizing the jth product category and is constant across the items within that category, and ε is an error term. The average product price of a product item is included as an independent variable because relative price

Table 5. Regression Results of Price Dispersion Change.

Measure of Price Dispersion (Dependent Variable)	Coefficient of Variation	Percentage Difference
−2 Res log likelihood	13,741.9	18,638.3
Number of observations	2,176	2,176
Intercept	11.56[a] (10.08)	22.59[a] (6.44)
Average price level	−0.0003[b] (−2.47)	−0.001[b] (−2.49)
Number of sellers	0.03 (0.32)	1.79[a] (5.59)
Number of sellers (square)	−0.001 (−0.23)	−0.03[a] (−2.90)
Year 2001 dummy	−2.13[a] (−6.07)	−6.78[a] (−6.25)
Year 2003 dummy	−1.77[a] (−4.75)	−7.61[a] (−6.61)
Product category heterogeneity ($\sigma^2_{\text{intercept}}$)	6.15[b] (1.95)	56.34[b] (1.94)

[a] $p < 0.01$, t-statistics in parenthesis.
[b] $p < 0.05$, t-statistics in parenthesis.

dispersion for higher price products tends to be smaller due to higher involvement and more extensive consumer search (Pan, Ratchford & Shankar, 2003). Adding this variable allows us to compare price dispersion of products at different price levels. Number of sellers of a product item is included in the regression because it is a market characteristic that affects price dispersion (Baye, Morgan & Scholten, 2001; Pan, Ratchford & Shankar, 2003). A quadratic term of this variable is also used since the effect can be non-linear (Baye et al., 2001; Pan et al., 2003; Ratchford et al., 2003). The random effect specification allows us to control for category idiosyncratic effects and it also allows more appropriate interpretation than a fixed effects model since the categories we looked at are only a small subset of those in the Internet retail markets. Our main focus is how price dispersion has changed over the three time periods, after controlling other effects.

The results are shown in Table 5. As expected, more expensive products exhibit lower degrees of price dispersion. Number of sellers is found to have an inverted U-shape relationship with percentage difference in price, but no relationship with coefficient of variation in price. The product categories are heterogeneous.[4] The two time period dummy variables show that price dispersion indeed decreased since year 2000. However, there is no change in price dispersion between November 2001 and February 2003 (when year 2001 is used as the base, the year 2003 dummy is insignificant for both dependent measures).

4.2. Analysis of Multi-Channel Retailers vs. Pure Play e-Tailers

We further investigate how multi-channel retailing affects online price dispersion. Pan, Shankar and Ratchford (2002) analytically and empirically showed that the two types of retailers have different pricing behavior. However, only limited empirical evidence has been provided regarding price dispersion between the two different types of retailers. Tang and Xing (2001) examined DVD prices in the summer of 2000 and found that price dispersion among multi-channel retailers is sharply higher than that among the pure Internet retailers. In an analysis of retailers in the Italian market, Ancarani and Shankar (2003) found that price dispersion is generally higher for multi-channel e-tailers than it is for pure play e-tailers and traditional retailers if standard deviation is the dispersion measure, but is the opposite if price range is the dispersion measure. We compare our three samples to examine the relationship between price dispersion and retailer type and how this relationship changes over time.

To achieve this objective, we calculate price dispersion for multi-channel retailers and pure play e-tailers separately. Then we compare their relative levels of price dispersion for the same product item. If the sellers of a product item include none or only one multi-channel retailer or include none or only one pure play e-tailer, then that product item is dropped from the analysis since measures of price dispersion cannot be appropriately constructed. For each of our samples, we determined the number of product items for which multi-channel retailers have larger price dispersion than that for pure play e-tailers. The proportions are shown in Table 6. Contrary to Tang and Xing (2001), we found that multi-channel retailers generally have less price dispersion than pure player e-tailers if the price dispersion measure is percentage difference in price. This result, however, is consistent with Ancarani and Shankar (2003). In November 2000, multi-channel retailers had larger percentage difference in price only for 10% of the product items and larger coefficient of variation in price only for about one-third of the product items. The percentages of product items for which multi-channel retailers have higher price dispersion have steadily increased from November 2000 to February 2003. However, still much less than 50% (41% for coefficient of variation and

Table 6. Comparison of Price Dispersion: Proportions of Items for which Price Dispersion is Greater for Multi-channel e-Tailers than for Pure Play e-Tailers.

Variable Measure	November 2000 ($n = 216$)	November 2001 ($n = 426$)	February 2003 ($n = 398$)
Coefficient of variation in price	32%	38%	41%
Percentage difference in price	10%	23%	27%
Total number of multi-channel retailers in sample	12	19	31
Total number of pure play e-tailers in sample	92	70	112

only 27% for percentage difference). Thus, pure play e-tailers still appear to have larger price dispersion than multi-channel retailers. Over the same time period, both the absolute number and the proportion of multi-channel retailers steadily increased, reflecting the multi-channel retailing trend on the Internet.

5. ANALYSIS OF THE VALUE OF PRICE INFORMATION AND SEARCH COST

Value of price information and consumer search cost, related to price dispersion, are also indicators of market efficiency and competitiveness. One measure of the value of price information, also the surplus for consumer (gross of search cost), is the expected difference between the prices paid by a completely uninformed and a completely informed consumer. A completely uninformed consumer expects to pay the average price in the market, whereas a fully informed consumer pays the lowest price (Ratchford, Pan & Shankar, 2003; Varian, 1980). Ratchford, Pan and Shankar (2003) also showed that the difference between the highest price and the average price reveals a lower bound on the highest search cost in the market. Since the consumer encountering the highest price prefers to accept it rather than search more with the expectation to pay an average price, the search cost must be at least the same as the gain from additional search. Hence, comparison of the difference between the average price and minimum price and between the maximum price and average price of a product over the three samples allows us to understand how the value of price information and consumer search cost have changed since November 2000.

Table 7 provides the means and standard deviations of the value of price information and the consumer search cost for each sample. Note that these measures of price difference are deflated by the average price so they are comparable across product items. The value of price information decreased slightly from November 2000 to November 2001 (the t statistic is -0.88 and insignificant), and then

Table 7. Comparison of Value of Price Information and Search Cost.

Variable	Mean & Std. Dev. (2000)	Mean & Std. Dev. (2001)	Mean & Std. Dev. (2003)
Value of price information[a]	0.145 (0.08)	0.140 (0.10)	0.131 (0.09)
The highest search cost[b]	0.240 (0.17)	0.147 (0.12)	0.157 (0.12)

Note: Number of observations: 581 (2000), 826 (2001), and 769 (2003).
[a] Difference between average price and minimum price relative to average price.
[b] Difference between maximum price and average price relative to average price.

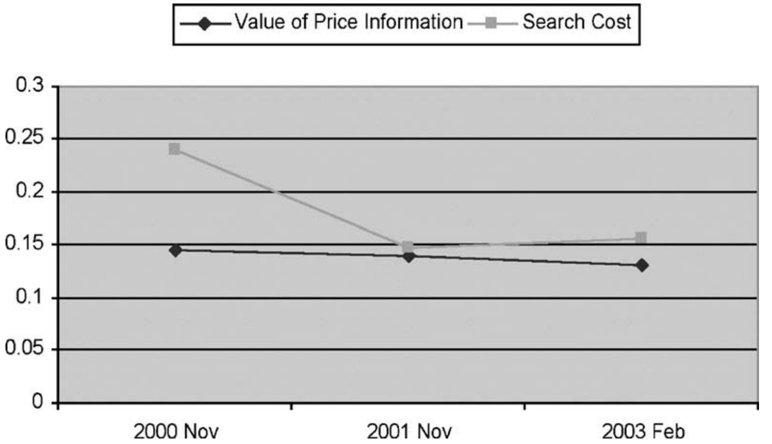


Fig. 3. Comparison of Value of Price Information and Search Cost.

dropped significantly by February 2003 (the *t* statistic is −2.69 and significant at the 0.01 level). First, this finding suggests that maturing Internet markets drive down prices and thus price dispersion. As a result, consumers benefit less from knowing information about prices. Second, despite the decrease of the value of price information, the trend is quite moderate (Fig. 3). This supports Baye and Morgan's (2001) analytical prediction that in a market with information gatekeeper, price dispersion exists in equilibrium when it is costly for sellers and buyers to transmit information, so the value of price information will not converge to zero.

The highest consumer search cost dramatically decreased since November 2000. The *t* statistics are −13.10 between the 2000 and 2001 samples and −11.53 between the 2000 and 2003 samples, both significant at the 0.01 level. There is no significant change between November 2001 and February 2003. Again, the results suggest that the highest consumer search cost declined as Internet market matured. However, the Internet market is not frictionless and the search cost has remained stable since November 2001.

Figure 3 illustrates the changes of the value of price information and the highest search cost. Baye, Morgan and Scholten also monitor the daily changes on value of price information based on price data of consumer electronics and computer products (Fig. 4). Their results are similar to ours in that the value of price information was similar between 2000 and 2001. However, their results are different from ours in that they found the value of price information has persistently increased since early 2002, whereas we found only a moderate decrease. Again, such discrepancy is similar to that of price dispersion and it is probably because our samples contain different product categories. To have a more close comparison, we look at the

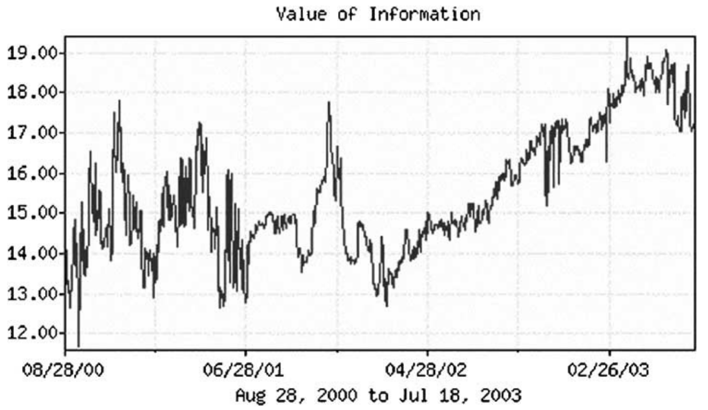


Fig. 4. Changes in Value of Price Information. *Note:* Value of information is measured as differences in average price and minimum price, relative to the minimum price. *Source:* http://www.Nash-Equilibrium.com

value of price information and search cost within each product category (Table 8). Table 8 shows that values of price information have generally declined for books, CDs, and DVDs. However, for the other categories that are also studied by Baye, Morgan, and Scholten, the values of price information have generally increased from November 2001 to February 2003. Thus, our results are indeed consistent with theirs. We found a similar pattern for changes in search cost.

We run the following regressions for a more in-depth analysis on how value of price information is affected by price level and number of sellers in market. Further, we want to examine changes in the value of price information after controlling the effects of these variables. The regression, as given by Eq. (3), is the same as what we used to analyze price dispersion, except that the dependent variable is different.

$$\begin{aligned}\mathrm{VI}_{mjt} = {} & \beta_0 + \beta_1 \bar{p}_{mjt} + \beta_2 \mathrm{Sellers}_{mjt} + \beta_3 \mathrm{Sellers}^2_{mjt} + \beta_4 \mathrm{Year2001}_t \\ & + \beta_5 \mathrm{Year2003}_t + \mu_j + \varepsilon_{mjt} \end{aligned} \tag{3}$$

The results of the model estimation are reported in Table 9. The value of price information is independent with the price level of the product. However, consistent with Baye, Morgan and Scholten (2003), we found that value of price information systematically varies with number of sellers in market. In particular, the quadratic term of number of sellers is negative and significant, revealing the existence of an inverted U-shape relationship. The product categories are heterogeneous and books have consistently larger errors. After controlling these effects, the values of price information are about the same in November 2000 and February 2003, and

Table 8. Changes of Value of Price Information and Search Cost by Product Category.

Category	November 2000		November 2001		February 2003	
	Mean & Std. Dev.	*N*	Mean & Std. Dev.	*N*	Mean & Std. Dev.	*N*
Value of price information						
Book	0.27 (0.11)	105	0.27 (0.10)	134	0.14 (0.07)	141
CD	0.33 (0.17)	43	0.17 (0.08)	120	0.11 (0.05)	108
DVD	0.28 (0.13)	96	0.14 (0.07)	103	0.14 (0.07)	110
Desktop	0.25 (0.22)	105	0.07 (0.06)	107	0.07 (0.06)	41
Laptop	0.14 (0.08)	78	0.08 (0.09)	96	0.10 (0.08)	110
PDA	0.26 (0.21)	37	0.14 (0.08)	52	0.23 (0.14)	49
Software	0.22 (0.21)	51	0.09 (0.06)	120	0.16 (0.11)	100
Consumer electronics	0.18 (0.10)	66	0.12 (0.06)	94	0.13 (0.07)	110
Search cost						
Book	0.22 (0.06)	105	0.21 (0.09)	134	0.20 (0.11)	141
CD	0.18 (0.07)	43	0.23 (0.12)	120	0.11 (0.07)	108
DVD	0.16 (0.06)	96	0.18 (0.13)	103	0.17 (0.11)	110
Desktop	0.09 (0.06)	105	0.08 (0.07)	107	0.10 (0.10)	41
Laptop	0.12 (0.09)	78	0.10 (0.11)	96	0.11 (0.11)	110
PDA	0.11 (0.07)	37	0.16 (0.13)	52	0.23 (0.19)	49
Software	0.13 (0.09)	51	0.10 (0.07)	120	0.17 (0.11)	100
Consumer electronics	0.13 (0.05)	66	0.10 (0.10)	94	0.16 (0.12)	110

Table 9. Regression Results of Changes on Value of Price Information.

Dependent Variable	Value of Price Information
−2 Res log likelihood	−4672.3
Number of observations	2,176
Intercept	0.067[a] (3.88)
Average price level	0.00 (−1.38)
Number of sellers	0.008[a] (5.65)
Number of sellers (square)	−0.0001[a] (−2.62)
Year 2001 dummy	**0.012**[b] (2.44)
Year 2003 dummy	**−0.004 (−0.69)**
Product category heterogeneity ($\sigma^2_{\text{intercept}}$)	0.001[b] (1.96)

[a] $p < 0.01$, *t*-statistics in parenthesis.
[b] $p < 0.05$, *t*-statistics in parenthesis.

higher in November 2001 (the *t* statistic is −3.80 and significant at the 0.01 level for the *Year2003* dummy when the 2001 sample is used as the base). The results again support Baye and Morgan's (2001) view that value of price information will not vanish even when Internet markets mature.

6. CONCLUSIONS AND LIMITATIONS

We extend Baye, Morgan and Sholten (2001) and Ratchford, Pan and Shankar (2003) by investigating how online price dispersion has evolved since the bursting of the Internet bubble. We compared price dispersion levels in years 2000, 2001, and 2003 and between multi-channel and pure play e-tailers using three data sets compiled in years 2000, 2001, and 2003 that contain information on both e-tailer prices and e-tailer characteristics for eight product categories – books, CDs, DVDs, desktop computers, laptop computers, PDAs, electronics and software. The results show that although online price dispersion declined between 2000 and 2001 when there was a shakeout in Internet retailing, it did not decline overall from 2001 to 2003. In particular, online price dispersion appeared to increase from 2001 to 2003 for desktop computers, laptop computers, PDAs, electronics and software. Thus, price dispersion among e-tailers has been persistent over time. The proportion of items for which price dispersion at multi-channel retailers was higher than that pure play e-tailers, increased steadily during 2000–2003. With the number and size of multi-channel retailers growing rapidly relative to pure play e-tailers, the findings suggest that online price dispersion is likely to be persistent even as Internet markets mature.

The limitations of our study can serve as fruitful avenues for future research. First, our research has examined price dispersion levels at three discrete points in time. A continuous time tracking of online price dispersion on the same categories would be a useful supplement. Second, our comparison among retailer types was between pure play e-tailers and multi-channel retailers. It would be interesting to study the evolution of price dispersion within traditional retailers in conjunction with the other retailer types. Finally, it would be useful to analyze the evolution of the drivers of online price dispersion over time.

NOTES

1. Using the logarithm of the ratio of the price to its mean as the dependent variable produces similar results.

2. Ratchford et al. (2003) included another factor of third party certification. When we collected the data in 2003, we found that several third party certification web sites no

longer provided such information. Hence, we cannot include that factor in our analysis. However, the remaining factors on Bizrate ratings are consistent over time. Pan et al. (2003) found that third party certification did not affect e-tailer prices in general.

3. Baye, Morgan and Scholten use similar measures for price dispersion. It should be noted that their measure of percentage difference is price range deflated by minimum price, so they found higher values than our measure of percentage difference. However, our measures using coefficient of variation are consistent. Their most recent data start to cover additional product categories such as books and CDs. For details about their methodology, see http://www.Nash-Equilibrium.coms

4. For both dependent measures, books have the largest average errors among all categories, illustrating that it is an atypical category for price dispersion.

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ONLINE PRICE DISPERSION WITHIN AND BETWEEN SEVEN EUROPEAN COUNTRIES

J. Rupert J. Gatti and Paul Kattuman

ABSTRACT

This paper provides a comprehensive analysis of online price dispersion in Europe, across a broad range of product categories and countries. Using the dominant European price comparison site we collected firm specific prices, weekly, from seven European countries (Denmark, France, Italy, Netherlands, Spain, Sweden and the United Kingdom) for 31 unique products, falling into five distinct product categories (printers, PDAs, scanners, games consoles, computer games and music), over the nine-month period October 2001 to June 2002. The resulting data set comprises over 17,000 individual price observations.

Using a number of alternative measures of price dispersion we find significant differences in the degree of price dispersion observed in online markets, both between countries and across product categories. We consider alternative explanations for online price dispersion and analyze their significance in explaining the observed differences.

1. INTRODUCTION

In recent years there has been a growing empirical literature documenting surprisingly large degrees of price dispersion in online markets. Initial expectations were

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that the introduction of the Internet, by dramatically lowering consumer search costs, would generate greater competition between firms, and result in lower prices and reduced degrees of price dispersion. However empirical evidence from online markets does not provide unambiguous support for either proposition.[1]

Early empirical estimates, possibly reflecting less developed online markets, showed online prices to be higher than prices in conventional markets.[2] More recent work suggests that online markets, especially in association with online price listing services, may indeed be fostering increased competition, and lowering prices.[3] However there is little evidence of a similar reduction in online price dispersion over the period, with observed degrees of price dispersion comparable to, or even greater than, those in conventional markets. Clay, Krishnan and Wolff (2001), for example, observe price ranges of 38–65% amongst U.S. online book sellers, while Baye, Morgan and Scholten (2002) find average price ranges of around 40% for a wide variety of electronic appliances listed on an online price comparison site in the U.S. To date the empirical evidence for online price dispersion has been obtained, almost exclusively, from the United States and concentrated in a restricted set of markets – primarily books and CDs. The intention of our study is to extend the analysis in two dimensions: comparing degrees of price dispersion between different product categories and between different national markets. The broad scope of the study allows us to investigate the extent to which results obtained from U.S. markets generalise to other national settings, and determine to what extent institutional differences that may exist between countries and product types impact on the operation and competitiveness of online markets.

To achieve this, firm specific pricing data was downloaded for a selection of 31 products from an online price listing service in seven European countries – Denmark, France, Italy, Netherlands, Spain, Sweden and the U.K. This data was downloaded from the dominant price comparison service in Europe, Kelkoo, which operates separate websites in all seven countries. Firm and product specific pricing data was downloaded from each national website, weekly, from October 2001 until June 2002 – giving 17,644 individual price observations. To enable a broad analysis across both product types and national boundaries the products were selected from within six broad categories of goods (Games, Games Consoles, Music, PDAs, Printers and Scanners) which all have fairly developed online markets and well defined products, allowing us to monitor identical products in all seven countries. To the best of our knowledge this is the first study of price dispersion for a varied basket of products in any one of the seven countries involved, and the first to directly compare price dispersion between countries.[4]

We find significant and systematic differences in the degrees of price dispersion observed between both product categories and countries, and consider a number of alternative explanations. A robust finding from the analysis is that relative price dispersion falls as the level of prices rise, so cheaper goods typically have relatively greater price dispersion than more expensive items. Consistent with theoretical predictions, we find that the impact of changes in the number of firms listing prices depends on which measure of price dispersion and which country is considered. However, having corrected for these and other determinants, we find Games Consoles, Music and Computer Games have significantly lower levels of price dispersion than the other categories, and that France and Spain have significantly lower levels of price dispersion than the other European countries studied.

The remainder of the paper proceeds as follows: in Section 2 we discuss the existing theoretical and empirical literature on price dispersion, in both conventional and online markets. Section 3 describes in detail the nature of the data we collected and Section 4 provides a descriptive summary of the results obtained. Regression results, using the two-part model to account for mass points of zero dispersion markets, are presented in Section 5, and the conclusions are contained in Section 6.

2. PRICE DISPERSION: THEORY AND EMPIRICAL EVIDENCE

There are two main theoretical approaches to modelling price dispersion for homogenous products. One approach, following Stigler's (1961) seminal paper most directly, is to assume that consumers are imperfectly informed about prices and that searching amongst firms to obtain price information is a costly activity. In these "search" models, price dispersion in equilibrium is typically obtained by introducing variations in the consumer search costs (Rob, 1985), willingness to pay (Diamond, 1987), or firm characteristics (Reinganum, 1979) although such variation is not strictly necessary (Burdett & Judd, 1983; Gatti, 2002). One consistent comparative static prediction from these models is that price dispersion falls as the cost of search falls. Stigler (1961) also conjectured that price dispersion would be relatively lower for higher priced products than lower priced products.

The second theoretical approach for modelling price dispersion, following Salop and Stiglitz (1977), Varian (1980) and Stahl (1989), is to have a proportion of consumers who have access to a complete list of posted prices and are thus perfectly "informed" about available prices, and a proportion of "uninformed" consumers with no access to the list of prices. The "informed" consumers are price sensitive and purchase from the store charging the lowest price while the "uninformed" consumers select stores at random, although their behaviour may also take the form of store loyalty rather than ignorance. This "price posting" approach has been particularly popular when modelling price dispersion in online markets (Baye & Morgan, 2001; Baye et al., 2003; Brown & Goolsbee, 2002) where consumers possessing internet access are assumed to be able to access multiple prices costlessly, possibly through a price listing service such as Kelkoo, while consumers without online access face costly search. Interesting, and at times counter-intuitive, comparative static results may occur in these models.[5]

Brown and Goolsbee (2002) show that price dispersion will initially increase with increases in the number of informed consumers, but will eventually fall. Equilibria in these models depend on the maximum level of mark-up that firms can sustain over marginal costs. An increase in the mark-up, through either an increase in the consumers' "willingness to pay" for the product or a reduction in marginal costs, will be associated with an increase in both the mean price and price dispersion. Baye, Morgan and Scholten (2002) show that an increase in the number of firms listing prices may be associated with either an increase or a decrease in the range of the distribution of prices – depending on whether or not, and how, changes in firm numbers are correlated with changes in consumer demand.

There is now a wealth of empirical evidence of price dispersion for almost homogeneous products. Stigler (1961) motivated his analysis by arguing that price dispersion is ubiquitous and citing two examples, one for Chevrolet cars in Chicago in 1959[6] and the other for anthracite coal delivered in Washington DC in April 1953. Subsequently there have been a number of studies providing empirical evidence for price dispersion across a broad range of product types. The results from a selection of these studies are summarised in Table 1.

While various alternative measures of price dispersion have been applied, the two reported in Table 1, the coefficient of variation and the range, are the most frequently applied measures. The coefficient of variation, defined as the standard deviation of prices divided by the mean price, has the advantage of being both scale independent and unaffected by changes in the number of price observations sampled. The range, being the difference between highest and lowest price quotation observed, is most usually represented as a percentage or ratio of the minimum price. As such, the range measure remains scale independent but is not independent of the size of the sample taken.[7] The range measure is also particularly susceptible to distortion by outliers.

Pratt et al. (1979) and Carlson and Pescatrice (1980) provide early examples of systematic empirical studies of price dispersion across a range of product types. Pratt et al. selected 39 "standardized" products at random from the Boston Yellow Pages, ranging from the provision of a horoscope to a microwave oven. Sampling all firms listed in the Yellow Pages for the selected products, they obtained price ranges that varied from 11% (for a bicycle) to 567% (for a styling brush), with an average range of nearly 120%. The coefficient of variation can be easily calculated

Table 1. Summary of Price Dispersion Literature.

Study	Product Type	Region	Data Source	Coeff. of Variation	Range
Conventional markets					
Stigler (1961) [from Jung (1960)]	Automobiles	Chicago	Individual dealers	1.7%	7.0%
Stigler (1961)	Coal	Washington D.C.	Bids for govt. purchases	6.8%	22.4%
Pratt, Wise and Zeckhauser (1979)	Varied	Boston	Individual stores	21.6%[e]	119.5%[e]
Carlson and Pescatrice (1980)	Varied	New Orleans	Individual stores	13.1%	–
Sorensen (2000)	Prescription drugs	Upstate New York	Individual stores	22.0%	–
Scholten and Smith (2002)	Varied	Indiana	Individual stores	18.2%	–
Aalto-Setala (2002)	Groceries	Finland	Individual stores	12.6%	–
Online markets					
Clemon, Hann and Hitt (2000)	Airline Tickets	U.S.	Online travel agents	–	18%
Brynjolfsson and Smith (2000)	Books	U.S.	8 Online stores	–	33%
	CDs	U.S.	8 Online stores	–	25%
Clay and Tay (2001)	Books	U.S., Canada, U.K. and Germany	9 Online bookstores	23.5–33.7%[a,e]	–
Clay, Krishnan and Wolff (2001)	Books	U.S. bookstores	32 Online	12.9–27.7%[b,e]	38.6–65.2%[c,e]
Baye, Morgan and Scholten (2002)	Electronics	U.S.	Shopper.com	9.7%	∼40%
Scholten and Smith (2002)	Varied	U.S.	mySimon.com	14.5%	–
Ellison and Ellison (2001)	Computer memory	U.S.	Pricewatch.com	–	∼4%[d]

[a] Figures vary across book category.
[b] Figures vary across class of book: [New York Times bestsellers: 27.7%; Former NYT bestsellers: 17.8%; Computer bestsellers: 15.6%; Former computer bestsellers: 14.0%; Random books: 12.9%].
[c] As a percentage of mean (not minimum) price and, therefore, an underestimate relative to the other figures. Figures vary across class of book. [New York Times bestsellers: 65.2%; Former NYT bestsellers: 42.8%; Computer bestsellers: 38.6%; Former computer bestsellers: 35.7%; Random books: 31.9%].
[d] Uses Range of 10 lowest price offers, while the full range is of hundreds, and so is not directly comparable.
[e] Own calculations from Summary Data.

from the summary statistics provided, and these vary from 4 to 71% with an average of 21.6%.

Carlson and Pescatrice (1980) selected 34 specific products designed to cover a range of possible search behaviours, such as frequent/infrequent purchases (potatoes vs. mattress) and routine/emergency purchases (deodorant vs. batteries). They report coefficients of variation that vary from 3.27% (expensive camera) to 41.38% (contraceptives) with an overall average of 13.1%.

More recently Sorensen (2000) collected price quotations for 152 top selling prescription drugs from 20 pharmacies in Middleton and Newburgh, NY, and reported an average coefficient of variation of 22%. Aalto-Setala (2002) analysed price data for 120 grocery items obtained from 157 stores across Finland. He obtained values for the coefficient of variation between 4% and 32%, with an average of 12.6%.

Two robust findings emerge from these studies. Price dispersion is "ubiquitous, even for homogenous goods" and there is wide variation between levels of price dispersion observed in different markets. All the studies cited appeal to search-based models of price dispersion to motivate analysis of observed variations in price dispersion. Without exception these studies find price dispersion to be significantly lower for products expected to have lower search costs, such as frequently purchased items. Interestingly, they also consistently demonstrate a significant reduction in the coefficient of variation as the mean price of the commodity rises – but less than proportionately. That is, a 10% increase in mean price is associated with a positive, but less than 10% increase in the standard deviation of prices – causing a reduction in the overall coefficient of variation. This is usually cited as confirmation of Stigler's conjecture.

The general lesson obtained from empirical studies of price dispersion in conventional markets has been that lower search costs are associated with lower levels of price dispersion, leading to the expectation that the introduction of online markets would significantly reduce observed levels of price dispersion. Recent empirical evidence from online markets challenges this hypothesis. As Table 1(b) shows, measures of price dispersion in online markets do not appear to be significantly lower than those observed in conventional markets.

Scholten and Smith (2002) measure levels of price dispersion in both conventional and online markets in 2000 for a basket of products directly comparable with those selected by Carlson and Pescatrice (1980), and conclude that there is no evidence for lower price dispersion in either market since the original article. Brynjolfsson and Smith (2000) collect price information on 20 book titles and 20 CD titles from 16 firms selected to form a cross section of online and conventional stores. They find significant levels of price dispersion in online markets for both books and CDs and conclude that, in comparison with conventional stores, there is weak evidence for slightly higher levels of price dispersion in the book market and slightly lower levels of price dispersion in the CD market. Clay, Krishnan and Wolff (2001) conduct a more extensive survey of the online book market, collecting prices for 399 book titles from 32 online book stores over a 25 week period. They find levels of price dispersion comparable with Brynjolfsson and Smith (2000), together with significant variation in price dispersion across book categories. Specifically they find books in high demand (NYT bestsellers) have the lowest average prices and the highest price dispersion while books with low demand have the highest average prices and lowest price dispersion. These results are consistent with theoretical price posting models if the number of firms listing prices is independent of, or at least only weakly correlated with, demand for the book.

Clay and Tay (2001), is the only previous study we are aware of to compare online prices internationally, monitoring the prices for 95 textbooks at nine online stores based in four countries (U.S., Canada, U.K. and Germany). They find significant difference between prices charged across countries (summarised by the price dispersion measures reported in Table 1) but the size of their sample makes it impractical to calculate price dispersion measures for each country separately.

Undoubtedly the most comprehensive study of online pricing to date is Baye, Morgan and Scholten (2002). Their study collects prices for the 1000 best selling consumer electronic products from the price listing service Shopper.com, daily, for eight months. Overall the average coefficient of variation in their study is 9.69% and the average range is approximately 40%. In contrast to Clay et al. (2001) they find that both the coefficient of variation and percentage range are generally lower for the most popular products. They also analyse the impact of the number of firms quoting prices on levels of price dispersion, finding that the coefficient of variation falls as the number of firms rise while the range rises with the number of firms – at least initially. In contrast to our study, Baye, Morgan and Scholten (2002) do not consider the impact of the price level itself on the degree of price dispersion, nor do they separate products into categories to allow inter-industry differences.

In recognition of the ambiguous impact from changes in the number of firms listing prices between the various theoretical models, Baye, Morgan and Scholten (2002) propose an alternative measure of price dispersion, which they term the "Gap," recording the difference between the lowest and second lowest price observed. They show that the various theoretical models all predict the Gap measure of price dispersion to fall as the number of firms in the market rises, although this may not reflect any change in the equilibrium distribution of prices per se. As predicted, their analysis confirms that the Gap falls significantly with the number of firms listing prices, and with product popularity.

As is apparent from Table 1, the existing empirical evidence on price dispersion has concentrated on U.S. markets. In this study we extend the empirical evidence on price dispersion by analysing and comparing online price dispersion for an identical basket of commodities in seven countries and between different product categories.

3. DATA DESCRIPTION

The price data for this study was downloaded directly from the price listing service, Kelkoo. Kelkoo is the dominant price listing service in Europe, operating within seven countries that are members of the European Union; Denmark, France, Italy, Netherlands, Spain, Sweden and the United Kingdom.[8] It is either the first or second most accessed price listing service in all seven countries and throughout the period of the study was accessed by over one million distinct users each month.[9]

Despite obvious language differences, the layout and structure of the Kelkoo web pages are very similar between countries. On each site consumers are offered a broad range of product categories which, while differing slightly between countries, typically includes music, books, computer hardware and software, electronic and household appliances, clothing, cars, telephones and telephonic services, travel services and so on. There are several alternative ways of searching for specific products on any site – but the choice of search methods available to consumers is identical on all the national sites. Once a product has been identified, Kelkoo provides a list of firms selling the desired product, together with the prices charged and some additional information such as delivery costs.

Figure 1 shows a screenshot of the prices listed for the Palm m505 PDA in the U.K. on 1 March 2002. Seven firms offer the product, at seven different prices ranging from £281.99 to £349.99. Consumers interested in purchasing an item "click through" from the Kelkoo page to the firm's own web site using the "More" button. Kelkoo's revenue is generated by charging firms a fee for each consumer "click through" to the firm's site. The fees charged vary between product categories and countries, but range from 0.30 to 1.50 per "click through." Firms are not charged a fixed fee to list on Kelkoo, although there is an implicit cost to the firm of formatting data on the web site for access by Kelkoo. Firms select the national sites that they wish to be listed on, so consumers accessing a specific site view price quotations only from firms that have selected to be listed at that site. Consumers are not charged any fees to access Kelkoo.

The similarity in structure and layout of the Kelkoo sites, both internationally and amongst product categories, is an important feature of the data collected. This similarity not only minimizes any behavioural differences that may be generated

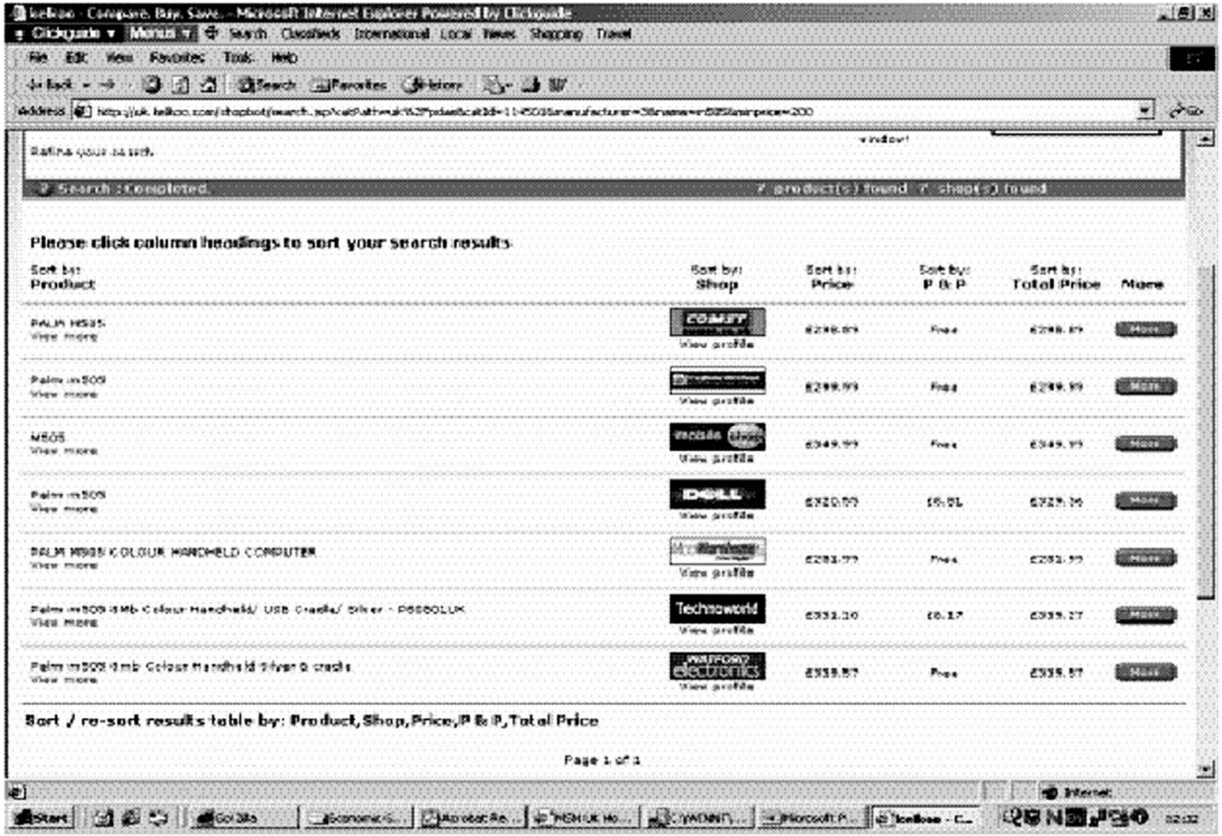

Fig. 1. Screenshot from Price Listing Service Kelkoo (U.K. Site).

by different web page layouts, but also minimizes differences in the cost of search between the different products. It is this consistency between different national and product specific web sites which allows us to meaningfully compare degrees of price dispersion between sites.

For this study we collected firm and price information from the Kelkoo sites in all seven EU countries for 31 specific and well-defined products, across six main product categories: Games, Games Consoles, Music CDs, PDAs, Printers and Scanners – a full list of the products selected appears in Table A1 in the Appendix. These categories were selected to reflect areas where online retailing was strongest and where product differentiation between countries was smallest.[10] Within categories all the products selected were identified to be selling well in at least three countries at the start of the study.

For each of the 31 products selected, all firm-specific price quotations listed on each of the seven national Kelkoo websites were downloaded, weekly, for 30 weeks – from October 25 2001 until June 6 2002.[11] This resulted in 17,644 individual price observations across 4699 country/product/date specific websites. Summary statistics, including mean and minimum prices together with the various measures of price dispersion, were calculated for each of the country/product/date specific websites to form the dataset used in the present study.

All the prices used in this study include sales tax, exclude transportation and delivery charges, and have been converted into Euros at the relevant daily rate. Including delivery charges into the analysis has no significant impact on the results reported, being typically small relative to the observed price variation.

4. SUMMARY STATISTICS

Table 2 presents summary statistics for three commonly used measures of price dispersion; coefficient of variation, range and Gap, all in percentages. As price dispersion is only meaningful when two or more firms are quoting prices, in this table we have excluded those (900) records for which only one firm listed a price – leaving 3799 records with two or more price quotations.[12]

Table 2 shows that price dispersion is a prevalent feature of online markets. Overall, across all countries and products, the average coefficient of variation is 10.1%, the average range is 28% and the average gap is 10.9% – figures broadly in line with those of previous studies. However these general averages disguise considerable variation across both countries and product categories, with the coefficient of variation varying from 2.2% for Consoles in Spain to 20.4% for Games in the Netherlands, the range varying from 3.8% for Consoles in Spain

Table 2. Price Dispersion by Country and Category.

	France	Italy	Netherlands	Spain	Sweden	U.K.	Denmark	Category Average	Rank
Coefficient of variation (%)									
Consoles	3.0	13.8	5.6	2.2	8.4	3.5	9.7	6.1	1
Games	9.8	6.2	20.4	9.6	13.6	12.8	20.2	13.9	6
CDs	15.3	8.8	12.3	13.3	14.0	16.2	8.7	12.8	5
PDAs	8.3	4.3	7.4	7.2	6.6	5.2	7.9	6.7	2
Printers	7.3	8.9	11.3	8.6	7.1	9.4	9.4	8.7	3
Scanners	12.4	14.2	10.1	6.0	8.0	3.9	6.3	8.9	4
Country average	9.5	8.5	12.6	8.7	10.4	10.0	11.6	10.1	
Rank	3	1	7	2	5	4	6		
Range (%)									
Consoles	7.8	27.7	8.9	3.8	17.3	8.7	18.9	12.8	1
Games	29.5	9.3	54.6	19.1	50.4	36.8	73.1	42.9	6
CDs	47.4	25.0	40.6	32.4	40.4	54.9	17.1	37.5	5
PDAs	27.9	10.0	15.9	16.3	16.4	11.7	20.2	17.1	2
Printers	21.0	21.3	24.8	21.6	18.9	23.1	23.9	22.0	4
Scanners	29.4	27.8	17.3	10.8	19.1	7.0	12.6	19.2	3
Country average	28.3	20.1	33.4	19.9	31.3	28.9	33.1	28.0	
Rank	3	2	7	1	5	4	6		
Gap (%)									
Consoles	1.6	13.7	8.9	3.7	9.1	2.5	10.1	6.1	1
Games	10.0	9.1	34.6	15.2	15.6	14.5	31.9	19.0	6
CDs	9.6	9.4	14.9	18.0	13.2	9.1	10.3	12.0	5
PDAs	8.7	3.6	10.5	5.6	6.4	3.9	5.9	6.2	2
Printers	4.2	10.8	12.8	9.9	5.9	6.8	3.6	7.5	3
Scanners	16.1	23.5	16.0	7.7	6.4	6.7	6.4	11.1	4
Country average	8.1	9.3	18.0	11.2	10.5	8.2	13.4	10.9	
Rank	1	3	7	5	4	2	6		

to 73.1% for Games in Denmark, and the Gap varying from 1.6% for Consoles in France to 34.6% for Games in the Netherlands.

Despite the variability, consistent patterns of relative dispersion measures across categories and countries are discernable from Table 2. The average price dispersion for Games is at least twice as large as the average price dispersion for Consoles whichever measure of price dispersion we consider and, looking more closely, the same is true within five of the seven individual countries. The relative rankings of products and categories, shown in Table 2, are remarkably consistent for each measure of price dispersion. Consoles and PDAs are ordered lowest and second lowest respectively in all measures, while Music and Games are consistently ranked second highest and highest. On the face of it these results are surprising, Music and Games are the two categories where one may expect consumers to make a greater proportion of multiple purchases – and thus may be expected to have the lowest degrees of price dispersion. Regression results in the following section show that this apparent anomaly can be fully explained by the fact that these are also the cheapest products in the study.

Comparing countries we see that Denmark and the Netherlands are ranked highest in all measures of price dispersion while France and Italy are always ranked within the lowest three countries.

Tables A2(a)–(h), in the Appendix, provide a more detailed breakdown of the principle summary statistics, calculated at the product/country level, together with the standard deviations of these values across the collection dates. The first two columns of each sub-table show the mean number of firms listing prices and the mean price listed for each commodity in the specified country, averaged over all periods the product was listed. The subsequent columns give the mean and standard deviation for the three measures of price dispersion considered, where empty cells denote products that were never listed by more than one firm in the specific country. Once again the variation in observed levels of price dispersion are large – not only between products and across countries, but also for the same product in the same country over time. The standard deviations for the measures of price dispersion are comparable to, and frequently larger than, the mean values themselves – suggesting skewed distributions since prices are bounded below.

There are of course a number of explanations for the variation in price dispersion displayed in Table 2 and Table A2 other than country and product specific differences in market structure. Table 3a shows the average number of firms listing prices at each site, by country and category. Clearly considerable differences exist. On average there are over twice as many firms listing prices in France (5.6) than in the Netherlands (2.5), while in (almost) every country there are more firms listing prices for both Music and PDAs than for either Scanners or Consoles.[13]

The numbers of firms listing prices, in all countries, are significantly lower than comparable statistics collected in the United States. Baye, Morgan and Scholten (2002) find an average of 17.3 firms listing prices, across more than 1000 commodities. This difference reflects, amongst other things, the relative size, level of development and sophistication of online markets in the U.S. and Europe. Further evidence of the relative development of online markets between countries is apparent form Table 3b, showing the frequency of the number of firms listing prices, by country. The countries with the highest mode number of firms, France(5), the

Table 3. Number of Firms Listing Prices.

(a) Mean Number of Firms by Country and Category

	France	Italy	Netherlands	Spain	Sweden	U.K.	Denmark	Average
Consoles	4.5	2.3	1.3	2.2	2.6	4.2	1.8	2.9
Games	6.2	1.1	1.9	2.3	4.7	4.1	4.1	3.7
CDs	5.0	4.6	4.1	3.3	4.6	6.8	2.4	4.4
PDAs	7.5	4.2	2.4	2.9	4.7	3.7	4.0	4.2
Printers	6.2	3.1	2.6	3.9	3.8	3.9	3.8	4.0
Scanners	2.9	1.8	1.6	1.7	3.8	2.0	1.6	2.4
Average	5.6	3.2	2.5	2.9	4.2	4.4	3.1	3.8

(b) Frequency Table: Number of Firms by Country

No. of Firms	France	Italy	Netherlands	Spain	Sweden	U.K.	Denmark	Total
1	64	164	215	130	87	75	165	900
2	39	95	158	221	80	80	173	846
3	66	90	104	131	89	93	114	687
4	103	71	56	99	146	114	80	669
5	156	92	33	57	110	121	60	629
6	112	36	35	25	54	88	49	399
7	55	12	16	12	34	64	24	217
8	52	5	1	11	33	39	12	153
9	37	7	0	1	19	14	6	84
10	29	4	0	0	17	3	6	59
11	19	1	0	0	1	2	2	25
12	10	0	0	0	0	0	1	11
13	7	0	0	0	0	0	0	7
14	6	0	0	0	0	0	0	6
15	7	0	0	0	0	0	0	7
Total	762	577	618	687	670	693	692	4699

U.K. (5) and Sweden (4), are the three European countries with the most developed online markets. In comparison the other four countries have modes of either one or two firms listing prices, with numbers tailing off quite rapidly above three firms.

Figure 2 shows how the three measures of price dispersion vary with the number of firms listing prices, averaged across all categories and countries. The Gap measure of price dispersion falls consistently from nearly 17% when only two firms are listing prices down to 4% when 10 firms are listing. This contrasts with the behaviour of the other two measures, which rise with the number of firms. The range measure doubling from 20 to 40% as the number of firms rise from two to nine, and the coefficient of variation rising slightly over the same interval.

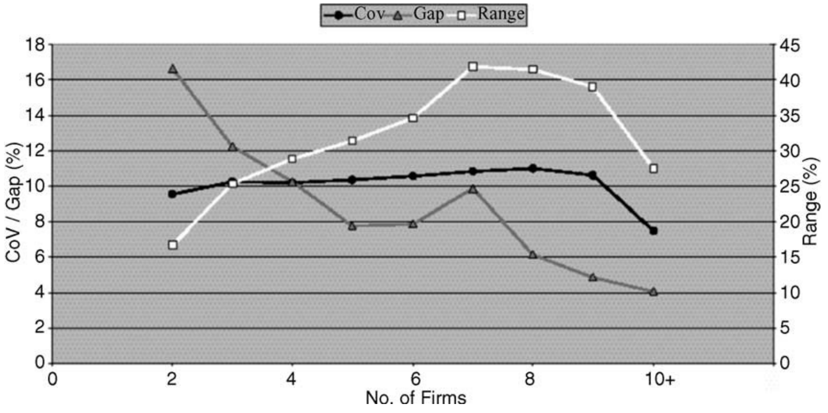

Fig. 2. Price Dispersion Against Number of Firms Listing Prices.

Both the range and the coefficient of variation measures decrease substantially when more than nine firms list prices, but this may reflect both a small sample set and selection bias – Table 3b shows that the overwhelming majority of the records involving 10 or more firms originate in France.[14]

The results displayed in Fig. 2 show some remarkable consistencies with the results obtained by Baye, Morgan and Scholten (2002) for the U.S. markets, and one notable inconsistency. While, as noted above, there are considerably fewer firms listing prices in our data set than there were in the U.S. study, over the same

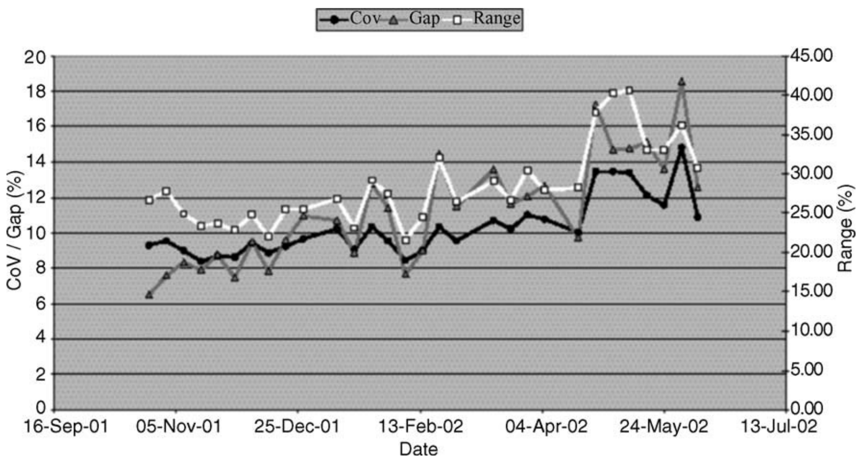

Fig. 3. Price Dispersion Measures Over Time.

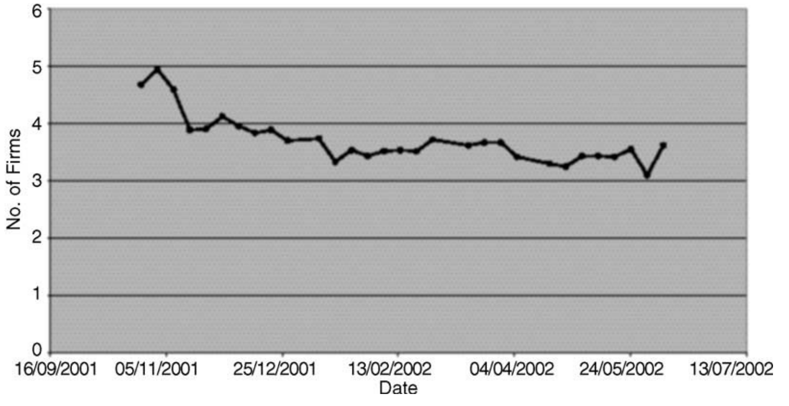

Fig. 4. Average Number of Firms Listing Prices Over Time.

domain Baye, Morgan and Scholten show a fall in the Gap measure from 23 to 4% as the number of firms listing rises from two to 10, and a rise in the range from 23 to 40%.[15] Although they do not report the direct relationship between the coefficient of variation and the number of firms, their regression results provide evidence for precisely the opposite effect than observed here, with the coefficient of variation decreasing as the number of firms rises. We discuss this discrepancy in more detail in Section 5.

Figure 3 shows how the average levels for the three measures of price dispersion drift upwards, in a consistent manner, over the course of the study. Given the contrasting impact of changes in the number of firms on the coefficient of

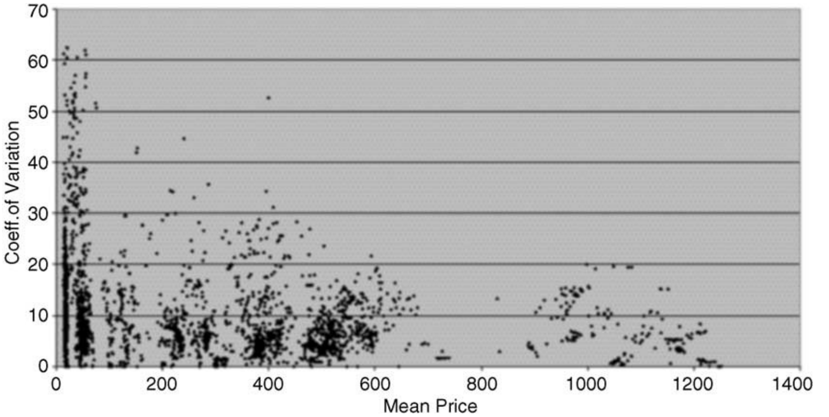

Fig. 5. Coefficient of Variation Against Mean Price.

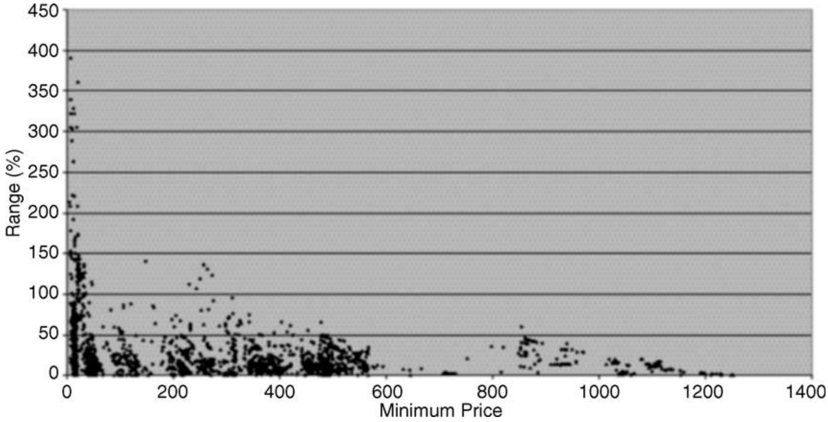

Fig. 6. Range Against Minimum Price.

variation/range measures and the Gap measure, this is unlikely to have been due to changes in the number of firms. Figure 4 shows that in fact the average number of firms listing prices fell over the period, further compounding the explanation for the increased coefficient of variation and range measures.

Finally, we consider the impact of variation in average prices on the various measures of price dispersion. Figures 5–7 plot price dispersion against mean or minimum price for all 3799 observations. Despite all three measures being, theoretically, scale independent these plots all suggest a negative correlation between price dispersion and average price. It is possible, however, that this

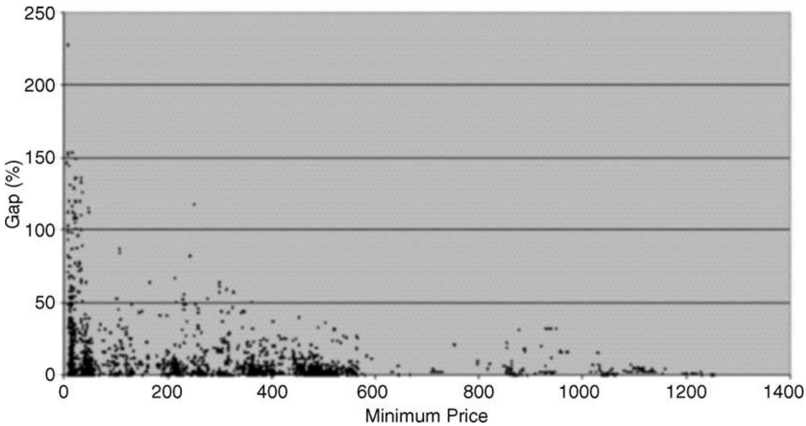

Fig. 7. Gap Against Minimum Price.

apparent negative correlation is just a repercussion of the relatively high price dispersion observed in the cheapest two categories, Games and Music, so some care is required in interpreting these figures.

The summary statistics suggest that there is considerable variation in the observed degrees of price dispersion between both countries and categories, and there are a number of possible explanations for these – including differences in the number of firms listing prices, differences in the value of the product as well as potentially important industry specific and country specific differences in market structure. In order to obtain a clearer understanding of the relevance and relative importance of these alternative explanations, more detailed econometric analysis is required, which is conducted in the next section.

5. REGRESSION ANALYSIS

Measures of price dispersion are continuous over their positive range, but potentially have a mass of observations at zero – thus they are limited dependent variables. This is a potential econometric issue which, to our knowledge, has not been sufficiently noted in the price dispersion literature.

Of the 4669 country/product/time specific observations made over the nine-month period, 900 had only a single firm listing prices and were therefore incapable of exhibiting price dispersion. Of the 3799 remaining observations, where price dispersion in principle could have been observed, the coefficient of variation and the range measures of price dispersion took zero values in 129 (3.4%) cases, while the gap measure was zero in 707 (19%) cases. By far the majority of these cases fell in France and Spain, in terms of countries; and in games and game consoles, in terms of categories.

There are many statistical approaches to the modeling of limited dependent variables. A straightforward method is the two-part model (2PM), which comprises of a probit or logit model for the probability that there is any dispersion at all in the price distribution, and an OLS, applied to the sub-sample with non-zero dispersion, to estimate determinants of the positive level of dispersion. Application of OLS to only part of the sample introduces the possibility of sample selection bias. The consistency of the 2PM for the model parameters rests on the assumption that, conditional on dispersion being positive, its unobservable determinants together giving rise to the error term has zero mean. This can be justified if the factors that make for positive dispersion have no relationship to the factors that actually determine the degree of dispersion. For example, it may be that a market with no price dispersion cannot be explained simply in terms of the absence (or reduction) of factors that increase the level of dispersion. In other words, causes that drive the positive level of dispersion (such as the price level) may not be related to factors that tip a market between no dispersion and positive dispersion. However, correlation between unobservables would still arise where common variables are omitted from the two stages of the dispersion driving process.

In contrast to the two independent processes assumed by 2PM, the Tobit model assumes a single process, an assumption which may appear strong. The motivation may be set out in terms of competition in markets being determined simultaneously by utility maximizing (search) behaviour of consumers, and the behaviour of firms. This model can be described using the concept of a latent, equilibrium level of dispersion, with zero dispersion representing corner solutions where, either due to excessive search or due to extreme competition between firms, all firms charge the same price. Positive dispersion corresponds to observed equilibria. The Tobit model can be estimated by maximum likelihood and these estimates are approximated by the OLS estimates from the 2PM divided by the proportion of non-zero observations in the sample.

The sample selection model (SSM) lies between the above two extremes and allows for two interdependent decisions. The process generating positive dispersion and the process determining the amount of dispersion can be influenced by distinct but correlated observable and unobservable factors. While the SSM is, in an informal sense, more general, it makes greater demands on the data from the point of view of identification. It is advantageous, but not always easy, to find a variable that influences whether there will be any dispersion, but conditional on this, does not influence the positive level of dispersion. The Tobit and 2PM circumvent this problem by assumption.

There cannot be an a priori case for the use of any one model over another. In choosing between the Tobit model, the 2PM and the SSM, we need to consider the strength of assumptions that are made, the likely degree of selection bias and the information available for identification. In this study we report the 2PM estimates.

In Table 4 we report the marginal effects on the probability of positive dispersion obtained from the Probit model, for each of the three measures of price dispersion. Dummy variables are included to account for differences in countries, categories, time (in months) and the number of firms, with the omitted variables being France, Consoles, October 2001 and “2 firms” respectively.

For both the coefficient of variation and the range the probability of positive dispersion increases significantly when the number of firms goes from two to three, but thereafter no further significant number of firm effects are observed. PDAs, printers and scanners have significantly higher probability of positive dispersion than games consoles, games and music while, as reported earlier, zero measures of price dispersion are most likely in France and Italy. The price level has no significant effect on the probability of positive dispersion with either of these measures.

Table 4. Probit Model for Positive Price Dispersion.

	Marg. Effect on Prob of CoV > 0		Marg. Effect on Prob of Range > 0		Marg. Effect on Prob of Gap > 0	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Log (mean price)	−0.003	(−0.72)				
Log (minimum price)			−0.001	(−0.36)	−0.103	(−2.95)**
Firms dummies						
3 Firms	0.008	(3.81)**	0.004	(3.66)**	0.001	(0.03)
4 Firms	0.008	(3.55)**	0.005	(3.42)**	−0.076	(−1.49)
5 Firms	0.009	(14.92)**	0.005	(17.21)**	−0.098	(−2.06)*
6 Firms	0.008	(15.50)**	0.005	(28.50)**	−0.093	(−1.55)
7 Firms	0.006	(6.05)**	0.003	(5.15)**	−0.189	(−2.55)*
8 Firms	0.006	(6.26)**	0.003	(5.61)**	−0.277	(−3.59)**
9 Firms	0.005	(5.35)**	0.003	(5.55)**	−0.208	(−3.94)**
More than 9 firms	0.006	(6.87)**	0.003	(7.05)**	−0.262	(−2.19)*
Category dummies						
Games	0.001	(0.23)	0	(0.04)	0	(0.01)
CDs	0.008	(1.54)	0.005	(1.40)	−0.013	(−0.13)
PDAs	0.009	(14.41)**	0.004	(12.28)**	0.201	(14.89)**
Printers	0.013	(8.63)**	0.006	(5.94)**	0.22	(10.68)**
Scanners	0.006	(8.10)**	0.004	(11.54)**	0.168	(11.34)**
Country dummies						
Italy	0.006	(1.50)	0.004	(1.77)	−0.037	(−0.3)
Netherlands	0.007	(3.41)**	0.004	(3.55)**	0.032	(0.64)
Spain	0.005	(10.01)**	0.004	(6.15)**	0.032	(1.09)
Sweden	0.007	(2.64)**	0.004	(2.68)**	0.014	(0.19)
U.K.	0.008	(2.18)*	0.007	(8.44)**	−0.053	(−0.54)
Denmark	0.01	(4.58)**	0.006	(4.63)**	0.106	(1.3)
Time dummies						
Nov-01	−0.003	(−1.05)	−0.003	(−1.61)	0.042	(2.37)*
Dec-01	−0.002	(−1.61)	−0.002	(−2.79)**	0.036	(1.58)
Jan-02	−0.001	(−0.33)	0	(0.28)	0.04	(1.85)
Feb-02	0	(0.21)	0	(0.47)	0.039	(1.18)
Mar-02	−0.001	(−0.96)	0.001	(0.7)	0.018	(0.47)
Apr-02	0.002	(0.69)	0.002	(1.18)	0.006	(0.19)
May-02	0.003	(1.77)	0.002	(2.02)*	0.019	(0.63)
Jun-02	0	(0)	0.001	(0.26)	0.045	(1.29)
Observations	3799		3799		3799	

Note: Robust standard errors are used.
* *t*-Statistic significant at 5%.
** *t*-Statistic significant at 1%.

The results are different in the case of the gap measure – the probability of positive dispersion generally declines with the number of firms, and an increase in the price level leads to a significant decrease in the probability of a positive gap measure. As with the other measures of dispersion, PDAs, printers and scanners have significantly higher probability of positive dispersion than games consoles, games and music. But in the gap measure there are no significant differences between countries.

In Table 5 we report estimates from the OLS regression, applied only to the sub-sample of observations with non-zero dispersion. Since all the measures of dispersions showed positive skew, log transformations of the dispersion variables was appropriate for this model, and allow intuitive interpretation of the results. The relatively small proportion of zero valued observations, and the large sample size, suggest that applying OLS to only positive part of the sample should not cause serious concerns about sample selection bias.

Table 5 shows regression results for each of the three measures of price dispersion. Once again the omitted dummy variables in these regressions are France, Consoles, October 2001 and "2 firms" listing prices, so the results are with reference to these. It is important to note that, in addition to taking log transformation, the range and Gap measures have been taken as ratios rather than being expressed in percentage terms, which makes a difference to the interpretation of the coefficients in Table 5.

All three measures of price dispersion show highly significant, and negative, price level effects. Having allowed for product category dummies, which may be expected to pick up industry specific differences between, say, cheaper CDs and the more expensive electronic items, the elasticity of the coefficient of variation with respect to mean price is –0.48. The elasticity of range ratio with respect minimum price is -0.21, and that of the gap ratio, -0.13. All these coefficients are also significantly greater than -1, thus in all cases increases in the denominator of each of the dependent variables is associated with increases in the numerator, but a less than proportional increase. Thus products with higher price levels have higher standard deviations, but *lower* coefficients of variation.

We find a strong positive relationship between the number of firms listing and both the coefficient of variation and the range measures, and a negative relationship between the number of firms and the Gap. Increasing the number of firms listing prices from two to eight or more raises the coefficient of variation by over 30%, the range ratio by over 17% and decreases the Gap ratio by around 6%. Represented in term of percentages, rather than ratios, these figures correspond to an increase in the coefficient of variation from 10 to 13%, a rise in the range from 20 to 42% and a fall in the Gap from 20 to 13%, very much in line with the results displayed in Fig. 2.

Table 5. OLS Regressions on Price Dispersion.

	Model 1: Log (Coeff. of Variation)		Model 2: Log(Range)		Model 3: Log (Gap)	
	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
Log (mean price)	−0.48	(−10.32)**				
Log (minimum price)			−0.213	(−19.31)**	−0.13	(−15.04)**
Firms dummies						
3 Firms	0.017	(0.28)	0.065	(7.04)**	−0.032	(−4.01)**
4 Firms	0.182	(3.51)**	0.087	(9.03)**	−0.045	(−5.55)**
5 Firms	0.196	(3.67)**	0.114	(12.12)**	−0.063	(−8.23)**
6 Firms	0.265	(4.85)**	0.137	(13.42)**	−0.063	(−7.71)**
7 Firms	0.249	(3.88)**	0.15	(9.93)**	−0.057	(−5.04)**
8 Firms	0.329	(4.84)**	0.172	(9.95)**	−0.063	(−5.49)**
9 Firms	0.399	(4.85)**	0.177	(8.25)**	−0.079	(−6.16)**
More than 9 firms	0.32	(4.76)**	0.172	(11.51)**	−0.045	(−3.99)**
Category dummies						
Games	0.303	(2.58)**	−0.202	(−10.62)**	−0.11	(−7.65)**
CDs	0.014	(0.10)	−0.421	(−13.65)**	−0.287	(−12.66)**
PDAs	0.798	(8.40)**	0.1	(8.31)**	0.063	(6.44)**
Printers	1.216	(11.74)**	0.223	(14.99)**	0.119	(9.67)**
Scanners	0.964	(9.02)**	0.107	(7.41)**	0.057	(4.90)**
Country dummies						
Italy	0.242	(4.04)**	0.027	(2.50)*	0.031	(3.80)**
Netherlands	0.172	(2.38)*	0.087	(6.29)**	0.054	(4.76)**
Spain	0.087	(1.49)	0.017	(1.66)	0.008	(1.04)
Sweden	0.237	(4.96)**	0.041	(3.79)**	0.019	(2.34)*
U.K.	0.059	(1.18)	0.03	(2.98)**	0.001	(0.10)
Denmark	0.345	(6.60)**	0.069	(5.58)**	0.014	(1.72)
Time dummies						
Nov-01	−0.009	(−0.11)	0.005	(0.36)	0.015	(1.78)
Dec-01	0.042	(0.51)	0.007	(0.48)	0.022	(2.41)*
Jan-02	0.088	(1.06)	0.015	(1.07)	0.03	(3.05)**
Feb-02	0.016	(0.19)	0.004	(0.26)	0.023	(2.42)*
Mar-02	0.165	(1.96)	0.027	(1.82)	0.042	(3.91)**
Apr-02	0.25	(2.74)**	0.045	(2.73)**	0.054	(4.38)**
May-02	0.228	(2.65)**	0.065	(4.28)**	0.052	(4.92)**
Jun-02	0.061	(0.54)	0.028	(1.33)	0.035	(2.15)*
Constant	3.347	(12.13)**	1.146	(19.94)**	0.758	(16.74)**
Observations	3653		3653		3092	
R-Squared	0.2		0.37		0.28	

Note: Robust standard errors are used.
* *t*-Statistic significant at 5%.
** *t*-Statistic significant at 1%.

Controlling for all else, we find that Music, Games and Games Consoles have significantly lower levels of price dispersion than the other categories of goods, no matter which measure of price dispersion is used. The higher absolute levels of price dispersion observed in the Games and Music sectors are thus fully explained, primarily by the price effect. In fact, confirming search theoretic predictions, dispersion is relatively lower in these sectors. The surprising result here is that Games Consoles have unusually low measures of price dispersion.

Between countries, Italy, the Netherlands and Sweden consistently have significantly higher levels of price dispersion than France, while price dispersion in Spain is not significantly different from France under any measure.

Table 6. OLS Regressions on Coefficient of Variation within National Markets.

Dependent Variable	Model 1 France Log CoV	Model 2 Italy Log CoV	Model 3 Netherlands Log CoV	Model 4 Spain Log CoV	Model 5 Sweden Log CoV	Model 6 U.K. Log CoV	Model 7 Denmark Log CoV
Log (mean price)	−0.345	−0.165	−0.984	−0.75	−0.364	−0.768	−0.768
	(−4.12)**	(−1.23)	(−3.82)**	(−4.70)**	(−3.84)**	(−6.84)**	(−6.84)**
Firms dummies							
3 Firms	−0.502	−0.203	−0.246	−0.008	0.032	0.234	0.234
	(−2.34)*	(−1.40)	(−1.43)	(−0.07)	(0.24)	(1.43)	(1.43)
4 Firms	−0.57	0.044	0.149	0.155	0.041	0.323	0.323
	(−3.32)**	(0.34)	(0.87)	(1.62)	(0.34)	(2.42)*	(2.42)*
5 Firms	−0.517	−0.153	0.086	0.328	0.151	0.397	0.397
	(−2.66)**	(−1.27)	(0.51)	(3.01)**	(1.15)	(3.01)**	(3.01)**
6 Firms	−0.422	−0.137	0.32	0.396	0.161	0.526	0.526
	(−2.39)*	(−1.06)	(1.91)	(2.87)**	(1.22)	(3.95)**	(3.95)**
7 Firms	−0.735	−0.008	0.33	0.51	0.489	0.373	0.373
	(−3.80)**	(−0.04)	(1.47)	(3.42)**	(3.34)**	(2.82)**	(2.82)**
8 Firms	−0.597	−0.462	−0.047	0.713	0.533	0.54	0.54
	(−3.21)**	(−1.88)	(−0.22)	(4.16)**	(3.53)**	(3.63)**	(3.63)**
9 Firms	−0.269	0.047	–	1.252	0.389	0.514	0.514
	(−1.19)	(0.29)	–	(8.52)**	(2.20)*	(3.62)**	(3.62)**
More than 9 firms	−0.51	0.086	–	–	0.436	0.426	0.426
	(−3.04)**	(0.46)	–	–	(2.87)**	(2.30)*	(2.30)*
Category dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.649	3.432	5.485	2.746	4.072	4.329	4.329
	(5.25)**	(5.01)**	(3.87)**	(2.83)**	(7.38)**	(6.62)**	(6.62)**
Observations	652	400	391	504	572	610	610
R-Squared	0.4	0.26	0.27	0.49	0.31	0.53	0.53

Note: Robust standard errors are used.

* *t*-Statistic significant at 5%.

** *t*-Statistic significant at 1%.

To test for the robustness of these general results we ran similar country and category specific regressions. With all but one exception, the results were consistent with all of the results identified above. The exception was the impact of the number of firms on the coefficient of variation.

Table 6 shows the results of country specific regressions on the coefficient of variation. As observed earlier, the impact of mean price on the coefficient of variation is negative in all countries, and highly significant everywhere except Italy. A positive impact of number of firms on the coefficient of variation is observed in four countries, but in Italy and Spain there is no significant relationship between the two, and in France there is a significant negative affect. As was noted earlier, Baye, Morgan and Scholten (2002) also observe a negative relationship between the number of firms and the coefficient of variation in their analysis of U.S. markets. Given the theoretical ambiguity on the predicted impact of changes in the number of firms on price dispersion, highlighted in Section 2, these apparently inconsistent empirical findings are perhaps more revealing than matters of concern.

6. CONCLUSION

In this descriptive study we have analysed price dispersion within, and between, seven European countries for a variety of directly comparable products. Considerable variation in the levels of price dispersion between countries, products, and over time are apparent.

One robust finding from our analysis is that price dispersion is relatively lower for higher valued products than cheaper products. We show that, ignoring this relationship can lead to misleading comparisons of price dispersion and market structure across product categories.

Comparing product categories, we find the lowest degrees of price dispersion for Games and Music sectors and, more surprisingly, for Games Consoles as opposed to the other categories. Significant cross country differences in price dispersion are also observed, with France and Spain having the lowest degrees of price dispersion and Italy, the Netherlands and Sweden the highest.

The impact on price dispersion of the numbers of firms listing prices for a product is shown to be ambiguous, depending not only on which measure of price dispersion is adopted but also which countries are considered – a result itself consistent with the theoretical literature.

In addition to providing detailed information on, and insight into, the determinants of price dispersion in online markets within Europe in this study, we also highlight the need to take separate account of the mass of observations where price dispersion is zero. This will be an important consideration for the growing number of studies of online markets where many thousands of separate observations may be recorded.

NOTES

1. Smith, Bailey and Brynjolfsson (2000) and Daripa and Kapur (2001) provide good reviews of competitive impact of online markets and (early) empirical literature.

2. Lee (1997) and Bailey (1998).

3. Brynjolfsson and Smith (2000) find prices for a selection of books and CDs 9–16% lower online than at conventional stores. Brown and Goolsbee (2002) have estimated similar savings for life insurance. Zettelmeyer et al. (2001) show that not all consumers benefit equally by purchasing automobiles online, but estimate an average saving of around 2%. Ellison and Ellison (2001) estimate extremely high elasticities of demand for computer memory sold from a price listing service. See also Pan et al. (2002) for a comparison of prices charge by purely online firms with bricks-and-clicks firms.

4. The timing of the data collection coincided with the introduction of the Euro for retail transaction in four of the countries involved. In an associated study (Baye, Gatti, Kattuman & Morgan, 2003) we analyse the impact of the introduction of the Euro on average and lowest prices in these countries.

5. Rosenthal (1980) shows that the mean price will rise as the number of firms in the market increase. Morgan, Orzen and Sefton (2001) derive additional comparative static results, which they confirmed experimentally.

6. This example is drawn from Jung (1960).

7. Clearly, as a purely statistical property, an increase in the number of observations taken will both raise the expected maximum price observed and lower the expected minimum observed price.

8. In addition to these countries Kelkoo also operates in Norway (not a member of the EU) and, since the completion of the study, has opened a site in Germany.

9. Kelkoo was founded in France in 1999 and, primarily through mergers and acquisitions, rapidly expanded into other European countries over the following two years. In the two countries with the most developed Internet retail markets (France and the United Kingdom), Kelkoo is accessed by over twice as many individual users each month as its next closest rival. Within France it has the same name recognition as Amazon.com. (Statistics from Jupiter MMXI and Hitwise Statistics).

10. As is apparent from Table A1 all products are identical at the level of product model or name, however national language differences mean products are not strictly identical. PDAs and games have language specific software differences, while other products may have language specific packaging differences. Books, for example, were ignored in this study as they suffer particularly from language specificity.

11. Specifically, the program GoZilla! was used to download the relevant pages from the various Kelkoo sites. These files were converted from html code into a format suitable for econometric analysis by a specialist software company in India, Cordiant Interweb Technologies.

12. The averages have been calculated giving equal weighting to each relevant record – so, for example, the overall average for a specific country takes the average of all records

from that country, rather than taking an average of the category or product averages within the country. Clearly, as not all products have multiple price quotations in all countries at all times, these two methods differ.

13. The one exception to this in the U.K. where, on average, more firms listed Consoles than PDAs.

14. It is for this reason that the results in Fig. 2 have been aggregated for 10 firms and over.

15. Baye, Morgan and Scholten (2002), Figs 6 and 7.

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APPENDIX A

Table A1. Products List.

Product Code	Product Name
Games consoles	
11	Sony Playstation 2
12	Nintendo Gameboy Advance
13	Sega Dreamcast
14	X-Box
15	Nintendo Gamecube
Games	
21	Super Mario Advance (Gameboy Advance)
22	FIFA 2001 (PC)
23	Black & White (PC)
24	Pokemon Gold (Gameboy Color)
25	Gran Turismo 3 (Playstation 2)
26	FIFA 2002 (PC)
Music CDs	
31	Gorillaz (Gorillaz)
32	No Angel (Dido)
33	Hot Shot (Shaggy)
34	Hybrid Theory (Linkin Park)
35	All that you can't leave behind (U2)
PDAs	
41	Palm Vx
42	Palm 505
43	Compaq iPaq H3630
44	Handspring Visor Deluxe
45	HP Jordana 720
Printers	
51	Epson Stylus Color 1160
52	Epson Stylus Photo 1290
53	Canon S600
54	Canon S800
55	HP Deskjet 840
Scanners	
61	Epson 1640SU Photo
62	Canon CanoScan N656U
63	HP ScanJet 5370C
64	Epson Expression 1600 Pro
65	HP ScanJet 5300C

Table A2.

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(a) France								
11	5.3	306.64	2.7	6.59	1.1	0.22	1.0	0.00
12	5.5	109.90	3.2	3.74	1.1	0.10	1.0	0.02
13	3.0	140.97	1.3	3.62	1.0	0.11	1.0	0.11
14	4.3	403.75	7.1	11.96	1.2	0.28	1.1	0.17
15	2.8	199.01	0.0	0.02	1.0	0.00	1.0	0.00
Consoles avg.	4.5	210.42	3.0	6.27	1.1	0.17	1.0	0.08
21	6.9	45.46	1.4	1.99	1.0	0.07	1.0	0.05
22	3.1	52.66	12.5	16.38	1.4	0.58	1.3	0.53
23	6.3	51.11	12.6	9.62	1.4	0.45	1.2	0.30
24	7.3	43.49	3.9	0.41	1.1	0.01	1.0	0.01
25	6.7	49.75	22.2	22.31	1.6	0.60	1.0	0.04
26	7.3	49.97	5.5	0.92	1.2	0.03	1.0	0.00
Games avg.	6.2	48.62	9.8	14.04	1.3	0.44	1.1	0.26
31	4.8	18.08	9.7	3.35	1.3	0.11	1.1	0.08
32	5.4	16.19	24.1	8.43	1.8	0.35	1.2	0.18
33	5.3	18.90	16.0	3.84	1.5	0.16	1.2	0.10
34	4.4	16.55	11.0	2.99	1.3	0.08	1.0	0.03
35	5.2	17.94	15.9	2.62	1.4	0.09	1.0	0.04
CDs avg.	5.0	17.54	15.3	6.89	1.5	0.28	1.1	0.12
41	5.1	358.35	12.7	9.01	1.4	0.39	1.1	0.12
42	11.9	506.55	5.3	1.94	1.2	0.11	1.1	0.09
43	8.1	219.44	8.5	1.23	1.3	0.07	1.1	0.03
44	7.2	403.73	5.4	2.67	1.2	0.14	1.1	0.09
45	3.9	129.24	11.1	4.37	1.3	0.15	1.1	0.12
PDAs avg.	7.5	342.44	8.3	5.66	1.3	0.23	1.1	0.10
51	5.5	380.59	8.9	4.83	1.3	0.20	1.1	0.11
52	10.5	527.52	6.7	2.33	1.2	0.10	1.0	0.01
53	6.3	590.28	6.2	0.81	1.2	0.05	1.0	0.04
54	4.0	236.50	4.2	1.18	1.1	0.06	1.1	0.03
55	4.4	1033.45	9.7	5.06	1.3	0.16	1.0	0.02
Printers avg.	6.2	556.86	7.3	3.90	1.2	0.14	1.0	0.06
61	2.5	397.57	10.1	6.04	1.2	0.10	1.1	0.13
62	4.5	95.33	11.7	4.61	1.3	0.16	1.1	0.09
63	2.5	267.88	4.0	6.55	1.1	0.16	1.1	0.14
64	1.4	1090.49	9.9	0.00	1.2	0.00	1.2	0.00
65	2.5	179.81	30.5	13.48	1.8	0.21	1.5	0.34
Scanners avg.	2.9	351.71	12.4	9.58	1.3	0.23	1.2	0.21
Overall averages	5.6	245.80	9.5	9.41	1.3	0.30	1.1	0.16

Table A2. (*Continued*)

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(b) Italy								
11	3.3	338.34	13.6	8.11	1.3	0.21	1.1	0.10
12	1.9	131.28	12.3	7.32	1.2	0.13	1.2	0.14
13	1.5	187.13	24.4	1.87	1.4	0.00	1.4	0.13
14	2.6	414.23	12.4	14.24	1.3	0.30	1.1	0.22
15	1.8	219.47	2.3	0.06	1.0	0.01	1.0	0.01
Consoles avg.	2.3	245.48	13.8	9.18	1.3	0.20	1.1	0.17
21	1.3	52.95	6.5	1.74	1.1	0.03	1.1	0.03
22	1.0	48.04						
23	1.0	51.13						
24	1.0	44.53						
25	1.2	53.84	5.7	3.63	1.1	0.05	1.1	0.06
26	1.0	54.15						
Games avg.	1.1	51.61	6.2	2.38	1.1	0.04	1.1	0.04
31	4.3	17.94	6.8	1.41	1.2	0.04	1.1	0.03
32	4.7	17.35	8.5	1.67	1.2	0.06	1.1	0.04
33	4.6	18.11	8.5	1.27	1.2	0.04	1.0	0.04
34	4.2	16.57	9.8	5.99	1.3	0.19	1.1	0.14
35	5.5	18.67	9.9	4.73	1.3	0.23	1.2	0.20
CDs avg.	4.6	17.65	8.8	3.85	1.2	0.15	1.1	0.12
41	4.0	379.90	5.1	1.31	1.1	0.03	1.0	0.04
42	6.1	482.58	4.3	0.48	1.1	0.02	1.0	0.03
43	3.9	228.62	4.9	2.76	1.1	0.05	1.0	0.03
44	4.0	426.29	4.0	1.63	1.1	0.06	1.0	0.05
45	1.6	102.22	1.4	4.08	1.0	0.06	1.0	0.06
PDAs avg.	4.2	348.55	4.3	2.16	1.1	0.05	1.0	0.04
51	2.3	304.13	22.9	11.29	1.6	0.30	1.4	0.24
52	4.7	528.03	3.6	2.35	1.1	0.07	1.0	0.01
53	2.7	662.49	7.5	5.38	1.2	0.14	1.1	0.09
54	1.3	237.71	5.1	0.00	1.1	0.00	1.1	0.00
55	3.5	976.61	8.0	3.51	1.2	0.08	1.1	0.07
Printers avg.	3.1	589.09	8.9	8.52	1.2	0.22	1.1	0.16
61	2.6	361.54	14.7	2.21	1.3	0.04	1.2	0.03
62	1.5	104.35	8.3	1.21	1.2	0.06	1.1	0.03
63	1.6	287.72	15.8	2.07	1.3	0.02	1.3	0.02
64								
65	1.0	201.42						
Scanners avg.	1.8	240.79	14.2	3.12	1.3	0.05	1.2	0.06
Overall averages	3.2	268.51	8.5	6.81	1.2	0.17	1.1	0.13

Table A2. (*Continued*)

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(c) Netherlands								
11	1.4	324.82	7.7	8.71	1.1	0.14	1.1	0.15
12	1.1	120.41	2.1	0.00	1.0	0.00	1.0	0.00
13								
14								
15	1.4	219.20	0.3	0.00	1.0	0.00	1.0	0.00
Consoles avg.	1.3	226.02	5.6	7.65	1.1	0.13	1.1	0.13
21	1.5	46.64	6.1	16.55	1.1	0.38	1.1	0.38
22	1.5	31.14	25.0	22.75	1.6	0.54	1.1	0.37
23	1.7	41.02	34.3	22.79	1.8	0.58	1.4	0.53
24	2.4	44.10	15.2	23.50	1.7	1.26	1.3	0.47
25	2.3	62.88	18.5	25.43	1.4	0.60	1.4	0.60
26	1.7	55.99	27.5	25.21	1.6	0.56	1.6	0.57
Games avg.	1.9	46.89	20.4	24.24	1.5	0.79	1.3	0.52
31	4.1	17.02	9.0	4.99	1.3	0.28	1.1	0.19
32	4.8	17.45	16.1	6.29	1.6	0.40	1.2	0.18
33	4.3	18.11	14.9	4.86	1.5	0.31	1.2	0.19
34	2.7	17.07	9.7	9.61	1.3	0.51	1.2	0.36
35	4.3	19.41	11.8	4.82	1.4	0.28	1.1	0.20
CDs avg.	4.1	17.82	12.3	6.81	1.4	0.38	1.1	0.23
41	2.9	360.95	9.5	3.06	1.2	0.07	1.1	0.04
42	2.9	492.09	7.6	4.45	1.2	0.19	1.1	0.14
43	2.3	277.03	6.1	1.19	1.1	0.04	1.1	0.04
44	1.7	438.62	2.8	1.61	1.1	0.03	1.0	0.03
45	1.0	95.77						
PDAs avg.	2.4	390.50	7.4	3.87	1.2	0.13	1.1	0.09
51	1.6	473.84	16.1	14.07	1.3	0.33	1.3	0.32
52	4.9	527.62	11.0	3.32	1.3	0.14	1.0	0.11
53	2.0	608.64	13.9	6.04	1.3	0.14	1.2	0.12
54	1.5	295.60	11.2	9.06	1.2	0.16	1.1	0.18
55	2.3	1027.50	5.9	6.37	1.1	0.10	1.1	0.11
Printers avg.	2.6	605.11	11.3	8.00	1.2	0.19	1.1	0.18
61	1.8	380.20	12.4	2.13	1.2	0.03	1.2	0.03
62	1.5	129.54	3.3	4.87	1.0	0.07	1.1	0.07
63	1.7	268.09	11.6	10.82	1.2	0.21	1.2	0.21
64								
65	1.4	288.23	5.9	2.47	1.1	0.03	1.1	0.07
Scanners avg.	1.6	277.90	10.1	8.24	1.2	0.16	1.2	0.16
Overall averages	2.5	239.78	12.6	13.75	1.3	0.47	1.2	0.31

Table A2. (*Continued*)

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(d) Spain								
11	2.3	299.95	0.0	0.04	1.0	0.00	1.0	0.00
12	2.1	115.22	4.4	5.74	1.1	0.09	1.1	0.09
13	1.5	120.16	0.0	0.00	1.0	0.00	1.0	0.00
14	2.3	359.62	5.1	11.06	1.1	0.27	1.1	0.27
15	3.0	199.17	0.4	0.22	1.0	0.00	1.0	0.00
Consoles avg.	2.2	209.07	2.2	5.06	1.0	0.10	1.0	0.10
21	2.7	42.62	12.6	3.96	1.3	0.08	1.1	0.10
22	1.1	35.13	11.5	11.07	1.2	0.19	1.2	0.19
23	2.0	47.28	1.3	3.66	1.0	0.08	1.0	0.08
24	1.8	44.39	5.4	1.29	1.1	0.02	1.1	0.02
25	2.7	55.06	15.5	13.67	1.3	0.28	1.3	0.29
26	3.2	39.05	11.6	3.96	1.3	0.11	1.2	0.08
Games avg.	2.3	44.64	9.6	8.88	1.2	0.19	1.2	0.18
31	3.4	17.50	10.6	7.45	1.2	0.17	1.1	0.16
32	3.2	17.18	14.4	12.09	1.3	0.29	1.2	0.29
33	2.7	19.21	11.6	7.54	1.3	0.18	1.1	0.05
34	4.0	15.85	17.7	7.42	1.5	0.20	1.3	0.21
35	3.3	18.38	11.6	7.19	1.3	0.17	1.1	0.15
CDs avg.	3.3	17.59	13.3	8.85	1.3	0.22	1.2	0.21
41	3.6	419.49	5.6	3.24	1.1	0.11	1.0	0.02
42	4.1	482.24	5.0	0.99	1.1	0.04	1.0	0.02
43	3.0	249.49	13.1	11.07	1.3	0.32	1.1	0.05
44	2.9	418.81	7.5	3.76	1.1	0.06	1.1	0.07
45	1.1	149.91	5.9	0.00	1.1	0.00	1.1	0.00
PDAs avg.	2.9	350.72	7.2	5.71	1.2	0.16	1.1	0.05
51	2.0	475.30	9.0	2.71	1.2	0.06	1.1	0.05
52	6.9	535.05	10.1	3.02	1.3	0.14	1.1	0.10
53	3.9	589.54	5.2	1.43	1.1	0.05	1.0	0.03
54	3.3	242.49	10.7	4.80	1.3	0.13	1.1	0.08
55	3.0	1017.68	7.2	4.22	1.2	0.12	1.1	0.10
Printers avg.	3.9	560.66	8.6	3.93	1.2	0.14	1.1	0.08
61	2.7	377.55	6.4	1.29	1.1	0.01	1.1	0.04
62	1.0	125.61						
63	1.3	273.90	5.4	2.16	1.1	0.06	1.1	0.02
64	2.0	833.45	2.9	1.0	1.0			
65	1.9	199.30	6.3	1.62	1.1	0.00	1.1	0.03
Scanners avg.	1.7	264.60	6.0	1.66	1.1	0.03	1.1	0.03
Overall averages	2.9	239.04	8.7	7.57	1.2	0.19	1.1	0.15

Table A2. (*Continued*)

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(e) Sweden								
11	2.5	396.82	6.4	5.16	1.1	0.11	1.1	0.05
12	2.3	144.60	12.5	3.36	1.2	0.08	1.2	0.08
13	1.0	148.65						
14	4.0	430.88	11.0	11.67	1.3	0.29	1.1	0.17
15	4.8	268.80	1.4	0.77	1.0	0.02	1.0	0.02
Consoles avg.	2.6	298.52	8.4	7.30	1.2	0.17	1.1	0.11
21	4.9	53.85	5.2	1.46	1.1	0.05	1.0	0.04
22	5.4	29.45	28.0	14.79	2.3	1.01	1.5	0.75
23	5.5	44.36	16.7	9.85	1.6	0.53	1.1	0.11
24	2.4	43.96	6.4	4.85	1.1	0.11	1.1	0.08
25	5.7	54.96	15.3	11.17	1.5	0.40	1.1	0.23
26	4.3	46.58	6.8	1.21	1.2	0.04	1.0	0.05
Games avg.	4.7	45.53	13.6	12.18	1.5	0.67	1.2	0.38
31	5.0	16.48	12.7	5.25	1.3	0.17	1.1	0.12
32	4.9	16.44	12.4	3.23	1.4	0.12	1.1	0.07
33	4.7	16.22	16.3	6.11	1.5	0.20	1.2	0.19
34	4.2	17.75	12.3	6.76	1.3	0.20	1.1	0.15
35	4.1	18.53	16.0	10.34	1.5	0.53	1.1	0.24
CDs avg.	4.6	17.10	14.0	6.93	1.4	0.29	1.1	0.17
41	5.3	402.29	4.3	1.58	1.1	0.05	1.0	0.02
42	8.2	578.38	6.1	1.45	1.2	0.06	1.0	0.04
43	2.9	281.17	7.5	2.73	1.2	0.05	1.0	0.07
44	3.3	495.95	4.6	2.21	1.1	0.04	1.1	0.04
45	2.2	131.16	18.8	8.90	1.4	0.18	1.3	0.20
PDAs avg.	4.7	407.97	6.6	4.91	1.2	0.10	1.1	0.09
51	2.7	420.80	8.5	3.54	1.2	0.13	1.0	0.06
52	5.9	531.59	8.1	4.73	1.3	0.17	1.1	0.04
53	2.5	669.68	8.0	7.23	1.2	0.21	1.1	0.11
54	3.0	226.55	5.2	3.26	1.1	0.10	1.0	0.03
55	4.3	1138.89	6.3	2.10	1.2	0.08	1.1	0.05
Printers avg.	3.8	624.78	7.1	4.46	1.2	0.15	1.1	0.06
61	1.7	496.46	19.6	7.67	1.4	0.13	1.3	0.18
62	1.2	119.55						
63	6.6	283.83	6.8	1.89	1.2	0.08	1.0	0.03
64	1.1	1060.46	13.3	1.2	1.2			
65	3.5	208.71	6.5	2.38	1.2	0.12	1.1	0.02
Scanners avg.	3.8	391.06	8.0	5.06	1.2	0.12	1.1	0.10
Overall averages	4.2	267.39	10.4	8.57	1.3	0.40	1.1	0.22

Table A2. (*Continued*)

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(f) U.K.								
11	4.5	316.96	1.8	2.74	1.0	0.07	1.0	0.01
12	5.8	119.58	5.1	4.02	1.1	0.10	1.0	0.04
13	1.5	141.66	1.2	0.89	1.0	0.01	1.0	0.01
14	3.0	438.32	4.2	6.80	1.1	0.17	1.0	0.11
15	4.5	207.50	3.7	6.24	1.1	0.14	1.0	0.01
Consoles avg.	4.2	257.31	3.5	4.57	1.1	0.12	1.0	0.06
21	5.3	47.93	6.8	2.00	1.2	0.06	1.0	0.03
22	3.5	34.74	25.0	13.19	1.8	0.49	1.5	0.46
23	3.7	50.92	13.9	6.54	1.3	0.22	1.1	0.17
24	3.9	40.90	7.9	2.00	1.2	0.05	1.1	0.05
25	4.9	54.88	16.3	14.74	1.5	0.55	1.2	0.30
26	3.2	45.28	6.2	3.34	1.1	0.07	1.1	0.05
Games avg.	4.1	45.85	12.8	10.87	1.4	0.39	1.1	0.28
31	7.9	17.52	17.5	3.42	1.6	0.17	1.0	0.06
32	6.7	16.52	16.5	5.16	1.6	0.36	1.1	0.18
33	6.3	17.17	15.9	7.78	1.5	0.36	1.1	0.06
34	7.6	16.70	14.4	3.35	1.5	0.15	1.0	0.06
35	5.5	18.19	16.3	2.12	1.5	0.07	1.1	0.12
CDs avg.	6.8	17.22	16.2	4.84	1.5	0.25	1.1	0.11
41	5.9	376.94	3.9	4.47	1.1	0.14	1.0	0.01
42	4.8	509.39	5.3	1.80	1.1	0.04	1.0	0.00
43	2.3	247.30	7.5	4.03	1.2	0.15	1.1	0.09
44	3.5	496.66	2.4	2.04	1.1	0.05	1.0	0.01
45	1.3	132.29	14.7	12.63	1.3	0.23	1.3	0.23
PDAs avg.	3.7	359.66	5.2	5.27	1.1	0.12	1.0	0.09
51	2.1	440.88	15.4	6.98	1.4	0.28	1.2	0.13
52	4.9	519.66	8.4	3.89	1.2	0.12	1.1	0.09
53	2.8	604.21	9.9	2.89	1.2	0.08	1.0	0.02
54	4.1	247.01	13.4	6.12	1.3	0.16	1.1	0.07
55	4.2	1013.79	3.7	2.63	1.1	0.06	1.0	0.03
Printers avg.	3.9	573.03	9.4	6.23	1.2	0.18	1.1	0.10
61	2.0	429.41	0.4	1.0	1.0			
62								
63	1.7	278.40	3.1	1.75	1.0	0.03	1.0	0.03
64	2.3	1210.74	4.5	7.19	1.1	0.13	1.1	0.14
65	1.0	206.65						
Scanners avg.	2.0	830.65	3.9	5.92	1.1	0.11	1.1	0.11
Overall averages	4.4	271.52	10.0	8.52	1.3	0.31	1.1	0.17

Table A2. (*Continued*)

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(g) Denmark								
11	2.2	357.15	13.2	3.28	1.3	0.11	1.1	0.08
12	1.9	133.65	8.7	4.40	1.1	0.07	1.1	0.08
13	1.1	276.04	21.0	1.3	1.4			
14	1.4	420.51	2.7	1.86	1.0	0.03	1.0	0.03
15	1.0	270.56						
Consoles avg.	1.8	273.58	9.7	5.19	1.2	0.13	1.1	0.09
21	2.2	53.01	15.9	3.17	1.3	0.05	1.2	0.14
22	4.6	25.57	42.5	13.94	3.1	1.06	1.8	0.49
23	4.4	48.20	14.5	10.61	1.4	0.30	1.2	0.24
24	1.9	44.72	13.2	11.66	1.2	0.23	1.2	0.23
25	5.1	60.55	18.2	12.27	1.6	0.38	1.2	0.23
26	5.2	49.01	10.4	3.34	1.3	0.16	1.1	0.12
Games avg.	4.1	46.13	20.2	15.68	1.7	0.88	1.3	0.39
31	2.4	18.71	11.3	7.11	1.2	0.24	1.1	0.18
32	2.6	17.96	8.2	4.62	1.2	0.09	1.1	0.09
33	2.1	18.23	6.8	4.18	1.1	0.07	1.1	0.07
34	2.1	18.62	8.5	3.36	1.1	0.05	1.1	0.06
35	2.7	19.96	8.8	10.49	1.2	0.32	1.1	0.04
CDs avg.	2.4	18.68	8.7	6.51	1.2	0.19	1.1	0.10
41	3.9	379.45	6.0	3.30	1.2	0.11	1.0	0.03
42	5.1	537.38	5.7	2.05	1.2	0.07	1.0	0.03
43	2.0	299.22	5.1	3.85	1.1	0.08	1.0	0.06
44	4.3	520.84	9.5	2.19	1.2	0.05	1.1	0.06
45	3.6	138.96	13.2	2.40	1.3	0.16	1.1	0.09
PDAs avg.	4.0	384.33	7.9	3.84	1.2	0.12	1.1	0.06
51	1.7	411.63	3.3	3.48	1.1	0.08	1.0	0.05
52	5.5	537.67	9.5	4.49	1.3	0.14	1.0	0.05
53	3.6	485.88	10.0	6.12	1.2	0.17	1.0	0.03
54	1.6	269.67	12.1	5.73	1.2	0.13	1.1	0.11
55	6.1	1084.28	10.7	4.21	1.3	0.13	1.0	0.02
Printers avg.	3.8	576.13	9.4	5.31	1.2	0.15	1.0	0.05
61	1.6	406.35	5.3	3.87	1.1	0.06	1.1	0.06
62	1.2	124.15	5.8	1.15	1.1	0.02	1.1	0.02
63	2.6	303.49	7.7	10.58	1.2	0.30	1.0	0.02
64	1.0	933.50						
65	1.9	226.58	6.0	1.59	1.1	0.07	1.1	0.02
Scanners avg.	1.6	371.22	6.3	6.06	1.1	0.17	1.1	0.04
Overall averages	3.1	262.85	11.6	10.51	1.3	0.52	1.1	0.23

Table A2. (*Continued*)

Product	Mean No. of Firms	Mean Price (€)	Coeff. of Variation		Range Ratio		Gap Ratio	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
(h) International averages								
11	3.1	334.07	5.7	7.44	1.1	0.19	1.0	0.07
12	3.1	123.61	6.8	5.98	1.1	0.11	1.1	0.10
13	1.9	166.12	6.6	10.37	1.1	0.19	1.1	0.18
14	2.9	416.79	7.3	10.52	1.2	0.25	1.1	0.16
15	2.8	224.06	1.4	2.68	1.0	0.06	1.0	0.02
Consoles avg.	2.9	244.58	6.1	7.67	1.1	0.17	1.1	0.11
21	3.7	48.59	7.1	6.56	1.2	0.14	1.1	0.13
22	3.3	35.09	27.4	18.16	2.1	1.02	1.5	0.58
23	3.7	47.47	13.9	13.24	1.4	0.43	1.1	0.26
24	3.2	43.63	8.4	11.14	1.2	0.54	1.1	0.23
25	4.2	56.10	17.4	17.15	1.5	0.48	1.2	0.34
26	3.9	48.17	10.1	10.17	1.2	0.23	1.1	0.25
Games avg.	3.7	46.76	13.9	14.90	1.4	0.62	1.2	0.35
31	4.6	17.60	11.3	5.97	1.3	0.22	1.1	0.13
32	4.6	17.00	14.6	8.38	1.5	0.35	1.1	0.17
33	4.3	18.00	13.0	6.53	1.4	0.27	1.1	0.13
34	4.1	17.00	12.0	6.59	1.3	0.25	1.1	0.19
35	4.4	18.72	13.3	7.34	1.4	0.30	1.1	0.16
CDs avg.	4.4	17.66	12.8	7.08	1.4	0.29	1.1	0.16
41	4.4	382.30	6.8	5.38	1.2	0.21	1.1	0.07
42	6.1	512.72	5.6	2.38	1.2	0.10	1.1	0.08
43	3.8	251.82	7.6	5.17	1.2	0.16	1.1	0.06
44	3.9	455.46	5.4	3.39	1.1	0.09	1.1	0.06
45	2.2	132.85	11.6	7.97	1.3	0.19	1.1	0.15
PDAs avg.	4.2	367.80	6.7	4.85	1.2	0.15	1.1	0.08
51	2.6	412.52	11.7	9.18	1.3	0.26	1.2	0.19
52	6.2	529.55	8.2	4.16	1.2	0.15	1.0	0.08
53	3.5	598.11	8.3	5.38	1.2	0.13	1.1	0.09
54	2.9	249.67	9.2	6.02	1.2	0.15	1.1	0.08
55	4.0	1040.74	7.5	4.62	1.2	0.13	1.1	0.07
Printers avg.	4.0	582.03	8.7	5.91	1.2	0.17	1.1	0.11
61	2.2	404.52	10.5	6.26	1.2	0.11	1.2	0.12
62	2.5	110.07	10.0	5.26	1.3	0.17	1.1	0.09
63	3.0	278.61	7.3	6.76	1.2	0.16	1.1	0.12
64	1.6	1104.59	5.7	6.72	1.1	0.12	1.1	0.12
65	2.4	214.80	10.1	10.40	1.2	0.26	1.1	0.22
Scanners avg.	2.4	385.92	8.9	7.50	1.2	0.18	1.1	0.15
Overall averages	3.8	256.19	10.1	9.47	1.3	0.36	1.1	0.20

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PRICE DISPERSION, PRODUCT CHARACTERISTICS, AND FIRMS' BEHAVIORS: STYLIZED FACTS FROM SHOPPER.COM

Jihui Chen and Patrick Scholten

ABSTRACT

We study how price dispersion varies with product characteristics at a popular online price comparison site – Shopper.com. Our primary finding suggests that price dispersion in online markets varies with product characteristics and firm behavior. We also find evidence that the level of dispersion varies with the percent of firms listing price information in multiple categories. When the percent of firms listing prices in multiple categories is relatively high (low), price dispersion is low (high).

1. INTRODUCTION

This paper explores the extent to which price dispersion varies across categories of products in online markets. The existing literature on price dispersion in online markets focuses either on explaining the observed dispersion for products in similar categories – like books and CDs – or explains observed dispersion at the aggregate level across many product categories. The casual evidence from this study suggests that certain product categories tend to exhibit more price dispersion than others.

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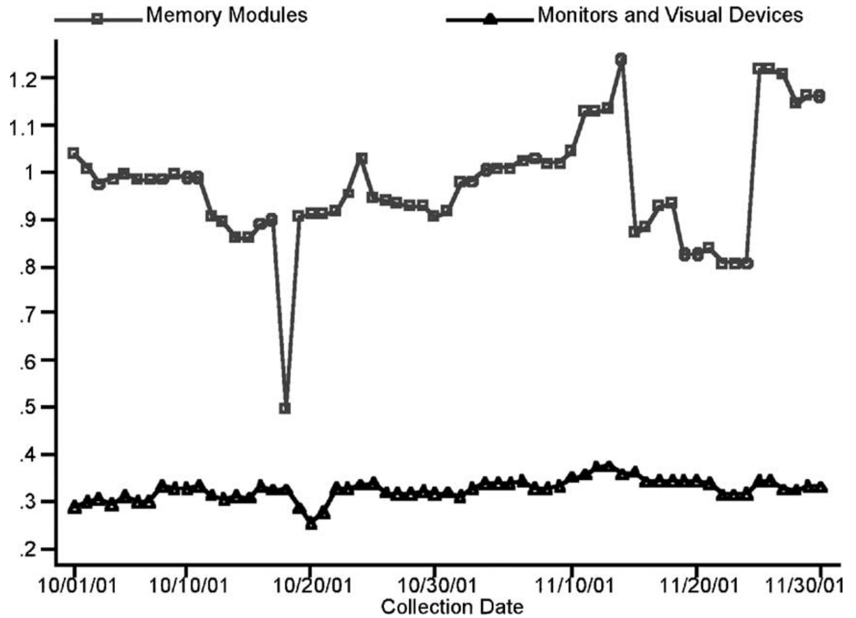


Fig. 1. Percent Range for Two Shopper.com Product Categories.

Moreover, there appears to be an association between firms' behaviors and price dispersion across product categories.

Figure 1 provides the primary motivation for this paper. This figure charts one measure of price dispersion – the average range in prices as a percent of the lowest price – for two product categories at Shopper.com: computer memory modules and computer monitors and visual devices. Two features are immediately apparent from Fig. 1. First, there is a dramatic difference in the average percent price range between the two categories. The average price range for the computer memory modules category is remarkably high at about 90%. In contrast, computer monitors and visual devices tend to have a relatively low price range, ranging about 30%. A second distinguishing feature of Fig. 1 is the fluctuations in the average percent range experienced for the two product categories. While the average range is relatively stable for computer monitors and visual devices, the computer memory modules category experiences large fluctuations. In particular, notice that on October 18, 2001, the average percent range for the computer memory modules category dramatically fell. While one might be inclined to dismiss this event as a pricing error made by a specific firm, such fluctuations are commonly observed at sites like Shopper.com.[1] A careful look at the data reveals that the dramatic drop in the average price range is driven by a single firm's behavior in the market for a specific 256 MB memory module. Specifically, prior to October 18, Computer4Sure.com listed a relatively high price for this product, chose not to list a price on October 18, and re-posted the same high price after October 18 for the remainder of the sample period. Thus, the decision by Computer4Sure.com not to list a price on October 18 is the factor responsible for the large fall in the average price range for the computer memory modules category.

Other studies documenting price dispersion in online markets are of the magnitude observed in Fig. 1. For instance, Brynjolffson and Smith (2000) find price ranges in online book and CD markets of 33% and 25%, respectively.[2] Similarly, Clay, Krishnan and Wolf (2001) find percentage ranges of 60% to 73% for hardcover and paperback books on the best-seller list, respectively. Averaging across many products and product categories, Baye, Morgan and Scholten (2004) also find price ranges of about 57% at Shopper.com. This paper deviates from these previous studies by examining how dispersion varies across product categories.

Using data from Shopper.com's 12 product categories we find that, consistent with Fig. 1, there is considerable variation in average price ranges across categories. This observation suggests an association may exist between firms' behaviors and the average percent range across product categories. Indeed, we find there is a negative correlation between the average price range and the percentage of firms that list price information in multiple categories and for multiple products. When the percent of firms listing prices in multiple categories or for products is high (low), the average percent price range is low (high). In addition, the weighted average percent price range varies with the number of firms displaying company logos. When the number of firms with a company logo is below the median, the weighted range averages about 35%, but is only 16% when this number is above the median number of firms with company logos.

The remainder of the paper proceeds as follows. Section 2 discusses the Shopper.com environment and provides an overview of the data. Section 3 examines how price dispersion at Shopper.com varies across each of the 12 product categories and looks at how product life cycles affect price dispersion. Section 4 examines the extent to which firms' behaviors impact price dispersion. Section 5 concludes.

2. INSTITUTIONAL FEATURES OF SHOPPER.COM AND OF THE DATA

2.1. The Shopper.com Environment

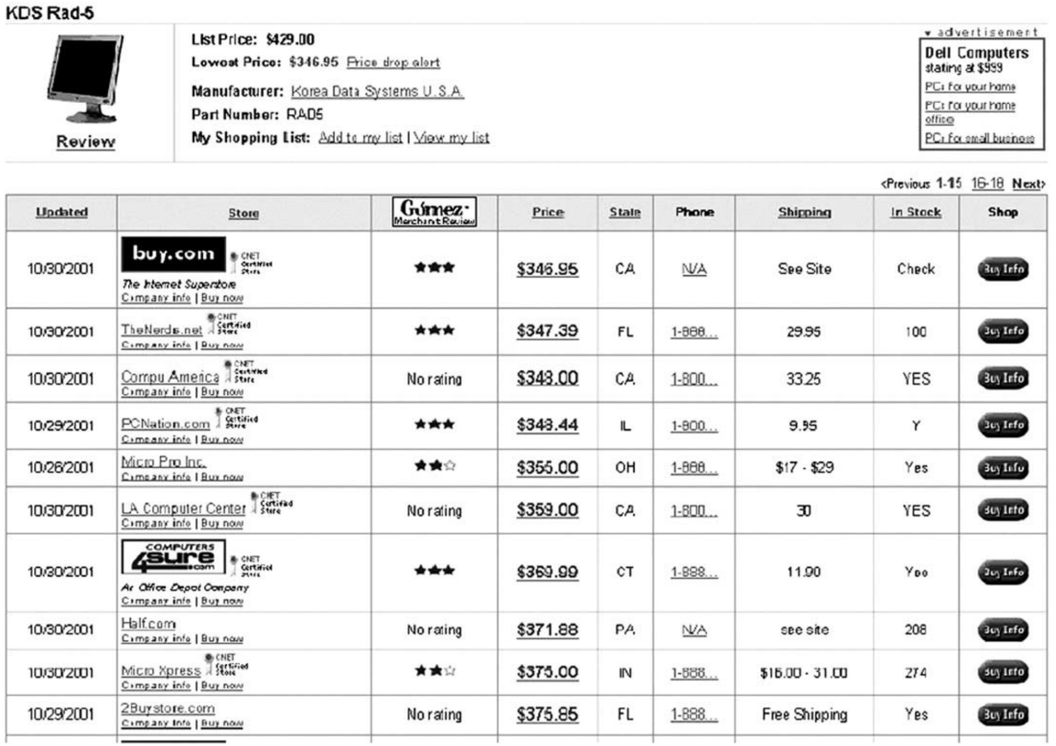
Shopper.com is an Internet price comparison service, which provides consumers with lists of prices charged by firms selling physically identical products.[3] One way to obtain price information for, say, a KDS Rad-5 flat panel monitor is to directly enter the product name into Shopper.com's search engine. Alternatively, a consumer could click on Shopper.com's "monitor" category and sift through the various brands and models of computer monitors and click "check latest prices" once the KDS Rad-5 was identified. Using either method on October 10, 2001 would result in the list of prices in Fig. 2. Notice, each of the 10 firms lists a unique price ranging from $346.95 to $375.85, or about 8% of the minimum price. Compared to other studies, the dispersion observed in Fig. 2 is relatively low. We explore whether this is an artifact of being associated with a particular product category, as would be consistent with the observation in Fig. 1.

Accessing Shopper.com's database of more than 200,000 computer and consumer electronics products is costless to consumers with Internet access. In contrast, firms listing price information at Shopper.com pay[4] for the privilege to do so. In addition to deciding what price to list each day, firms must also decide how frequently and for which products to list information. These decisions can be updated up to two times each day. To ensure accuracy, firms are responsible for directly inputting and uploading this information to the Shopper.com servers. The institutional features at Shopper.com have important implications for firms competing in this online environment. In particular, Baye-Morgan (2001) show that firms competing in a Shopper.com-style environment will randomize both the frequency with which price information is advertised and the price charged. By randomizing both the price and advertising frequency, firms can avoid the deleterious outcome associated with classical Bertrand-style price competition. We explore whether some of the stylized facts at Shopper.com are consistent with the predictions of Baye-Morgan.

2.2. *Data Description and Summary Statistics*

To examine the relationship between the level of price dispersion and product categories, we assemble a data set consisting of daily price observations listed at Shopper.com spanning the two-month period October 1, 2001 to November 30, 2001. In total, 193,159 observations were collected for 220 products in 12 product categories. These categories are defined using exactly the same scheme employed at Shopper.com, which we use to examine the across category differences in price dispersion.

Table 1 shows the summary statistics of the daily price data for the 12 Shopper.com product categories over the sample period. As illustrated in Table 1, the number of observations and number of products vary across categories. For example, the computer memory modules category consists of the smallest number



KDS Rad-5

Review

List Price: $429.00
Lowest Price: $346.95 Price drop alert
Manufacturer: Korea Data Systems U.S.A.
Part Number: RAD5
My Shopping List: Add to my list | View my list

advertisement
Dell Computers
starting at $999
PCs for your home
PCs for your home office
PCs for small business

‹Previous 1-15 16-18 Next›

Updated	Store	Gómez Merchant Review	Price	State	Phone	Shipping	In Stock	Shop
10/30/2001	buy.com The Internet Superstore Company info | Buy now	★★★	$346.95	CA	N/A	See Site	Check	Buy Info
10/30/2001	TheNerds.net Company info | Buy now	★★★	$347.39	FL	1-888...	29.95	100	Buy Info
10/30/2001	Compu America Company info | Buy now	No rating	$348.00	CA	1-800...	33.25	YES	Buy Info
10/29/2001	PCNation.com Company info | Buy now	★★★	$348.44	IL	1-800...	9.95	Y	Buy Info
10/26/2001	Micro Pro Inc. Company info | Buy now	★★☆	$355.00	OH	1-888...	$17 - $29	Yes	Buy Info
10/30/2001	LA Computer Center Company info | Buy now	No rating	$359.00	CA	1-800...	30	YES	Buy Info
10/30/2001	Computers 4sure.com An Office Depot Company Company info | Buy now	★★★	$369.99	CT	1-888...	11.90	Yes	Buy Info
10/30/2001	Half.com Company info | Buy now	No rating	$371.88	PA	N/A	see site	208	Buy Info
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10/29/2001	2Buystore.com Company info | Buy now	No rating	$375.85	FL	1-888...	Free Shipping	Yes	Buy Info

Fig. 2. Screenshot from Shopper.com.

Table 1. Summary Statistics by Category.

Product Category	Number of Observations	Number of Products	Average Price	Average Minimum Price	Average Maximum Price	Average Shopper.com Product Rank
Notebook computers	671	11	$1,876.65	$1,660.19	$2,312.61	315.1
Computer monitors & visual devices	2013	33	902.40	803.21	1101.08	370.4
Digital cameras	1586	27	500.46	409.61	600.57	351.8
Computer printers & supplies	1647	27	482.09	409.87	555.98	383.9
Handheld PDAs	854	15	292.78	238.25	361.92	352.8
Computer software titles	2013	33	226.09	198.00	260.31	375.5
MP3 players	671	11	192.00	158.92	251.48	299.8
Computer storage devices	610	10	186.63	160.87	226.40	354.4
Networking hardware	732	12	169.33	144.55	202.75	397.2
Computer graphics	915	15	150.85	132.86	174.49	408.7
Computer hardware components	1159	18	146.72	122.13	194.34	326.1
Computer memory modules	488	8	75.88	54.35	111.54	321.8

of products, eight in total. In contrast, the categories consisting of computer software titles and computer monitors and visual devices each have 33 products; the two categories with the largest number of products among the 12 categories. Table 1 also provides the average price for each of the 12 product categories.[5] Notice, the categories are fairly well divided into relatively expensive and inexpensive products: six categories have average prices less than $200 and six greater than $200. The computer memory modules category is the cheapest among the 12 categories, with an average price of $75.88. The notebook computers category, in contrast, has the highest average price of $1,876.65. Table 1 also reports the average Shopper.com product rank. Based on the number of unique consumer "click throughs," each day Shopper.com assigns a product rank between one and 1000 to each product. Thus, the Shopper.com product rank is a relative measure of product popularity (also a proxy for relative demand), where a rank of one indicates the most popular product and that of 1000 being the least popular. For the 12 categories in our sample, the average Shopper.com product ranking across categories is between 300 and 409. This suggests that products in our sample are relatively popular; although, products do tend to go through identifiable life cycles – an issue further explored later in this paper.

2.3. Market Structure at Shopper.com

Given that firms can change their decisions to list prices on a given product date, the number of actual firms listing price information can be viewed as a random variable. Accordingly, a distinction exists between the number of *potential* firms listing prices and the number of *actual* firms listing prices for a product date. Given the relatively short time horizon of this study, one way to measure the number of potential rivals is to use the total number of distinct firms that list price information for a given product. That is, as long as a firm listed a price for a given product over the two-month sample period, this firm is considered a potential rival.[6]

Using this as the number of potential firms for a given product, Fig. 3 charts the average number of actual firms listing prices and the average number of potential firms for each of the 12 product categories. Notice, the average number of potential firms is up to eight firms higher than the average number of actual firms listing prices. This suggests that firms do not advertise price information for each product date. More importantly, when making daily pricing decisions the number of potential firms is relevant. Thus, firms paying to list price information

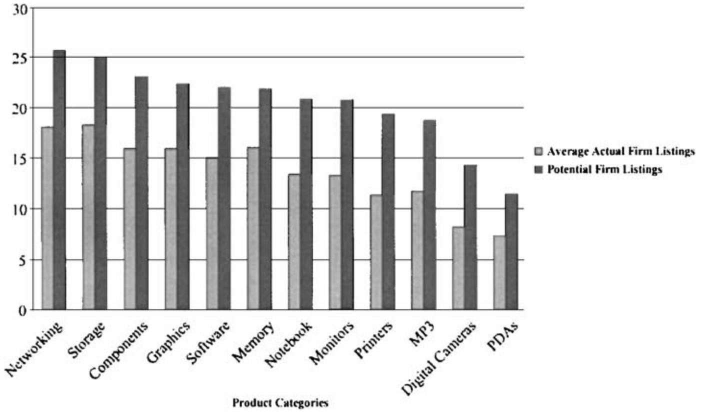

Fig. 3. Actual vs. Potential Number of Firms Listing Prices.

at Shopper.com for the average product date in our sample tend to face a large number of potential firms.

Baye-Morgan (2001) show how firms can avoid the deleterious outcome of classical Bertrand competition when firms compete in an environment similar to Shopper.com. Equilibrium in the Baye-Morgan model consists of firms' symmetrically advertising price information with propensity less than one and a distribution of prices where the identity of the low-price firm changes with each random draw (for instance, each day). The idea behind these strategies is that in equilibrium, firms will be unable to systematically undercut each others' prices. Moreover, consumers will be unable to learn the identity of the low-price firm without visiting the price comparison site. In expectation, firms pursuing this strategy can earn positive expected profits.

Using the ratio of the average number of actual firms listings to average potential number of firms as a measure of advertising propensity, Fig. 3 provides casual evidence that advertising propensities are strictly less than unity; a result consistent with Baye-Morgan (2001). Further evidence that firms' propensity to advertise at Shopper.com is presented in Section 4.

3. PRICE DISPERSION AND PRODUCT CHARACTERISTICS AT SHOPPER.COM

Price dispersion at Shopper.com and other online retail markets has been well documented (cf. Baye, Morgan and Scholten (2002, 2004); Brynjolfsson and Smith (2000, 2001); Morton, Zettelmeyer and Silva-Risso (2001) and Scholten and Smith (2002)).[7] The source and nature of price dispersion remains an important and interesting debate in the literature. These studies focus on either reporting price dispersion for relatively few product categories with similar product characteristics – like books and CDs – or present price dispersion statistics aggregated over many product categories. Two competing explanations for the observed dispersion in these idealized markets have emerged. One view, expressed by Brynjolffson and Smith (2000, 2001), attributes observed dispersion in the online markets for books and CDs to heterogeneities – like branding, trust, and reputation – among retailers. According to this view, branded retailers charge relatively high prices to their loyal consumers. Other firms must charge low prices to attract more price sensitive consumers. Given the Shopper.com environment where consumers can costlessly observe price lists for identical products, any price dispersion owing to branding or other firm heterogeneities should dissipate over time since consumers can easily identify the low-price seller. In contrast, Baye, Morgan and Scholten (2002) find evidence that price dispersion is remarkably stable over what is perhaps the most turbulent eight-month period in e-commerce's short history; a result that, as they note, is consistent with several clearinghouse models of equilibrium price dispersion (cf. Varian (1980) and Baye-Morgan (2001)). How does one reconcile these seemingly contradictory results? Given that Brynjolfsson and Smith examine price dispersion for books and CDs and Baye, Morgan and Scholten examine computer products and consumer electronics products, one explanation is that the nature of price dispersion varies across product categories. That is, the nature of the price dispersion is somehow fundamentally distinct for products in different categories or with varying characteristics.[8]

3.1. Measures of Price Dispersion

Price dispersion in traditional and online retail markets has been measured in several ways. The most commonly used measure is the range in prices (the difference between the maximum and minimum price).[9] Carlson and Pescatrice (1980) and Sorensen (2000) have used the coefficient of variation (σ/μ) to measure price dispersion, which has the benefit of allowing for direct comparisons between product categories with different price levels. Both of these measures of price dispersion are zero when the "law of one price" holds. Baye, Morgan and Scholten (2002), however, have recently proposed a new measure of price dispersion called the "gap." They argue that, if firms are viewed as classical Bertrand competitors, observed price distributions can be consistent with the competitive pricing even when the price range and coefficient of variation are strictly positive. For this to be true, the two lowest prices in the markets must coincide, or in the language of Baye, Morgan and Scholten, the "gap" between the two lowest prices in the market must be zero.

For each product category, Table 2 presents three measures of price dispersion averaged across each product date; the average price range as a percent of the minimum price, the average gap as a percent of the minimum price, and the coefficient of variation. Converting the range and the gap to percentages allows for easy comparisons across product categories. Notice that independent of the way price dispersion is measured, each of the product categories in our sample exhibits considerable dispersion. For the typical product category in our sample, the average price range is 51%, the average gap (between the two lowest prices) is 7% and the average coefficient of variation measures 13%.

While it is certainly remarkable to observe price dispersion of such magnitude in this environment, it is also important to note that each of these measures result in similar order rankings. That is, ranking each of these measures from the highest to the lowest results in a similar order ranks for each product category. Prices

Table 2. Comparison of Price Dispersion Measures by Product Category.[a]

Product Category	Number of Observations	Average Percent Range[b]	Range Order Rank	Average Percent Gap[b]	Gap Order Rank	Average Coefficient of Variation[b]	Coefficient of Variation Order Rank
Computer memory modules	488	0.91 (0.86)	1	0.12 (0.42)	2	0.25 (0.23)	1
MP3 players	671	0.67 (0.47)	2	0.09 (0.19)	3	0.16 (0.09)	2
Handheld PDAs	854	0.59 (0.48)	3	0.14 (0.47)	1	0.15 (0.10)	4
Computer hardware components	1159	0.58 (0.71)	4	0.05 (0.12)	8	0.15 (0.14)	3
Computer printers & supplies	1647	0.52 (0.55)	5	0.06 (0.13)	7	0.13 (0.10)	6
Digital cameras	1586	0.50 (0.21)	6	0.08 (0.12)	4	0.14 (0.06)	5
Computer storage devices	610	0.43 (0.16)	7	0.06 (0.09)	6	0.11 (0.04)	8
Notebook computers	671	0.41 (0.46)	8	0.02 (0.05)	11	0.12 (0.10)	7
Networking hardware	732	0.41 (0.25)	9	0.04 (0.06)	9	0.10 (0.06)	9
Computer graphics	915	0.39 (0.27)	10	0.07 (0.14)	5	0.09 (0.04)	11
Computer software titles	2013	0.38 (0.34)	11	0.04 (0.11)	10	0.09 (0.07)	10
Computer monitors & visual devices	2013	0.35 (0.21)	12	0.01 (0.03)	12	0.08 (0.04)	12
Average		0.51		0.07		0.13	

[a] Standard deviation in parenthesis.
[b] Calculation based on observations with multiple firms listing prices.

for computer memory modules tend to exhibit the most dispersion (Range and Coefficient of Variation Order Ranks = 1 and Gap Order Rank = 2). While prices are least dispersed in the computer monitor and visual devices category; an order rank of 12 for each measure of price dispersion. Despite having the lowest order rank, price dispersion for computer monitors and visual devices remains remarkably high; the average price range is 35%, the average gap is 1% and the average coefficient of variation is 8%.

The consistent order ranking of these three measures of price dispersion is not, however, a general property of the data or of the measures of price dispersion. Indeed, Table 3 reveals that this property fails to hold at the product-level in the computer monitors and visual devices category. The order ranks of the percent range and coefficient of variation for the LT150 XGA Portable Projector are 33, indicating the highest level of price dispersion within this category. The average percent gap, however, indicates very little relative dispersion with an order rank of four. Thus, these measures of dispersion tell completely different stories suggesting that it is important to measure price dispersion in different ways before making general statements about market performance.

Based on the evidence presented in Table 2, it is clear that price dispersion varies across product categories. In particular, some categories tend to exhibit relatively low levels of price dispersion, while others exhibit very high dispersion. The remainder of this paper examines factors that may contribute to the differences in price dispersion across product categories.

3.2. Product Life-Cycle

Tables 2 and 3 report three measures of price dispersion averaged across product dates for each category ignoring the possibility that products are at different stages of their life cycle. The behavior of prices (and price dispersion) may, however, vary with product life cycle. Early in a product's life cycle the minimum price charged may be relatively high. As a product becomes more popular competitive forces may drive the minimum price down. To examine the relationship between product life-cycle and the minimum price, we use the product rank Shopper.com assigns to the most popular 1000 products in its database – measured by the number of unique consumer requests for product and price information. Popular products have low Shopper.com product ranks, while relatively unpopular products have high product ranks. To the extent that across-category differences in price dispersion are, at least partially, attributable to life cycle effects, one might expect to observe a product's minimum price to vary with Shopper.com's product ranking.

The evidence presented in Table 4 suggests that the average minimum price for a product varies with Shopper.com's product rank. We use the median Shopper.com

Table 3. Comparison of Price Dispersion for the Products in the Computer Monitors and Visual Devices Category.

Product in Computer Monitor and Visual Device Category	Average Percent Range	Range Order Rank	Average Percent Gap	Gap Order Rank	Average Coefficient of Variation	Coefficient of Variation Order Rank
LT150 XGA PORTABLE PROJECTOR	1.049	33	0.001	4	0.265	33
ViewSonic VG 175	0.753	32	0.004	11	0.124	29
19″ Sony Multiscan CPD-G400 Trinitron	0.684	31	0.007	17	0.126	31
ViewSonic PF790	0.561	30	0.010	24	0.126	30
Sony VPL-CX1 Superlite LCD Projector	0.529	29	0.003	7	0.142	32
ULTRALIGHT X350 XGA PROJECTOR	0.466	28	0.020	29	0.101	26
Samsung Syncmaster 950P	0.397	27	0.008	21	0.110	27
ViewSonic E70f	0.368	26	0.003	8	0.078	20
Samsung SyncMaster 753 DF	0.362	25	0.008	20	0.081	22
Samsung Electronics Co. Ltd. SyncMaster	0.353	24	0.008	19	0.082	23
Hitachi CM771 (Ergo Flat)	0.353	23	0.061	32	0.123	28
Samsung SyncMaster 700NF	0.334	22	0.002	5	0.076	17
LG Electronics Flatron 795FT Plus	0.333	21	0.046	31	0.079	21
ViewSonic VE 150	0.329	20	0.004	13	0.062	8
Samsung SyncMaster 570v	0.328	19	0.002	6	0.075	16
Samsung Electronics Co. Ltd. SyncMaster	0.325	18	0.003	9	0.074	15
Samsung SyncMaster 150T	0.319	17	0.005	16	0.073	12
ViewSonic GS 790	0.316	16	0.003	10	0.092	25
Samsung SyncMaster 955DF	0.308	15	0.000	1	0.077	19
Samsung SyncMaster 900NF	0.303	14	0.011	25	0.066	11
Samsung SyncMaster 170 MP	0.297	13	0.009	22	0.073	13
Sony Multiscan LCD Display SDM-M81	0.296	12	0.009	23	0.077	18
NEC MultiSync LCD1530V	0.292	11	0.007	18	0.063	10
Samsung SyncMaster 770 TFT	0.270	10	0.000	2	0.074	14
ViewSonic Optiquest Q95	0.254	9	0.001	3	0.083	24
Samsung SyncMaster 170 T	0.247	8	0.016	28	0.060	6
KDS Rad-5	0.242	7	0.013	26	0.061	7
MP2800 MICRO PROJECTOR	0.236	6	0.016	27	0.063	9
Philips Professional Brilliance 180P	0.193	5	0.005	15	0.056	5
Samsung SyncMaster 150 Mp	0.187	4	0.004	14	0.048	3
NEC MultiSync LCD1800	0.098	3	0.088	33	0.054	4
22″ Apple Cinema Flat Panel Display	0.068	2	0.004	12	0.027	2
Apple Studio Display	0.043	1	0.026	30	0.021	1

Table 4. Average Minimum Price and Product Life Cycle.

Shopper.com Product Rank	Computer Software Titles	Computer Storage Devices	Networking Hardware	Computer Memory Modules	Computer Graphics	Computer Hardware Components	Notebook Computers	Computer Monitors & Visual Devices	MP3 Players	Computer Printers & Supplies	Digital Cameras	Handheld PDAs	Average
Average minimum price for low rank[a]	$162.52	$162.13	$120.25	$32.09	$142.87	$134.16	$1,605.39	$642.70	$154.46	$339.93	$474.32	$277.41	$354.02
Percent of products with low rank	0.80	0.83	0.63	0.80	0.68	0.82	0.73	0.79	0.73	0.70	0.81	0.79	0.76
Number of observations	1007	305	367	244	459	583	336	1013	337	825	793	427	
Average minimum price for high rank[b]	$233.52	$159.61	$168.98	$76.61	$122.80	$109.95	$1,715.16	$965.82	$163.41	$480.07	$344.91	$199.10	$394.99
Percent of products with high rank	0.80	0.75	0.75	0.80	0.74	0.70	0.73	0.82	0.73	0.81	0.65	0.71	0.75
Number of observations	1006	305	365	244	456	576	335	1000	334	822	793	427	

[a] Calculated by averaging the minimum price for a product-date if the product popularity rank is less than (or equal to) the median rank.

[b] Calculated by averaging the minimum price for a product-date if the product popularity rank is greater than the median rank.

product rank to divide observations in each product category into low rank and high rank groups. Based on these groups, Table 4 summarizes the average minimum price for each product category. Across all categories, the average minimum price for low-rank products is $354.02 and that for high-rank products is $394.99. Notice, the percent of products in low-rank and high-rank groups is relatively high. On average, 76% of products have a low rank at some point in the sample and 75% have a high rank. The considerable overlap in the percent of products in the low-rank and high-rank groups suggests that the products in our two-month sample have relatively short life cycles at Shopper.com.

Furthermore, for seven out of the 12 product categories, the average minimum price for products with ranks at or below the median rank (low rank) is lower than the average minimum price for ranks above the median rank (high rank). While only about 60% of the categories exhibit this expected behavior, the 20–40% of the product that are not common to both low and high rank over the two-month sample may be driving the imperfect result. Taken together, the evidence suggests that, on average, products with low (high) ranks tend to have low (high) minimum prices. That is, there is a positive relationship between a Shopper.com's product rank and a product's minimum price; however, a more systematic approach is necessary to make a conclusive determination.

4. FIRM BEHAVIOR

From the above analysis, we find that price dispersion varies across product categories and that some of the variation across categories may be attributable to products being at different stages in their life cycle. In what follows, we explore other explanations to why price dispersion varies across product categories that rely on differences in firms' behaviors.

4.1. Product Breadth and Frequency of Listing Prices

Recall that in subsection 2.1, firms pay to list price information at Shopper.com and must decide: (1) which products to list at Shopper.com; (2) how frequently to list price information for the products they do sell; and (3) what price to list. Viewed in this way, the nature of price dispersion across product categories may stem from differences in firms' behaviors. For instance, based on product characteristics, some of the 141 firms in the sample may choose to specialize in selling products in a particular category (or even a particular product). Table 5 shows that only about 29% of firms in the sample specialize in listing prices in a single category, while

Table 5. Advertising Frequency, Specialization and Product Breadth.

Firm Type	Percent of Firms	Average Percent of Days Listing Prices	Minimum Percent of Days	Maximum Percent of Days
Single-category firms	0.29	0.67	0.03	1.00
Multiple-category firms	0.71	0.63	0.02	1.00
Single-product firms	0.09	0.73	0.16	1.00
Multiple-product firms	0.91	0.64	0.02	1.00

the remaining 71% list prices in multiple categories. Similarly, only 9% of firms in our sample list price information for a single product, while 91% list prices for multiple products.

Despite whether firms list prices in single or multiple categories (products), on average, firms only list price information about 66% of the time; a result consistent with Baye-Morgan. Interestingly, the Baye-Morgan model suggests that firms will symmetrically advertise with propensity strictly less than unity. At the aggregate level, there appears to be some support for this idea: single and multi-category firms list price information with roughly the same frequency. However, more thorough empirical work is needed to formally test this hypothesis.

Table 6 illustrates the degree to which firms specialize in listing price information for certain product categories (and products) and the resulting price dispersion. Column 2 of Table 6 indicates that no firms specialize in listing prices for computer memory modules, computer hardware components or computer

Table 6. Price Dispersion, Specialization and Breadth by Product Category.

Product Category	Percentage of Firms		Percentage Range	Percentage of Firms	
	Single Category	Multiple Categories		Single Product	Multiple Products
Computer memory modules	0.00	0.27	0.91	0.00	0.27
MP3 players	0.01	0.38	0.67	0.01	0.38
Handheld PDAs	0.02	0.41	0.59	0.01	0.42
Computer hardware components	0.00	0.29	0.58	0.00	0.29
Computer printers & supplies	0.03	0.40	0.52	0.01	0.42
Digital cameras	0.06	0.49	0.50	0.01	0.54
Computer storage devices	0.01	0.37	0.43	0.01	0.38
Notebook computers	0.03	0.31	0.41	0.01	0.34
Networking hardware	0.01	0.29	0.41	0.00	0.30
Computer graphics	0.00	0.36	0.39	0.00	0.36
Computer software titles	0.06	0.29	0.38	0.00	0.35
Computer monitors & visual devices	0.05	0.49	0.35	0.03	0.51

graphics categories. One potential explanation for this observation is that complementarities may exist to selling products in these categories. For instance, consider a consumer wanting a build computer. In this case sellers, presumably, do better by offering a diverse selection of product across categories in an attempt to being the low-price on a bundle of products.[10] In contrast, approximately 6% of firms in our sample list prices for only digital cameras and another 6% list prices for software titles. A similar pattern is observed for firms specializing in listing prices for single products.

Table 6 also computes the percent of firms selling in multiple product categories. That is, conditional on listing price information for each particular category, what fraction of firms also list price information in at least one other category? Table 6 indicates that 27% of the firms that list prices for computer memory modules also list prices in at least one other product category. This figure is 49% in the digital camera and computer monitors and visual devices categories. A similar observation exists for multiple-product firms. Interestingly, the correlation coefficient for firms selling products in multiple categories and the percentage price range is -0.25; suggesting that a high percentage of firms listing prices in multiple categories is associated with lower price dispersion (measured by the percentage price range). Similarly, the correlation coefficient is -0.34 between the percentage of multiple-product firms and the percentage price range across categories.

While there appears to be little systematic differences between the frequencies with which single- and multi-category firms list price information, Table 7 shows that the average minimum price for firms listing price information in a single category is higher than for multi-category firms. Specifically, for seven out of the nine categories that have firms listing prices in both single and multiple categories, the average minimum price is higher for firms listing in a single category. Similarly, the average minimum price for single-product firms is higher than that of multi-product firms for five of seven categories where both single- and multi-product firms are present.

Taken together, this casual evidence suggests that an important line of future research is to explore the behavior of single and multi-product firms and the impact of their presence in online markets; an area of research largely left unexplored in online markets.

4.2. Firm Logos and Differentiation

Online retail markets have been touted as the new example of perfectly efficient markets; an idealized environment in which to observe the "law of one price." As mentioned, a great deal of research provides evidence to the contrary and offers

Table 7. Average Minimum Price by Product Category.

Product Category	Average Minimum Price for Single-Category Firms	Average Minimum Price for Multiple-Category Firms	Difference	Average Minimum Price for Single-Product Firms	Average Minimum Price for Multiple-Product Firms	Difference
Notebook computers	1948.45	1662.54	285.91	1590.72	1709.41	−118.69
Computer printers & supplies	571.07	412.79	158.28	21.49	560.58	−539.09
Networking hardware	251.02	144.55	106.47	–	133.91	–
MP3 players	199.95	163.25	36.70	199.95	160.13	39.82
Digital cameras	441.17	414.95	26.22	706.19	421.09	285.10
Handheld PDAs	261.53	238.49	23.04	325.15	245.09	80.06
Computer monitors & visual devices	825.13	803.22	21.91	2455.14	824.40	1630.74
Computer storage devices	161.51	161.60	−0.10	170.95	162.09	8.86
Computer software titles	182.70	201.41	−18.71	–	210.20	–
Computer memory modules	–	54.35	–	–	49.85	–
Computer graphics	–	132.86	–	–	138.20	–
Computer hardware components	–	122.13	–	–	124.64	–

competing explanations for the dispersion observed in online markets. Section 4.1 provides some evidence that firms may randomize their decisions to list price information; a result that is consistent with Baye-Morgan. In the remainder of the paper we explore how firms' observable attempts to differentiate themselves from rivals impact price dispersion.

One way firms at Shopper.com attempt to distinguish themselves from their rivals is by paying to display their company's logo next to their names. Since displaying a firm logo is costly, there must be a strategic benefit from doing so. Specifically, a firm displaying its logo may be attempting to build a loyal consumer to earn higher profit. To the extent that such a strategy is successful, one might expect the level of price dispersion observed in these markets to increase, depending on the number of other firms in the market displaying logos.

Of the 141 firms in our sample only 10 displayed their company logos. Table 8 reports the number of categories and products for which firms displaying logos list price information. Interestingly, half of the firms with a logo list price information for over 100 products in each of Shopper.com's 12 product categories. Three out of the 10 firms with a logo list prices in more than three categories but less than nine, and four between eight and 19 products. This suggests that 80% of the firms displaying a logo receive exposure from at least two product categories and all of these firms sell multiple products. That is, firms with logos may receive across category and product benefits. Furthermore, all firms with logos sell more than one product. These observations make sense since firms with logos selling in multiple products in several categories can, presumably, spread the added cost of displaying a logo over many products and reach more consumers.

Table 8. Number of Product Categories and Products where Firms Display Logos.

Firm names	Number of Product Categories	Number of Products
Buy.com	12	157
Computers4SURE.com	12	149
CDW	12	148
Amazon.com	12	119
Gateway.com	12	112
AtomicPark.com	8	17
Toshiba	6	18
Circuit city	4	9
800.com	1	29
Handspring Inc	1	6
Average	8	76.4

Table 9. Weighted Average Percentage Range & Firms with Logos by Category.[a,b]

	Computer Software Titles	Networking Hardware	Computer Monitors & Visual Devices	MP3 Players	Handheld PDAs	Computer Storage Devices	Computer Printers & Supplies	Computer Graphics	Computer Hardware Components	Notebook Computers	Computer Memory Modules	Digital Cameras Cameras	Average
Weighted average percentage range (of the minimum price) when the number of firm logos is below the median	0.22	0.37	0.28	0.44	0.59	0.23	0.31	0.21	0.33	0.18	0.70	0.33	0.35
Number of observations below the median	1023	654	1643	403	853	342	859	574	909	403	312	1037	
Weighted average percentage range (of the minimum price) when the number of firm logos is above the median	0.15	0.04	0.07	0.22	0.00	0.20	0.19	0.16	0.22	0.23	0.22	0.17	0.16
Number of observations above the median	990	78	370	268	1	268	752	341	250	268	176	549	
Median number of firm logos	5	5	4	4	4	3	3	3	1	1	1	1	2.92

[a] Weighted by the number of observations for each product-date.
[b] The large discrepancy between the number of observation above and below the median reflects a mass point of observations at the median.

The presence (or lack) of firms with logos appears to impact the level of price dispersion observed in markets. To reach this conclusion, we calculate the median number of firms displaying logos within each product category and report the weighted average percent price range. The results, presented in Table 9, suggest that when the number of firms displaying logos is below the median, the average percent range is higher than when the number of logo firms is above the median. On average, when the number of firms with logos is below the median, the range is about 35%, and falls to 16% when the number of firms with logos is above the median.

Interestingly, the categories with the largest median number of firms with logos – software titles, networking hardware, and monitors and visual devices – tend to have the smaller percent price ranges, as shown in Table 9. In contrast, the median number of firms with logos is the lowest for the computer memory modules category, which also has the highest percent price range.[11] This suggests that the characteristics of products are likely to influence whether firms incur the cost associated with displaying a logo, which in turn impacts the level of price dispersion in a market.

Based on the evidence presented in Table 9, price dispersion varies with the number of firms that pay to display a logo. Specifically, characteristics of some product categories make it more attractive for firms to differentiate themselves from rivals by displaying a logo. This, in turn, appears to impact the level of price dispersion observed in the market. This suggests that premia accrue to firms with logos, but that the size of the premia depends on the number of other firms that display logos. A more systematic study is required to determine the magnitude of these premia under various competitive conditions.

5. CONCLUSION

This paper offers some new stylized facts about the nature of price dispersion in online retail markets. Specifically, we find that price dispersion varies across product category. While some of the difference is likely to be the result of products being at different stages of their life cycle, we find casual evidence that price dispersion varies with the percent of firms listing price information in multiple categories or for multiple products. Specifically, conditional on listing price information in a particular category, when the fraction of firms selling in multiple categories is high (low), price dispersion will be low (high). Furthermore, price dispersion varies with the number of firms displaying their company logos. When the number of firms with logos is below the median, the weighted-average price range is about 35%, and is 16% when the number of firms with logos is below its median value. This suggests that firms' behaviors in markets varies with product characteristics, which influences price dispersion.

NOTES

1. For examples see http://nash-equilibrium.com
2. The ranges reported in Brynjolfsson and Smith are a percent of the average price, not the minimum price. Therefore, the ranges reported in this study are not directly comparable with Brynjolfsson and Smith.
3. Shopper.com's database technology relies on member firms' to input price information. In contrast, "shopbot" technology – programs written to automatically retrieve price information from firms' web sites – is used by competing Internet price comparison services like MySimon.com and Pricescan.com.
4. Firms must pay a one-time, set-up fee plus a fixed monthly fee provided the number of qualified leads does not exceed a threshold, where qualified lead occurs when a consumer "clicks through" from a Shopper.com web page to a firm's web page. If this threshold is exceeded, firms must pay an additional fee for each qualified lead.
5. The average price for each category is obtained by giving equal weight to each product and date in the category, or a "product-date." For example, the average price for computer memory modules is the average of eight different products over a 61-day period, or the simple average of each product-date in the category.
6. Measuring the number of potential competitors in this way is consistent with an ML estimator. There are, of course, alternative ways to measure the number of potential competitors. For instance, one could also take the number of actual price listing on the previous day for a given product (consistent with an AR1 estimator) or use a moving average process of several days.
7. Various measures of price dispersion in online retail markets are available at http://www.nash-equilibrium.com
8. Another potential explanation is the methodology used in each study. See the respective papers for the details.
9. The price range is typically expressed as a percent of either the low price or average price. For examples, see Pratt, Wise and Zeckhauser (1979); Brynjolffson and Smith (2000) Baye, Morgan and Scholten (2004).
10. Generally, one might not expect consumers to purchase bundles of products from shopper given the averages prices are relatively high. See Baye, Morgan and Scholten (2002) for additional arguments.
11. See Table 2.

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WHAT ATTRACTS A BIDDER TO A PARTICULAR INTERNET AUCTION?

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ABSTRACT

Livingston (2002) shows that bidders in Internet auctions are easily convinced of a seller's trustworthiness: they bid large amounts even if sellers have barely established a reputation for performance, suggesting that they believe that typical sellers usually perform. This study reinforces this conclusion by looking at how bidders choose which auction to bid in when there are several that are selling the same item. The analysis shows that so long as a seller has some history, bidders consider bidding in the seller's auction. They then choose auctions that offer the best chance to obtain the good at the lowest price.

1. INTRODUCTION

In recent years, the Internet has revolutionized person-to-person commerce. Markets for such commerce were once purely local, and limited to garage sales and classified ads in newspapers. The Internet now makes it easy to find potential trading partners, even if they are thousands of miles away. The most popular place to conduct such transactions is eBay, the dominant Internet auction company. eBay facilitates the costless matching of buyers and sellers by making it simple for buyers to find what they are looking for through the use of a search engine. The growth of eBay has been remarkable. There are now more than 61 million people

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registered as eBay users, 27 million of whom actively participated in an eBay transaction in the final quarter of 2002. A huge variety of products is exchanged: in the United States, there are nearly 13 thousand different categories of items for buyers to browse. Transaction volume is enormous: in the fourth quarter of 2002 alone, sellers posted 195 million listings, and the total value of items sold was \$4.6 billion.[1]

The unique aspect of eBay is that by convention, sellers do not ship goods to the winning bidder until after they have received payment. Malicious sellers can collect the bidder's money and send an item of inferior quality or nothing at all. Rather than enforcing agreements, eBay encourages self-enforcement through a reputation system that allows buyers and sellers to report whether their transaction partner behaved honestly. Reports can be classified as positive, neutral, or negative. Bidders can see how many of each type of report a seller has received, as well as the seller's feedback rating, which is equal to the number of positive reports, minus the number of negative reports. Potential bidders can use this information to form expectations about how the seller will behave in the future. Several studies, including Eaton (2002), Houser and Wooders (2000), Lucking-Reiley et al. (2000), McDonald and Slawson (2002), Melnik and Alm (2002), Resnick and Zeckhauser (2001) and several others have explored whether bidders bid larger amounts if the seller has a better reputation by looking at a cross section of auctions of a particular good, such as electric guitars or collectible coins. Their results are puzzling: they find either that reputation has an extremely small impact on the amount of bids, or no effect at all.[2] For example, Melnik and Alm (2002) find that doubling the seller's feedback rating from 452 to 904 will increase the winning bid by only \$0.18, for a good where the mean price was \$32.73. These papers typically control for a seller's reputation using a log-linear specification. Livingston (2002) shows that this specification does not capture the impact of positive reports, because the marginal returns to these reports decrease at an extremely severe rate. Auctions are much less likely to result in a sale, and bidders bid much smaller amounts, if a seller has no positive reports than if the seller has at least a handful of positive reports. Once a few reports have been received, however, bidders are largely convinced that the seller tends to perform, and they bid as if they are almost completely sure that the seller will perform. Additional positive reports have little impact on bidder behavior, because there is little room for improvement. This is interesting, because as the analysis shows, if bidders are so easily convinced of a particular seller's honesty, they must believe that nearly all sellers behave honestly most of the time. This belief helps overcome the adverse selection problem that threatens to disrupt the market.

In this study, I examine this finding in more detail. To do so, I look at how bidders decide which auctions they want to place a bid in. When bidders shop for an item on eBay, there are typically several auctions of that item running at the same time. Bidders must decide which auction they find most attractive. Naturally, bidders will look for auctions that they are likely to win with a relatively low bid, but they also must weigh the risk that a particular seller will be dishonest. The seller who has the worst reputation may post the auction that is most likely to end at the lowest price. If bidders seek the auctions of only the most reputable sellers, even when sellers who have relatively weak reputations post auctions where the winning bid is likely to be very low, then they are clearly quite worried about the possibility that the seller will act dishonestly. However, the analysis reveals a picture that is in accordance with the conclusions of Livingston (2002) – bidders are confident that most sellers tend to perform, so they need to see only a few positive reports to be willing to consider bidding in an auction. They then look for the auction that is likely to give the bidder a good deal from among those where the seller has at least a few reports. Once the seller's reputation is established, a good deal is all that matters. Among sellers who have at least a few positive reports, sellers who have relatively better reputations are not much more likely to be chosen by the bidder.

To conduct the analysis, I use data from auctions of sets of Taylor Made Firesole Irons, a type of golf club. A great deal of information is available about each auction regardless of whether the transaction results in a sale or not, including the complete bid history of the auction. The identity of every participating bidder, when they placed their bid, and the amount of the bid is available, as is the time when each auction is active. This makes it possible to examine the reasons why bidders choose to bid in a particular auction, rather than other auctions of the same item that are going on at the same time. Using different specifications, one can see precisely how bidders use information about the sellers' relative reputations, how they take into account the likelihood that each auction will result in a good deal, and how they react to differences in the presentation of the auctions.

The analysis proceeds as follows. The econometric strategy is discussed in Section 2. The data and the variables used in this study are described in Section 3. Section 4 presents and discusses the results of the analysis. Section 5 concludes.

2. ECONOMETRIC STRATEGY

Before thinking about how bidders choose which auction to bid in, we must first identify the auctions that are in a bidder's choice set. Imagine a bidder who wants to purchase a set of Taylor Made Firesole golf clubs. Using eBay's search engine, the bidder is presented with a list of all active auctions of Firesole irons. The bidder can look at each auction to see all kinds of information about the clubs, about the rules of the auction, and about the seller. She can use this information to determine which auction is most attractive to her, and she places a bid in that auction. At the moment she places a bid, she has made a decision to place a bid in a particular auction, rather than in one of the other auctions of the same item that were active at the same time.

The strategy is the following: I identify the first time a bidder places a bid in any auction. I assume that when a bidder places a bid for the first time, she has started shopping for a set of Taylor Made Firesole irons. I then identify all of the other auctions that were active at the moment this bid was placed. These auctions are assumed to be the set of other auctions that the bidder also considered placing a bid in. This set of auctions, plus the auction the bidder first participated in, constitute a "bidder block."[3] Within each block, I identify whether the *relevant* bidder chose to place a bid, which is the dependent variable. These blocks are stacked together to form a dataset where the unit of observation is an auction in which the relevant bidder could have chosen to bid. I then ask what factors determined whether the relevant bidder chose to place a bid in each auction in her block. The independent variables measure relative differences between each auction. Four sets of controls are included in the econometric specifications. As discussed above, bidders will look for auctions that they are likely to win with a relatively low bid, but they also must weigh the risk that a particular seller might fail to perform. The first set of controls measures the relative reputations of the sellers, and the second set measures how likely each auction is to give the winning bidder a relatively good deal. Some regressions also include interactions between the reputation controls and the relative price controls. Estimates of the coefficients of the interactions will show whether bidders ignore sellers who have relatively poor reputations, even if their clubs are likely to sell for the lowest price, for example. The third set of covariates measures observable characteristics of the auctions that might affect the bidders' decisions. The final controls are bidder block fixed effects. Some bidders may have different bidding strategies. For example, bidders who are also golf club dealers may bid in several auctions at once.

To estimate the effect of different factors on the bidders' decisions, linear probability models of the following form are estimated:[4]

$$y_{ij} = X_{ij}\beta_1 + V_{ij}\beta_2 + Z_{ij}\beta_3 + \alpha_i + \varepsilon_{ij}, \tag{1}$$

where $y_{ij} = 1$ if the relevant bidder i submits a bid in auction j, and 0 otherwise; X_{ij} is a vector of variables that measures the seller's reputation relative to the sellers who run the other auctions in the bidder block; V_{ij} is a vector of controls that measure the likelihood of obtaining a relatively good deal, including variables that measure the relative prices between the auctions and the amount of time left until the end of the auction; Z_{ij} is a vector of controls for observed auction characteristics; α_i captures unobserved characteristics about the bidder block;

and ε_{ij} is a robust error term that is clustered by bidder, because there should be massive negative covariance between the outcomes within a block – if a bidder places a bid in one auction, she is probably much less likely to bid in the other auctions within her block.

3. DATA

For a period of 90 days after an auction has ended, eBay maintains web pages that describe the history of each auction. These pages are a very useful research tool because they provide the full bid history of each auction, including the eBay identity of each bidder, the amount of each bid, and the time that each bid was placed. Also, eBay's search engine makes it easy to find the web pages of all of the auctions of a specific kind of item. One can search for links to the pages of all auctions of an item that were completed in the past two weeks. It is therefore possible to create a very thorough picture of who is shopping for a specific item. Such a dataset is used here. From April 16th, 2001 through August 20th, 2001, data were collected from 678 eBay auctions of Taylor Made Firesole irons.[5] There is data from nearly every auction that was completed during this interval.[6] Figure 1 shows how many auctions were active on each day in this interval. On the average

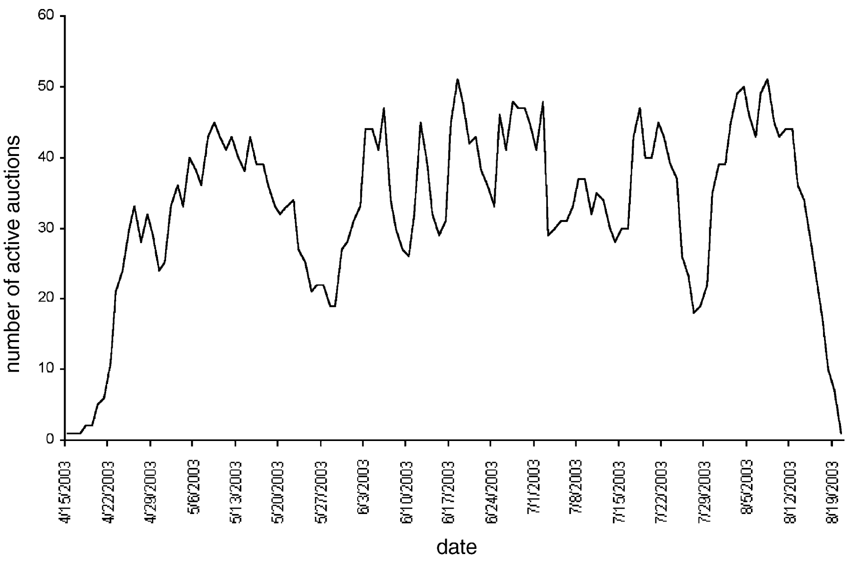

Fig. 1. Number of Active Auctions During Each Day.

Table 1. Characteristics of Bidder Blocks.

Bidder Type	Percent of Sample	Mean Number of Auctions in Bidder Block	Median Number of Auctions in Bidder Block	Modal Number of Auctions in Bidder Block
Left-handed	3.3	1.4	1	1
Ladies	1.7	1.4	1	1
Senior	3.6	1.9	2	1
Others (not any of the above)	91.3	28.5	29	28

day, there were 32 active auctions, so bidders usually had many auctions to choose from.

The first step in crafting our dataset is to create the bidder blocks by identifying all of the unique bidders in the auctions, finding out when they placed their first bid, and identifying the other auctions that were active at the time of that bid. There are 2233 unique bidders who participated in these auctions; accordingly, there are 2233 bidder blocks. Some auctions offer clubs that are clearly of no interest to the relevant bidder, so they are dropped from the bidder's block. While the golf clubs are relatively homogenous, there are some major differences to account for: some clubs are left-handed, some are made for women, and some are made for seniors. If an auction within a bidder block offers a set of clubs that does not have the same characteristics as the clubs in the auction that the bidder first chooses to bid in, then it is dropped from the bidder's choice set. For example, if a bidder places her first bid in an auction for right-handed clubs, then auctions of left-handed clubs are dropped from her bidder block. Table 1 presents information about the composition of the bidder blocks. 3.3% of the bidders were shopping for left-handed clubs, 3.6% were looking for senior clubs, and 1.7% were interested in ladies clubs. These bidders had few choices. Bidders who were interested in ladies clubs or left-handed clubs had on average 1.4 auctions to choose from, while bidders who were shopping for senior clubs have on average 1.7 auctions in their bidder block. The median number of auctions in the bidder block for any of these shoppers is one. The bulk of the bidders, however, had many auctions to choose from. For the rest of the sample, the average number of auctions in a bidder block is 28.5, the median number of auctions in a bidder block is 29, and the modal number is 28.

The bidder blocks are stacked to form a dataset where the unit of observation is an auction in which the relevant bidder i could have chosen to bid, yielding a total of 58,501 synthetic observations. These data make it possible to estimate models that are based on Eq. (1).

Table 2 presents definitions and summary statistics for the variables used in this study. When possible in the discussion that follows, subscripts of the variables are dropped for convenience. The dependent variable in each of the regressions indicates whether a bidder placed a bid in an auction that is part of her bidder block. $Bid\ Placed_{ij}$ takes a value of one if bidder *i* placed a bid in an auction *j* that is a part of her block. The relevant bidder placed a bid in 5% of the auctions in the synthetic sample.

Table 2. Variable Definitions and Sample Characteristics.

Variable Name	Definition	Mean and Standard Deviation
Dependent Variable		
Bid Placed	0–1 Dummy variable that equals one if the relevant bidder placed a bid in the auction	0.048 (0.215)
Reported History of Seller		
Positive Report Ranking	Seller's within-bidder block ranking by number of positive reports held	15.27 (9.52)
Best Positive Ranking	0–1 Dummy variable that equals one if the auction's seller has among the top 5 most positive reports among all sellers in the bidder block	0.19 (0.39)
No Positives	0–1 Dummy variable that equals one if the seller has 0 positive reports	0.07 (0.26)
Positive Q1	0–1 Dummy variable that equals one if the auction is in the first within-block quartile of positive reports received, less those with 0 reports	0.20 (0.40)
Positive Q2	0–1 Dummy variable that equals one if the auction is in the second within-block quartile of positive reports received	0.26 (0.44)
Positive Q3	0–1 Dummy variable that equals one if the auction is in the third within-block quartile of positive reports received	0.26 (0.44)
Positive Q4	0–1 Dummy variable that equals one if the seller is in the fourth within-block quartile of positive reports received	0.21 (0.41)
Bad Report Ratio	Percentage of reports that are neutral or negative	0.02 (0.07)
Good Deal Controls		
Most Expensive	0–1 Dummy variable that equals one if the auction is in the top quartile of the amount of the current winning bid	0.25 (0.43)
2nd Most Expensive	0–1 Dummy variable that equals one if the auction is in the second quartile of the amount of the current winning bid	0.26 (0.44)

Table 2. (*Continued*)

Variable Name	Definition	Mean and Standard Deviation
3rd Most Expensive	0–1 Dummy variable that equals one if the auction is in the third quartile of the amount of the current winning bid	0.24 (0.43)
Cheapest	0–1 Dummy variable that equals one if the auction is in the bottom quartile of the amount of the current winning bid	0.26 (0.44)
Lowest Winning Bid	0–1 Dummy variable that equals one if the winning bid at the time the bidder makes her decision is the lowest among all auctions in the bidder block	0.04 (0.20)
2nd Lowest Winning Bid	0–1 Dummy variable that equals one if the winning bid at the time the bidder makes her decision is the second lowest among all auctions in the bidder block	0.03 (0.17)
3rd Lowest Winning Bid	0–1 Dummy variable that equals one if the winning bid at the time the bidder makes her decision is the third lowest among all auctions in the bidder block	0.03 (0.17)
4th Lowest Winning Bid	0–1 Dummy variable that equals one if the winning bid at the time the bidder makes her decision is the fourth lowest among all auctions in the bidder block	0.03 (0.18)
5th Lowest Winning Bid	0–1 Dummy variable that equals one if the winning bid at the time the bidder makes her decision is the fifth lowest among all auctions in the bidder block	0.03 (0.17)
Auction Characteristic Controls		
5 Minutes Left	0–1 Dummy variable that equals one if the auction ends in 5 minutes or less from the time the bidder places her first bid	0.03 (0.16)
Business	0–1 Dummy variable that equals one if the seller runs a "business"	0.30 (0.46)
Fancy Display	0–1 Dummy variable that equals one if the item description is "fancy"	0.47 (0.50)
Shows Picture	0–1 Dummy variable that equals one if at least one picture of the item is displayed	0.67 (0.47)
Same Shaft Type	0–1 Dummy variable that equals one if the clubs have the same shaft type as the clubs in the auction in which the bidder places her first bid	0.44 (0.50)
Retail Price	Retail price of the clubs	849.79 (78.89)
High Minimum Bid	0–1 Dummy variable that equals one if the auction uses one of the five highest minimum bids, among those within the bidder block	0.22 (0.41)
3 Days Long	0–1 Dummy variable that equals one if the auction lasts 3 days	0.09 (0.29)

Table 2. (*Continued*)

Variable Name	Definition	Mean and Standard Deviation
5 Days Long	0–1 Dummy variable that equals one if the auction lasts 5 days	0.18 (0.38)
7 Days Long	0–1 Dummy variable that equals one if the auction lasts 7 days	0.60 (0.49)
10 Days Long	0–1 Dummy variable that equals one if the auction lasts 10 days	0.07 (0.26)
Secret Reserve Used	0–1 Dummy variable that equals one if a secret reserve price is used	0.53 (0.50)
New Clubs	0–1 Dummy variable that equals one if the clubs being auctioned are new	0.36 (0.48)
Buyitnow Used	0–1 Dummy variable that equals one if the seller allows the bidders to buy the clubs at a posted price	0.07 (0.26)

The independent variables are designed to capture relative differences between each auction within a bidder block. As discussed above, the first set of controls X_{ij} measures the seller's reputation. Sellers who ruin their reputations can start over as a new seller who has yet to establish a transaction history. Given this fact, it is not surprising that sellers in the data have very few negative reports on average. The analysis thus focuses on how bidders react to sellers who develop better reputations, rather than how bidders react to sellers who develop bad reputations, though bad reputations are controlled for using *Bad Report Ratio*, which is equal to the percentage of the seller's reports that are neutral or negative.

Positive reports are controlled for in several different ways. Sellers are ranked within each bidder block by the number of positive reports held at the time their auction began. *Positive Report Ranking* is equal to this ranking, where a ranking of 1 indicates that the seller had the most positive reports among all sellers in the bidder block. The first specification controls for the seller's relative reputation using *Positive Report Ranking*, to see if the chance that a bidder places a bid in an auction decreases linearly with the seller's ranking.

Best Positive Ranking takes a value of one if this ranking is among the top five within the bidder block. The second specification controls for a seller's reputation using *Best Positive Ranking*, to see if bidders tend to seek out the most reputable sellers.

Finally, the sample distribution of the number of good reports held by the seller in each auction is divided into within-block quartiles, and dummy variables are created that indicate whether an auction falls into each quartile. The first quartile is further divided by splitting off auctions where the seller has zero positive reports into a separate group. *No Positives* is a dichotomous variable that equals one if the seller has zero positive reports. *Positive Q1* takes a value of one if the auction is in the remainder of the first within-block quartile of the number of positive reports received. Auctions where *Positive Q1* equals 1 will still be referred to as the first quartile, though the reader should keep in mind that this group is not the true first quartile, since it excludes auctions where the seller has no positive reports. *Positive Q2* through *Positive Q4* take a value of one if the auction is in the second through fourth within-block quartiles of positive reports held, respectively. The third specification controls for *Positive Q1* through *Positive Q4*, using *No Positives* as the reference group. Livingston (2002) uses a similar strategy to control for reputation. Since sellers who ruin their reputations can start over with a new identity, I focused on the improved outcomes experienced by sellers who have established a reputation for acting honestly, relative to sellers who have no reports about their behavior. This analysis showed that bidders are easily convinced of a seller's good intentions: they react very strongly to the first few positive reports received by a seller, but additional positive reports beyond the first few have a much smaller marginal impact on how much bidders bid and the likelihood that a seller's auction results in a sale. The within-block quartiles are designed to capture this non-linear impact. One might expect that the bidder is more likely to choose to place a bid in auctions in quartile 1 than auctions where the seller has no reports, but the bidder may be no more likely to place a bid in auctions that are in quartiles 2 through 4 than auctions that are in quartile 1.

If bidders are not concerned about the risks involved, their choice will probably be based on which auction offers the greatest chance of buying the golf clubs at a low price. The second set of independent variables V_{ij} measures this factor. Bidders are more likely to win an auction at a low price if other bidders have not already bid the price up to a relatively high level. They are also more likely to get a good deal if there is little time left until the end of the auction, because there is less time for other bidders to outbid them. Also, Roth and Ockenfels (2002) show that bidders often wait until the closing minutes and even seconds of an auction to place bids, and they suggest that they do so for strategic reasons, such as the avoidance of bidding wars. The bidder has the best chance of getting a good deal if she can find an auction that ends soon and also has a relatively low winning bid. *Current Winning Bid* is equal to the winning bid at the time when the bidder places her first bid. For discussion purposes, we will refer to the winning bid at this time as the current winning bid. The average current winning bid is \$289.09, and it ranges from \$0.01 to \$822. Relative prices are controlled for using two different specifications. In one specification, the auctions are ranked within bidder blocks by their current winning bid. A rank of 1 means that the auction has the highest current winning bid. *Bid*

Rank percentage is equal to this rank divided by the highest possible rank within the block. Thus, if *Bid Rank percentage* is very low, then the auction's winning bid at the time the bidder makes her first decision is very high. Finally, auctions are divided into within-block quartiles of this percentage. *Most Expensive*, *2nd Most Expensive*, *3rd Most Expensive*, and *Cheapest* are dichotomous variables that equal one if the auction falls within quartile 1 through quartile 4 of *Bid Rank percentage*, respectively. If an auction is in the first quartile of this percentage, the auction has a current winning bid that is relatively high, and if an auction is in the fourth quartile of this percentage, the auction has a current winning bid that is low relative to the other auctions in the bidder block. We might expect bidders to be more attracted to auctions in the fourth quartile, in particular. The other specification controls for dummy variables that indicate whether the auction has the lowest current winning bid, the second lowest winning bid, the third lowest winning bid, the fourth lowest winning bid, and the fifth lowest winning bid (*Lowest Winning Bid* through *5th Lowest Winning Bid*). Finally, *5 Minutes Left* takes a value of one if there are five minutes or less left in the auction at the time the bidder placed her first bid. The specifications also control for the interactions between the relative price controls and the amount of time left in the auction, since auctions with low current winning bids that also end soon should be the most attractive to bidders.

The third set of independent variables Z_{ij} controls for auction-specific characteristics that may affect the bidders' decisions. One way that sellers may distinguish themselves is in the way the auction is presented. Bidders may be attracted to certain presentation styles, and others may turn them off. This is a difficult feature to control for, because whether a particular presentation is "good" is subjective. Three variables are included that capture part of this story. Bidders may be attracted to auctions where the seller operates an identifiable and verifiable business outside of eBay. *Business* equals one if the seller provides a telephone number at which he can be contacted or a website address that promotes the seller's business, if the seller is an eBay "power seller," or if the seller has an eBay store.[7] Bidders may also be impressed by attractive presentations of the description of the gold clubs. *Fancy Display* equals one if the description of the golf clubs is displayed in a "fancy" manner. Most descriptions are simply black text that looks much like the text of this paper. The fancy descriptions are characterized by features such as different background and font colors, unusual fonts and font sizes, scrolling text, and the use of tables to display information about the clubs.[8] Finally, bidders may be reassured that the seller actually possesses the clubs if the seller presents a picture of them. *Shows Picture* equals one if the seller shows at least one picture of the clubs being sold.

Other differences may also impact decisions. There are three different types of shafts in some of the sets of golf clubs: steel, sensicore (a more expensive steel shaft) and graphite. The shaft type affects how the club plays, and different bidders may prefer different types of shafts. Presumably, if the auction in which a bidder places her first bid is for steel-shafted clubs, then the bidder may prefer steel shafts to sensicore or graphite shafts. *Same Shaft Type* is a dichotomous variable that equals one if the shaft type is the same as the type for the clubs sold in the auction in which the bidder places her first bid. These differences affect the value of the clubs. Graphite shafts are more expensive than the other two types of shafts, for example. The value of the clubs is directly measured by *Retail Price*, which is equal to the retail price of the clubs. Bidders may be turned off by high minimum-allowable bids, which act as publicly-known reserve prices. *High Minimum Bid* equals one if the auction ranks among the 5 highest minimum bids within a bidder block.[9] Sellers can run auctions that last either 3, 5, 7 or 10 days. Bidders may have a greater chance of observing and choosing to participate in auctions that run longer. *3 Days Long, 5 Days Long, 7 Days Long* and *10 Days Long* equal one if the auction lasts 3, 5, 7 or 10 days, respectively. Each of these variables is included in the specifications; the reference group is the small number of auctions that lasted less than 3 days because a bidder ended the auction early by selecting the "buy it now" option, which is discussed below. Bidders may also react to the use of a secret reserve price.[10] *Secret Reserve Used* takes a value of one if the seller uses a secret reserve price. Bidders may be more or less inclined to bid on new clubs. *New Clubs* takes a value of one if the clubs are new, not used. Finally, eBay recently started allowing sellers to give bidders the option to "buy it now" at a posted price specified by the seller. If a bidder selects this option, the auction ends immediately and the bidder wins the "auction" at the posted price. *Buyitnow Used* equals one if the seller uses the buy it now feature.

4. RESULTS

The first regressions are designed to investigate how strongly bidders consider the seller's relative reputations when making their decisions. If bidders are concerned about finding as reputable a seller as possible, this suggests that they are very concerned about the risks associated with Internet auctions – the danger of receiving an item of inferior quality, or of receiving nothing at all. If these risks do in fact weigh heavily on bidders' minds, then we should observe a strong correlation between a seller's within-block ranking by the number of positive reports held and the chance that the bidder chooses to bid in an auction. In fact, they are barely correlated. Table 3 shows the results of three regressions that control for a seller's reputation in different ways. In the first specification reported in column 1, the seller's raw within-block rank is included as a covariate. If a seller's rank

Table 3. How Do Bidders Weigh a Seller's Relative Reputation?

	(1)	(2)	(3)
Reputation Controls			
Positive Report Ranking	0.0006** (0.0001)		
Best Positive Ranking		−0.016** (0.002)	
Positive Q1			0.018** (0.003)
Positive Q2			0.024** (0.003)
Positive Q3			0.031** (0.004)
Positive Q4			0.027** (0.004)
Bad Report Ratio	−0.025* (0.012)	−0.021 (0.012)	−0.017 (0.012)
Good Deal Controls			
2nd Most Expensive	0.010** (0.002)	0.011** (0.002)	0.011** (0.002)
3rd Most Expensive	0.053** (0.002)	0.054** (0.002)	0.054** (0.002)
Cheapest	0.104** (0.003)	0.105** (0.003)	0.105** (0.003)
5 Minutes Left	0.073* (0.029)	0.073* (0.029)	0.074* (0.029)
5 Minutes Left × 2nd Most Expensive	0.072 (0.038)	0.072(0.038)	0.070 (0.038)
5 Minutes Left × 3rd Most Expensive	0.139** (0.036)	0.139** (0.036)	0.138** (0.036)
5 Minutes Left × Cheapest	0.090** (0.034)	0.089** (0.034)	0.088** (0.034)
Auction Characteristic Controls			
Business	−0.035** (0.013)	−0.038** (0.013)	−0.037** (0.013)
Fancy Display	0.012** (0.003)	0.014** (0.003)	0.011** (0.003)
Business × Fancy Display	0.027* (0.013)	0.030* (0.013)	0.029* (0.013)
Shows Picture	−0.017** (0.002)	−0.018** (0.002)	−0.017** (0.002)
Same Shaft Type	0.094** (0.002)	0.094** (0.002)	0.094** (0.002)
Retail Price	−0.0002** (0.00001)	−0.0002** (0.00001)	−0.0002** (0.00001)
High Minimum Bid	0.047** (0.003)	0.046** (0.003)	0.046** (0.003)
3 Days Long	0.047** (0.006)	0.048** (0.006)	0.047** (0.006)
5 Days Long	0.024** (0.005)	0.025** (0.005)	0.024** (0.005)
7 Days Long	0.009 (0.005)	0.011* (0.005)	0.010* (0.005)
10 Days Long	0.003 (0.006)	0.005 (0.006)	0.003 (0.006)
Secret Reserve Used	0.034** (0.002)	0.035** (0.002)	0.036** (0.002)
New Clubs	−0.031** (0.002)	−0.032** (0.002)	−0.032** (0.002)
Buyitnow Used	−0.037** (0.005)	−0.038** (0.005)	−0.038** (0.005)
Constant	0.117** (0.009)	0.124** (0.009)	0.102** (0.009)
Observations	58501	58501	58501
R^2	0.17	0.17	0.17

Note: Robust standard errors in parentheses. Regressions include bidder block fixed effects.
*Significant at 5%.
**Significant at 1%.

improves by one, the chance that the bidder places a bid increases by only 0.06 percentage points.[11]

If bidders have strong concerns about being defrauded, they might also seek sellers who have the best available reputations. The second specification, reported in column 2 of Table 3, controls for *Best Positive Ranking*, a dummy variable that indicates whether the seller has one of the five best within-block ranks by reputation. The results are surprising. Such sellers are 1.6 percentage points less likely to receive a bid from the relevant bidder than a seller whose ranking is lower than five. Clearly, a seller with one of the best reputations is not guaranteed to do any better than sellers who have also received a good number of reports that they have behaved honestly in the past.

While these results suggest that bidders are not solely influenced by the seller's relative reputations, they do not mean that bidders do not care about a seller's reported history. Column 3 shows the results of a specification that controls for the within-block quartiles of the number of good reports received by the seller, using auctions where the seller has no positive reports as the reference group (recall that *Positive Q1* equals one for auctions where the seller has at least one good report but is still in the first within-group quartile). For the average bidder block, the first "quartile" contains auctions where the seller has 1–65 positive reports, the second quartile contains auctions where the seller has 66–331 positive reports, the third quartile contains auctions where the seller has 332–1252 positive reports, and the fourth quartile contains auctions where the seller has more than 1252 positive reports. These results show that reputation does have an effect on the bidder's choice, albeit a small one. Sellers for whom *Positive Q1* equals one are 1.8 percentage points more likely to receive a bid from the relevant bidder than sellers who have no reports. The marginal impact of having an even better reputation is not large. Sellers in quartile 2 are 0.6 percentage points more likely to receive a bid from the relevant bidder than sellers in quartile 1, sellers in quartile 3 are 0.7 percentage points more likely to receive a bid than sellers in quartile 2, and sellers in quartile 4 actually do 0.4 percentage points worse than sellers in quartile 3, though this difference is not statistically significant. A seller who has a few positive reports has a slightly better chance of receiving a bid from the relevant bidder than a seller who has no positive reports, and once a small indication of past honest behavior is present, having more reports relative to one's competitors barely enhances the chance of receiving a bid. These results suggest that sellers' relative reputations are not carefully scrutinized against each other, though bidders do prefer to see some evidence that the seller is honest.

Negative and neutral reports are rarely received, but they are also controlled for. The effect of having a higher percentage of negative or neutral reports, as controlled for by *Bad Report Ratio*, may be of some importance. In the first specification, a one percentage point increase in this ratio lowers the chance that a bid is received by 2.5 percentage points. The estimated effect is smaller and statistically insignificant in the other two specifications.

If searching for the most reputable seller is not the primary concern of bidders, what other factors might they consider? Naturally, most bidders look for the best deal. All three specifications control for *2nd Most Expensive* through *Cheapest*, leaving out *Most Expensive* as the reference group. Recall that auctions for which *Cheapest* equals one have relatively lower winning bids at the time that the relevant bidder places her first bid, while auctions for which *Most Expensive* equals one have the highest winning bids at this time. Bidders are clearly searching for the best price by placing bids in auctions that currently have lower winning bids than other auctions in their bidder block. Auctions for which *Cheapest* equals one are about 10 percentage points more likely to receive a bid than auctions in the most expensive group. Slightly more expensive auctions have a smaller advantage over the most expensive auctions – the “third most expensive” auctions are about 5 percentage points more likely to receive a bid than the most expensive auctions, and the “second most expensive” auctions are about 1 percentage point more likely. These estimates are statistically significant and robust across all three specifications.

Bidders have an even better chance of getting a good deal if they bid in an auction that ends soon, because there is less chance that they will be outbid later. The data show that bidders most often look for auctions where the current winning bid is relatively low, and the auction also about to end. Auctions that have less than five minutes remaining until they end are about 7 percentage points more likely to receive a bid than auctions that do not end until a later time. This effect is extremely strong for auctions that have lower winning bids at the time the bidder places her bid: this effect grows by 7 percentage points if *2nd Most Expensive* equals one, by 14 percentage points if *3rd Most Expensive* equals one, and by 9 percentage points if *Cheapest* equals one, relative to the most expensive auctions. These estimates are again robust across all three specifications, and the effects are extremely large. The most important factor in a bidder’s mind is clearly which auction provides the greatest chance to buy at the lowest possible price – if an auction ends very soon and the winning bid is low, it is very likely that a bidder will choose to place a bid in that auction.

Each specification controls for the same set of other auction characteristics, and the estimated impacts of these characteristics are similar across the specifications. If the seller runs a “business” as defined above, he is about 4 percentage points less likely to receive a bid from the relevant bidder, but sellers who use “fancy” descriptions of the clubs are about 1 percentage point more likely to receive a bid. Sellers who run businesses and who use fancy descriptions are about 3 percentage points more likely to receive a bid from the relevant bidder than sellers who run businesses but do not use enhanced descriptions. The display of pictures of the clubs, which should reassure bidders that the clubs exist and are not in poor condition, results in a decrease in the chance that the bidder bids in the auction by nearly 2 percentage points. Bidders are 9.4 percentage points more likely to place a bid in an auction if the clubs have the same type of shaft as the clubs sold in the first auction in which the bidder participates. More expensive clubs, as measured by their retail price are slightly less likely to receive a bid. Auctions that have one of the five highest minimum bids are about five percentage points more likely to receive a bid. This result is confusing, since we have seen that bidders seek lower prices. Bidders appear to prefer shorter auctions: examining the coefficient estimates for *3 Days Long* through *10 Days Long* shows that the chance that a bidder places a bid monotonically decreases as the auction length increases. Shorter auctions offer fewer opportunities for other bidders to outbid the relevant bidder. Auctions that use secret reserve prices, indicated by *Secret Reserve Used*, are about 3.5 percentage points more likely to receive a bid. *New Clubs* are about 3.2 percentage points less likely to be bid on than used clubs. Finally, auctions where the seller uses the "buy it now" option are about 3.8 percentage points less likely to receive a bid from the relevant bidder.

The next set of regressions looks more carefully at how bidders weigh the risk of being defrauded by a bidder who has no established reputation with the chance of getting the golf clubs for a cheaper price. The results of these regressions are reported in Table 4.[12] Previously we saw that sellers who have the best reputations within a bidder block do not do much better than sellers who have worse reputations, but still have at least some positive reports. Accordingly, the story is told more clearly by controlling for reputation by including a dummy variable indicating whether the seller has zero positive reports, and using auctions where the seller has at least one positive report as the reference group. Column 1 of Table 4 shows the estimate of a specification that is identical to that reported in column 3 of Table 3, except *No Positives* is used to control for reputation instead of *Positive Q1* through *Positive Q4*. The results from the two estimations are in fact nearly identical, suggesting that little or no bias is introduced by using this alternate specification.[13] Sellers who have no positive reports are 2.3 percentage points less likely than sellers who have at least one report to receive a bid from the relevant bidder, and the estimated magnitudes of the coefficients of all covariates other than the intercept differ from the estimates when *Positive Q1* through *Positive Q4* are included by at most two tenths of a percentage point.

In order to see how bidders balance the risk of being defrauded with the opportunity to buy at the lowest possible price, interaction terms between *No Positives* and the winning bid amount at *t* are added to the specification. The results of this estimation are reported in column 2 of Table 4. Having no reports

Table 4. Do Bidders Shop for a Better Deal?

	(1)	(2)
Reputation controls		
No positives	−0.023** (0.003)	0.010* (0.005)
Bad report ratio	−0.021 (0.012)	−0.034** (0.012)
Good deal controls		
2nd Most expensive	0.011** (0.002)	0.011** (0.002)
3rd Most expensive	0.054** (0.002)	0.057** (0.003)
Cheapest	0.104** (0.003)	0.112** (0.003)
5 Minutes left	0.073* (0.029)	0.074* (0.029)
5 Minutes left × 2nd most expensive	0.072 (0.038)	0.071 (0.038)
5 Minutes left × 3rd most expensive	0.140** (0.036)	0.139** (0.036)
5 Minutes left × Cheapest	0.090** (0.034)	0.086* (0.034)
Reputation – good deal interactions		
No positives × 2nd most expensive		−0.0003 (0.007)
No positives × 3rd most expensive		−0.037** (0.009)
No positives × cheapest		−0.088** (0.007)
Constant	0.123** (0.009)	0.122** (0.009)
Observations	58501	58501
R^2	0.17	0.18

Note: Robust standard errors in parentheses. Regressions also include as covariates the variables listed as "Auction characteristic controls" in Table 3, as well as bidder block fixed effects.
*Significant at 5%.
**Significant at 1%.

has a small positive impact on the chance that a seller receives a bid from the relevant bidder, and the results from the previous set of regressions are still present: bidders look for auctions where the current winning bid is relatively low, and where little time is left until the end of the auction. However, the interactions between *No Positives* and *2nd Most Expensive*, *3rd Most Expensive* and *Cheapest* show that the benefits to having a low current winning bid relative to other auctions in the bidder block are much smaller if the seller has no reports. Auctions for which *Cheapest* equals one (the auctions with the lowest current winning bids among those in the bidder block) are 11.2 percentage points more likely to receive a bid from the relevant bidder than auctions where the current winning bid is among the highest, but this effect is 8.8 percentage points smaller if the seller has no positive reports. Similarly, the slightly more expensive auctions for which *3rd Most Expensive* equals one are 5.7 percentage points more likely to receive a bid than the most expensive auctions, but this benefit falls by 3.7 percentage points if the seller has no reports. Bidders shop for the best deal, but they tend to ignore a potential good deal if the seller has yet to prove himself to be honest.

These results show that bidders tend to choose auctions that offer better chances to get a good deal, so long as the seller has at least some history of honest behavior. The final set of regressions, reported in Table 5, examine whether bidders seek the best chance at the best possible deal. Instead of controlling for the current winning bid using *2nd Most Expensive, 3rd Most Expensive* and *Cheapest*, the regressions incorporate *Lowest Winning Bid* through *5th Lowest Winning Bid*. Two specifications are estimated. The first is identical to the specification reported in column 1

Table 5. Do Bidders Shop for the Best Deal?

	(1)	(2)
Reputation controls		
No positives	−0.026** (0.003)	−0.006 (0.003)
Bad report ratio	−0.027* (0.012)	−0.037** (0.012)
Good deal controls		
Lowest winning bid	0.108** (0.007)	0.140** (0.009)
2nd Lowest winning bid	0.081** (0.008)	0.085** (0.008)
3rd Lowest winning bid	0.058** (0.007)	0.063** (0.008)
4th Lowest winning bid	0.048** (0.006)	0.050** (0.006)
5th Lowest winning bid	0.040** (0.006)	0.044** (0.007)
5 Minutes left	0.198** (0.013)	0.198** (0.013)
5 Minutes left × lowest winning bid	0.036 (0.053)	0.014 (0.053)
5 Minutes left × 2nd lowest winning bid	0.016 (0.053)	0.015 (0.053)
5 Minutes left × 3rd lowest winning bid	−0.030 (0.051)	−0.031 (0.051)
5 Minutes left × 4th lowest winning bid	−0.097* (0.045)	−0.097* (0.045)
5 Minutes left × 5th lowest winning bid	−0.076 (0.049)	−0.079 (0.049)
Reputation – good deal interactions		
No positives × lowest winning bid		−0.151** (0.010)
No positives × 2nd lowest winning bid		−0.065 (0.047)
No positives × 3rd lowest winning bid		−0.072** (0.011)
No positives × 4th lowest winning bid		−0.017 (0.016)
No positives × 5th lowest winning bid		−0.050** (0.014)
Constant	0.120** (0.009)	0.127** (0.009)
Observations	58501	58501
R^2	0.16	0.16

Note: Robust standard errors in parentheses. Regressions also include as covariates the variables listed as "Auction characteristic controls" in Table 3, as well as bidder block fixed effects.

* Significant at 5%.

** Significant at 1%.

of Table 4, except for the use of *Lowest Winning Bid* through *5th Lowest Winning Bid* instead of *2nd Most Expensive, 3rd Most Expensive* and *Cheapest* to control for the relative levels of the current winning bid. The results of this estimation are reported in column 1 of Table 5. The final specification adds interaction terms between *No Positives* and *Lowest Winning Bid* through *5th Lowest Winning Bid*. The results of this estimation are reported in column 2 of Table 5.

The specifications tell the same story, so only the results in column 2 are discussed. Bidders are much more likely to choose the auction that has the lowest winning bid amount at the time the choice is made. This auction is 14 percentage points more likely to receive a bid from the relevant bidder than an auction that is outside of the top 5 lowest current winning bids. As the seller's ranking by current winning bid improves, the chance that the seller receives a bid increases monotonically. The auction that has the fifth-lowest current winning bid is 0.6 percentage points less likely to receive a bid from the relevant bidder than the auction with the fourth-lowest bid, and the auction with the fourth-lowest bid is 1.3 percentage points more likely to receive a bid than the auction with the third-lowest bid, though these differences are not statistically significant. The auction with the second-lowest bid is 2.2 percentage points more likely to receive a bid than the auction with the third-lowest bid, and the auction with the lowest bid is 5.5 percentage points more likely to receive a bid than the auction with the second-lowest bid. These differences are statistically significant.

Interestingly, auctions that end soon are much more likely to receive a bid than auctions that are not, but the cheapest auction is no more likely to receive a bid if the auction is about to end. Auctions where there are only 5 minutes left in the auction are 19.8 percentage points more likely to receive a bid from the relevant bidder, but the cheapest auction is no more likely to receive a bid if it ends in the next five minutes. Also, the fourth and fifth cheapest auctions are actually much less likely to receive a bid if they end in the next five minutes. When the auction is the fourth cheapest and it is about to end, the benefits to having the fourth-lowest current winning bid fall by 9.7 percentage points, and when the auction is the fifth-cheapest and it is about to end, the benefits fall by 7.9 percentage points (though this effect is not statistically significant), more than canceling out the estimated gains to having these ranks. If an auction is about to end and there are three or four other auctions that currently offer a better chance at obtaining a lower price, the bidder will likely let the auction pass without placing a bid. Again, bidders are clearly trying to buy the golf clubs as cheaply as possible.

Bidders still appear to be hesitant to deal with sellers who have not established a reputation. They do not consider bidding in an auction if the seller has no positive reports, even if the auction offers the lowest price. The benefit to having the lowest current winning bid falls by 15.1 percentage points if the seller has no reports, completely eliminating the effect of having the lowest current winning bid. Similarly, the benefits enjoyed by the sellers with the second through fifth cheapest items are eliminated or severely mitigated. Bidders want to buy golf clubs as cheaply as possible, but they are only truly willing to consider buying from a seller if he has at least some reported history of honest behavior.

5. CONCLUSION

The Internet auction market that is supported by eBay is fascinating. It has grown without the support of formal contract enforcement, despite the fact that sellers have a large incentive to breach or underperform. In order for this market to function, bidders have to believe that most sellers plan on performing, or they would be unwilling to participate. This belief is strengthened by eBay's reputation system, which allows bidders to identify sellers who have reportedly performed in some past transactions. The analysis presented here looks at how bidders decide which auction to bid in when they have several to choose from. Bidders who make this choice have several factors to consider. Among the most important are the trustworthiness of the particular seller, and the price at which the good can be obtained. If bidders feel that there is a large risk of being defrauded, then they will be forced to pay careful attention to a seller's reputation. Even if other sellers run auctions where the good might be obtained for a lower price, the added risk might not be worth taking. Alternatively, if bidders are not as concerned about the risks involved, they will choose the auction that offers the best chance at obtaining the item at the lowest possible cost.

In fact, it is clear that bidders do not exclusively rely on a seller's reputation to help them make their decision. They do not bid more often in the auction of the seller with one of the best reputations, for example. Rather, a minimally established reputation is enough to convince bidders that a seller is honest. Bidders only want to see that the seller has at least a few positive reports. They then choose the auction that offers the greatest chance of obtaining the item they are shopping for at the lowest possible price. They are much more likely to place a bid in an auction if the winning bid at the time they make their decision is low relative to other auctions of the same item that they could possibly select, and if the auction is about to end so that other bidders have less of a chance to outbid them. This result is not surprising when one considers the findings of Livingston (2002), which shows that it only takes a few reports of past honest behavior to convince bidders that a seller is honest. The fact that bidders are also shown here to be easily convinced of a seller's good intentions, and that their primary concern is the search for a low price, is evidence that the market is operating efficiently despite the fact that sellers have an opportunity to defraud winning bidders.

NOTES

1. Figures are cited from eBay's press release announcing 2002 fourth quarter financial results. See http://www.shareholder.com/ebay/news/20030116–99663.htm

2. Resnick and Zeckhauser (2002) do find that sellers with highly established reputations receive larger returns than new sellers, using an experimental approach. However, in their investigation of whether the first few reports have an effect on bidder behavior, they regress the difference between the log of the final price and the log of the starting price against the number of positive reports held by the seller. Controlling for positive reports linearly also does not capture the severely decreasing returns nature of the benefits to having a better reputation.

3. The approach used to create the dataset introduces a clear sample selection problem into the analysis. Since the bidder blocks are formed around the moment a bidder places her first bid, the bidders are endogenously determining which auctions are included in the blocks. This approach excludes the decisions of other potential bidders who decided not to place a bid in any auction. It also excludes previous decisions of the bidders in the data, if they thought about placing a bid in a auction previously but elected not to at that time. The results to be presented should be considered with this problem in mind.

4. The natural choice to analyze this decision may seem to be a multinomial logit model, where the bidder decides which of the auctions within her choice set to participate in. However, this model is not appropriate because bidders can, and occasionally do, decide to bid in more than one auction within their bidder blocks.

5. Data were also collected from 183 auctions of Firesole irons that occurred between October 20th, 2000 and December 11th, 2000. These auctions are excluded from the data in order to focus on only one shopping period; however, including these auctions in the data has no effect on the qualitative results. Results from regressions using a dataset constructed from all 861 observations are available by request from the author.

6. Some auctions that finished on April 16th are missing. Because the first search was conducted on April 30th at approximately 4:00 PM EDT, auctions that finished on April 16th before 4:00 PM EDT are not in the data. Similarly, there is no data from auctions that finished in the late portion of the last day of the collection period. Figure 1 thus makes it appear that fewer auctions ended on the first and last days of the data collection period, though this is not necessarily true.

7. Power sellers are identified by an icon next to their username on their auction pages. To qualify, sellers must "meet and maintain a certain level of average gross monthly sales. If you have maintained the Bronze, Silver, Gold, Platinum, or Titanium average gross monthly sales levels for the past three months, you will qualify for the program. In addition, you are required to: Have at least 100 unique feedback results, 98% of which must be positive; Have an average monthly total listings of 4 for the past 3 months; Be in good standing by complying with eBay Listing Policies; and Keep your account current, by contacting bidders within three business days and upholding the eBay Community Values".

See http://pages.ebay.com/help/basics/f-powersellers.html. eBay stores can be maintained by any user. Through these stores, sellers can provide further contact information, and they can provide links to their other auctions.

8. This variable is somewhat subjective, but there are very few cases in the data where there was much question as to whether the presentation should be considered "fancy" or not.

9. High minimum bids will also be captured by the controls for the level of the winning bid at *t*, since this level is equal to the minimum bid if the auction has yet to receive any bids at *t*.

10. Sellers can set both publicly-known reserve prices (the minimum bid), and secret reserve prices. Bidders observe whether a secret reserve price is in use, but not the amount of the secret reserve price.

11. Recall that the best ranking is 1, so as the ranking increases the seller's reputation is relatively worse.

12. Since the estimated effects of the variables labeled "auction characteristic controls" in Table 3 are nearly unchanged from the previous set of regressions, they are not reported in order to save space. Full results are available from the author.

13. In fact, in all estimations that follow, controlling for the quartiles instead has no impact on the qualitative results, and the estimated coefficients of the other controls barely change, if they change at all.

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AN EXPERIMENTAL MARKET WITH NETWORK EFFECTS AND ONE SPONSORED SELLER

Sujoy Chakravarty

ABSTRACT

This paper studies product adoption as modeled by Katz and Shapiro (1986) in an experimental setting. Two sellers offer competing, incompatible technologies and two groups of buyers make purchase decisions sequentially in a two-stage game of complete information. Value to a buyer from purchasing a technology depends on the total number of buyers of that technology (installed base). There is mixed evidence that the results are qualitatively consistent with equilibrium predictions laid out in theory. Buyers of technology display behavior close to equilibrium predictions. However, the sellers in the laboratory do not exploit their installed bases significantly.

1. INTRODUCTION

This paper presents a laboratory experiment to examine the effects of a network of users on the pricing and adoption of a pair of competing technologies. There has been a rapid growth of new technologies in the areas of consumer durable goods, particularly electronics, in the last quarter century. Central to the markets for these technologies is the *network size* or the *installed consumer base*. This is simply the total number of consumers that use a particular technology. The benefits

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derived by the consumer due to a greater number of other users are referred to as *network externalities*, and they can even exceed the intrinsic utility provided by the product or service. The telephone is an oft-cited example of a technology whose benefits arise almost solely from network externalities. Having a telephone is not particularly useful if very few people use telephones.

One reason that network externalities have been of interest to economists is that they can lead to a condition described as a "lock in" or "path dependency." A lock in occurs when a particular technology emerges as a standard and remains one for reasons other than the quality of the technology. The standard QWERTY keyboard design has been cited as a common example of a lock in. Superior keyboard layouts have subsequently been developed, but they have never succeeded in undermining QWERTY's dominance. David (1985) explores the market for keyboard designs. According to his study, a large installed base of users for QWERTY and the network externalities that develop as a result, create an incentive for non-users to adopt this inferior, "locked in" technology even when more efficient keyboard designs (the Dvorak keyboard[1] for example) exist.

Computer operating systems provide a more contemporary example of lock in. Lopatka and Page (1995), identify network externalities as the main source of Microsoft's monopoly power in this sector. Microsoft sells applications software in competition with independent software vendors. However it also has a large installed base of customers for its operating systems MS-DOS and Windows. The presence of this network has allowed the software giant to make its applications software compatible with only Microsoft operating systems, thus adversely affecting market shares of the other independent software providers.

Arthur (1989) presents a simple dynamic model of technology adoption which has agents entering sequentially and stochastically and adopting one of two technologies with equal probability.[2] In the increasing returns to adoption (positive network externality) case, the difference between the installed bases of the technologies may provide an incentive for all agents to adopt one or the other, leading to a situation of lock-in. Katz and Shapiro (1985) on the other hand use the concept of rational expectations fulfilled equilibrium in their model of network externalities. Their model provides an important insight into a market with network externalities, i.e. – *there exist multiple fulfilled expectation equilibria, where if consumers expect a firm to be dominant in the future, they are willing to pay more for its product and consequently make it the market leader*. Much of the subsequent literature in this area makes use of this simple but powerful result.

Katz and Shapiro (1986) study industry evolution in the presence of network externalities by providing a simple game theoretic model, with two sellers who determine prices for two incompatible technologies. In this technology adoption model, property rights or "sponsorship" are central to industry evolution in the presence of significant network externalities.[3] Farrell and Saloner (1986) explore how consumers choose between two competitively supplied incompatible technologies. In this situation, the market can be biased either for or against new technologies, depending on variables like the date of new product introduction, the relative costs of the two technologies, and the size of the installed base of the incumbent technology. Katz and Shapiro (1992) extend Farrell and Saloner (1986) and study the introduction of a new product in a market with network externalities. Regibeau and Rockett (1996) extend the work of Farrell and Saloner (1985, 1986) and Katz and Shapiro (1992) and examine the process of setting standards in an industry with network externalities. An important result from their model is that compatibility speeds up the introduction of the first generation of the product but increases the delay before the second generation is introduced. Choi and Thum (1998) extend Katz and Shapiro (1986) and analyze the relationship between market structure and the timing of technology in the presence of network externalities. Compared to the socially optimal outcome, they find that there is too little waiting by the first generations of consumers when there is a superior technology on the horizon.[4]

Though there is a large volume of largely interrelated theoretical literature on network externalities, there are relatively few empirical studies that deal with this phenomenon. Gandal (1994) uses hedonic pricing to test for the presence of direct network externalities in the PC spreadsheet market and finds that the dominant *LOTUS* compatibility standard commands a price premium. Brynjolffson and Kemerer (1996) use pricing data from DataQuest and International Data Corporation on spreadsheet software for approximately the same period as Gandal (1994), and find the presence of significant network externalities in this market. Majumdar and Venkataraman (1998) study the adoption of new technology by telecommunications firms and find that network effects are significant in explaining the level of adoption of new switching technology among local exchange carriers. Chakravarty and Tomlinson (2002) analyze IDC data on word processing software and find the presence of significant network externalities.

The dynamics of the problem of technology adoption by consumers are often not effectively captured by aggregative empirical studies using field data and it seems logical that controlled laboratory experiments may be one way to explore the subtleties of adoption behavior in the presence of demand side economies that occur due to the network. Though coordination games, which have been used extensively in modeling technology choice for buyers have been studied experimentally, there has been almost no attempt to study the interaction between buyers and sellers in a market characterized by network externalities.[5] Etziony and Weiss (2002) study only the consumer side (no sellers, the price is given exogenously) of a one stage network market for one good, where buyers' value for the good increases as the number of buyers of the good increases. They obtain the result that the buyers coordinate better on one technology if they have different (but monotonic in the number of consumers) value schedules than if they have identical value schedules. Though Ruebeck et al. (2002) and Bergstrom and Miller (1999) propose classroom experiments on network externalities and standardization, this work is the first to report a series of controlled laboratory experiments on network externalities that use both buying and selling agents in a posted offers market.[6]

The experimental sessions reported here operationalize the *one-sponsored seller* case from Katz and Shapiro (1986) in the laboratory. There is mixed support for Katz and Shapiro's (1986) theoretical results. Almost three quarters of stage 1 buyers purchase the more expensive sponsored technology when it credibly promises to dominate the market in stage 2. Later arriving buyers buy the technology that enjoys the larger installed base from stage 1 over 90% of the time. In the third treatment, sellers of the sponsored technology use penetration pricing in half the periods and take stage 1 losses to establish their technology. These stage 1 losses are often higher in the laboratory than those predicted by theory. However, in contrast to theoretical predictions, the sponsored sellers in the laboratory do not exploit their stage 1 installed bases significantly. This last result supports the observations from Chakravarty (2002), which reports experimental sessions on markets with network externalities in which both sellers enjoy strict property rights over their technologies.[7]

2. THEORETICAL BACKGROUND

Katz and Shapiro (1986) guide the experimental design. Their theoretical model is presented below. There are two technologies, A and B, and two stages or generations of consumers ($t = 1, 2$) with N_t homogenous consumers in period t. We refer to t as *stages* and not *periods* (as is done in the game theory literature), as a period refers to one repetition of the two-stage game in the experimental sessions. Consumers in this framework have completely inelastic demands every stage for one unit of a good. There are two technologies A and B from which she can choose, and the prices of these technologies are given endogenously as p_t and q_t respectively. The framework here is of a single product network and not the hardware/software paradigm that has been explored in some later theoretical work (e.g. Church & Gandal, 1993). Each technology here is embodied in a single good A or B and we may refer to these as either goods or technologies. I have in the course of this paper used the two terms interchangeably. The benefit a consumer derives from a technology depends on how many other consumers ultimately buy the same technology. Thus, the extent of the consumption externality depends only on the ultimate size of the network. Let x_t and y_t ($t = 1, 2$) represent quantities purchased of technologies *A* and *B* respectively, in stages 1 and 2. The net benefit to a consumer from adopting technology *A* in stage *t* is

$$v_A = v(x_1 + x_2) - p_t \tag{1}$$

The net benefit to a consumer adopting technology *B* in stage *t*, is

$$v_B = v(y_1 + y_2) - q_t \tag{2}$$

The model assumes that the technologies are incompatible, which is why gross consumption benefits depend only on the number of consumers purchasing the same technology. Consumers are homogenous and have the same value function $v(\cdot)$.

Firms *A* and *B* produce these two technologies with marginal costs c_t and d_t. Assume $\Delta_t = c_t - d_t$ where $t = 1, 2$. Marginal costs for both technologies are constant within a stage but may vary across stages. Technology *B* is sponsored whereas technology *A* is not. An example of such a situation is *B* having patent protection and *A* no longer being subject to one.[8] The non-sponsorship of *A* implies that it is priced at cost in either stage of this two-stage interaction, i.e. $-p_t = c_t, \forall t$.[9]

The firms are assumed to be risk neutral. The market evolves as a game of *complete information*. All buyers know about the common value function, each seller's costs and that technology *A* is priced at cost. The sellers know each other's costs, the buyers' common value function for the two technologies and that seller *A* prices at marginal cost. Figure 1 illustrates the time line of the technology adoption game.

The technology adoption model uses the concept of a subgame perfect Nash equilibrium (SPNE). The timeline of decisions for this game is illustrated in Fig. 1. Given that all consumers are identical and all of them can affect network size by their purchase decision (i.e. we do not assume a continuum of consumers) there are no interior equilibria.[10]

Given the "no-switch" conditions for the consumers (see note 10) there may be numerous equilibria (including mixed strategy equilibria which are not examined in the analysis) in the technology adoption model. Given that consumers are identical, Katz and Shapiro (1986) assume that buyers in stage *i* can coordinate their decisions to choose the Pareto dominant outcome. They compare $v(N_1 + N_2) - p_i$ with $v(N_2) - q_i$ and coordinate to the action that gives them higher net surplus. This coordination assumption lets us treat each consumer group (i.e. the group of consumers buying in the 1st stage or the group buying in the 2nd stage) as a "single representative consumer." The game tree is shown in Fig. 2, which illustrates the payoffs to each group. Using Pareto dominance as a tool for equilibrium selection

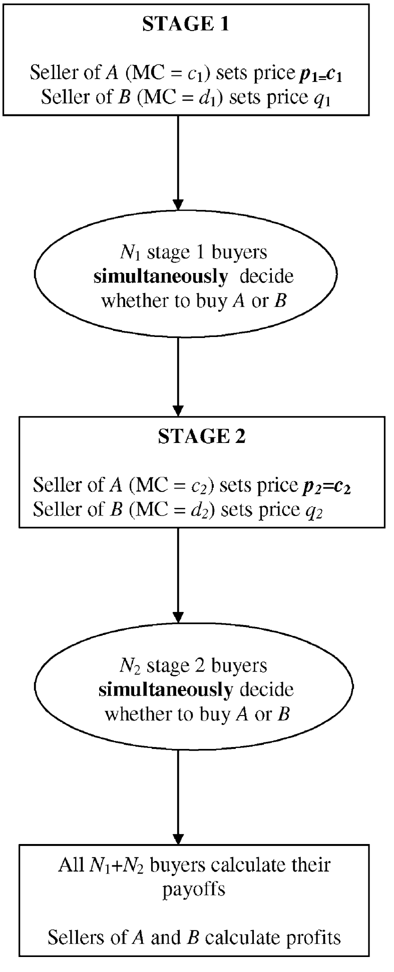

Fig. 1. Timing of Decisions.

has been used by many studies on coordination games and seems reasonable in this context.[11]

Following Katz and Shapiro (1986) let v_b stand for $v(N_1 + N_2)$ and v_1 and v_2 stand for $v(N_1)$ and $v(N_2)$ respectively. Given stage 1 sales, the sellers play Nash strategies in stage 2 prices. This implies that each seller is prepared to go down to his marginal cost in order to compete with his rival. The technology that can offer the buyers the highest surplus wins all stage 2 sales and its price is set to marginally beat the other technology.

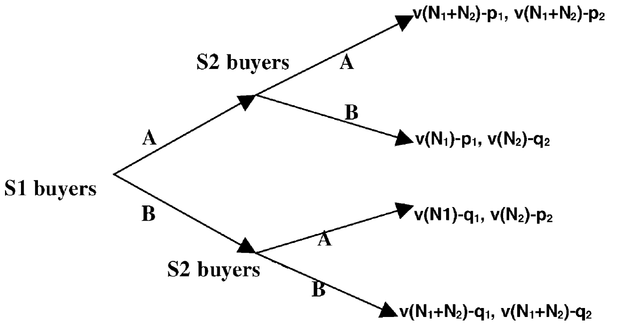

Fig. 2. Game Tree of Buyers' Decisions.

In the case where the stage 1 winner wins stage 2 we have,

$$v_2 - v_b \leq \Delta_2 \leq v_b - v_2 \tag{3}$$

Thus, If *B* is adopted (i.e. it "wins") in stage 1, then its first stage and second stage maximum prices are given as c_1 and $v_b - v_2 + c_2$ respectively.[12] The expression for its profit from winning both stages is given below.

$$\Pi_{BB} = N_1(c_1 - d_1) + N_2(v_b - v_2 + c_2 - d_2) = N_1\Delta_1 + N_2(v_b - v_2 + \Delta_2) \tag{4}$$

As long as $\Pi_{BB} \geq 0$, firm *B* would prefer to win in both stages rather than drop out. This expression may be positive even if technology *B* is costlier to produce in both the stages of the game, i.e. $\Delta_1 < 0$ and $\Delta_2 < 0$. The reason is that the seller of *B* is willing use penetration pricing in order to build up an installed base, while the seller of *A* is unwilling take stage 1 losses in order to establish its technology.

In the case where *B* wins in stage 2 regardless of stage 1 outcome, we have,

$$v_b - v_2 < \Delta_2 \tag{5}$$

The maximum prices that firm *B* can charge are given by $v_b - v_1 + c_1$ and $v_b - v_1 + c_2$ in stage 1 and stage 2 respectively. *B*'s total profit when it wins both stages is given by,

$$\Pi_{BB} = N_1(v_b - v_1) + N_2(v_b - v_2) + N_1\Delta_1 + N_2\Delta_2 \tag{6}$$

If *A* wins stage 1, $\Pi_{AB} = N_2(v_2 - v_b + \Delta_2)$ gives *B*'s profit. *B* wants to win in the first stage if and only if,

$$\Pi_{BB} \geq \Pi_{AB} \Rightarrow N_1(v_b - v_1 + \Delta_1) + 2N_2(v_b - v_2) \geq 0 \tag{7}$$

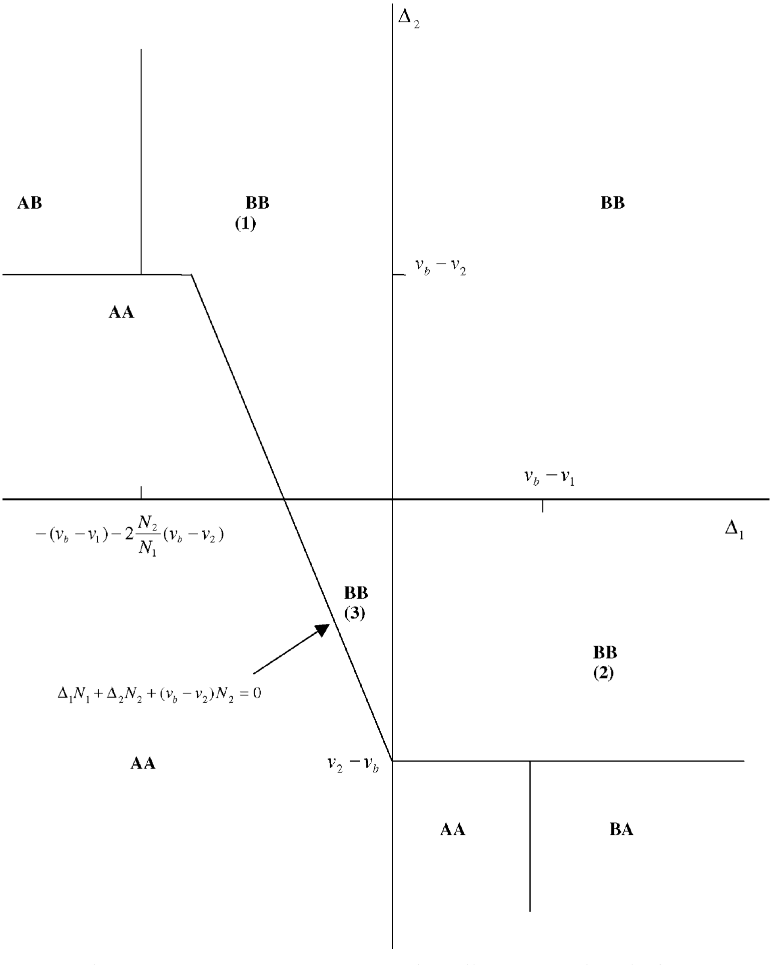

Fig. 3. Market Outcomes: One Sponsored Seller. Reproduced from Katz and Shapiro (1986).

Figure 3 (Fig. 4 in Katz & Shapiro, 1986) shows different market outcomes in equilibrium. Here, the *x*-axis represents the cost differential (Δ_1) between *A* and *B* in stage 1, and the *y*-axis represents the cost differential in stage 2 (Δ_2). The capital letters denote the adoption patterns obtained in equilibrium under different cost regimes. The lack of symmetry in the figure is due to the presence of one sponsored and one non-sponsored seller. Notice that because seller *B* can invest in an installed base, it is adopted more often than the generic technology *A*. An

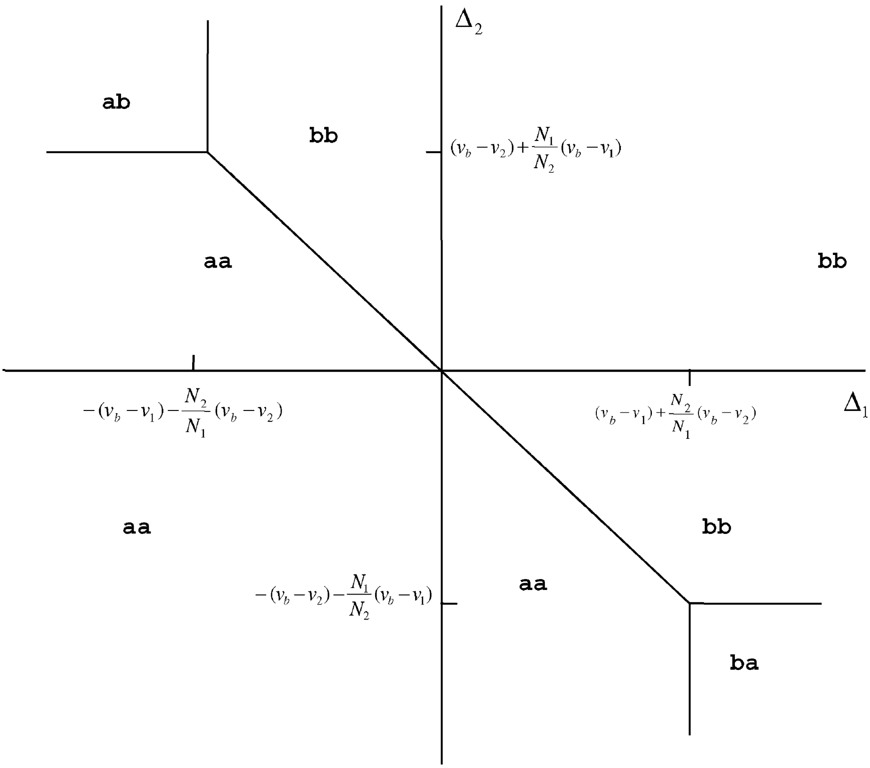

Fig. 4. Socially Optimal Outcomes: One Sponsored Seller. Reproduced from Katz and Shapiro (1986).

interesting phenomenon is observed in the third quadrant, namely that technology B is adopted in both stages even though its marginal cost is higher than A's marginal cost in both stages.

The expressions for total social surplus (the maximum possible gains from trade) for different adoption patterns are as follows,

$$W_{AA} = (N_1 + N_2)v_b - c_1 N_1 - c_2 N_2 \tag{8}$$

$$W_{BB} = (N_1 + N_2)v_b - d_1 N_1 - d_2 N_2 \tag{9}$$

$$W_{AB} = N_1 v_1 + N_2 v_2 - c_1 N_1 - d_2 N_2 \tag{10}$$

Here AA implies that A is adopted in both stages. Likewise BB implies standardization on B. To get which of the standardization outcomes yields higher social welfare, $W_{BB} - W_{AA} = \Delta_1 N_1 - \Delta_2 N_2$ is calculated. If this expression is less than

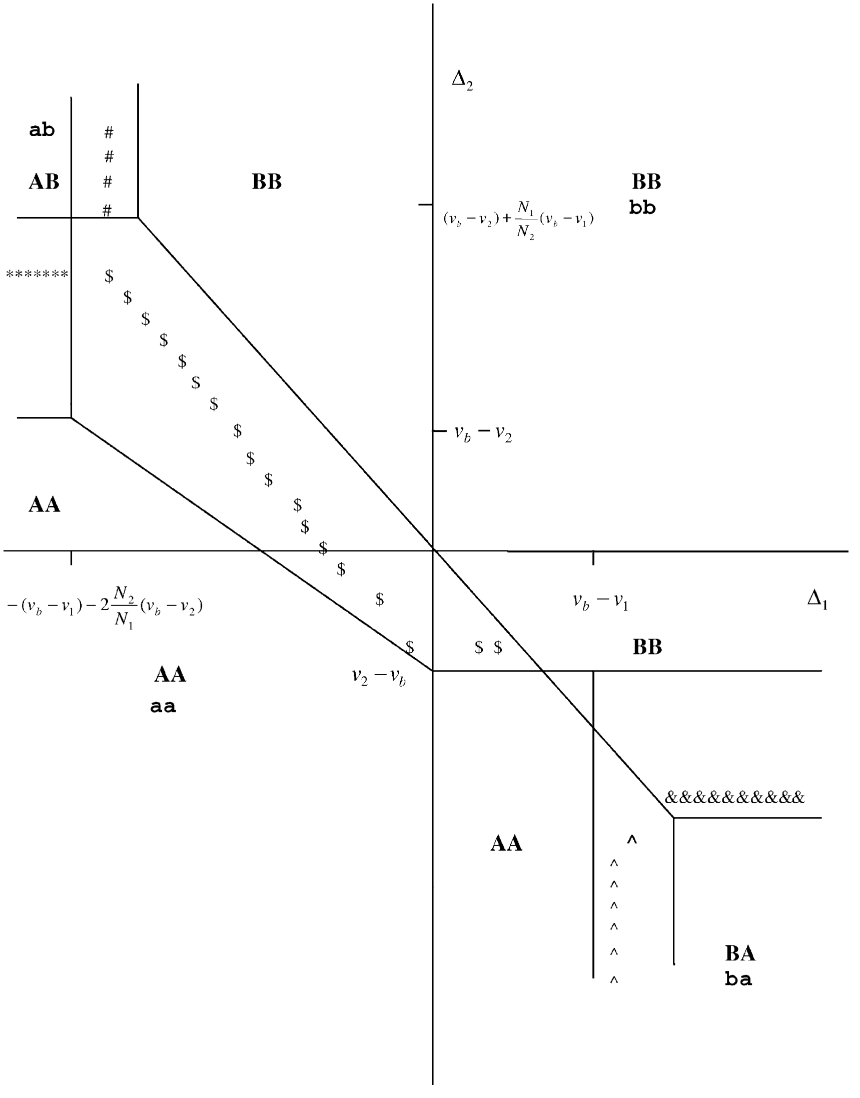

Fig. 5. Market Outcome vs. Social Optimum: One Sponsored Seller. Reproduced from Katz and Shapiro (1986).

zero then standardization on *A* yields higher surplus compared to standardization on *B*. On comparing the standardization outcomes with the stranding outcomes we get

$$W_{AA} - W_{AB} > 0 \Rightarrow \frac{N_1}{N_2}(v_b - v_1) + (v_b - v_2) > \Delta_2 \tag{11}$$

A similar line of argument shows that

$$W_{BB} - W_{AB} > 0 \Rightarrow \frac{N_2}{N_1}(v_b - v_2) + (v_b - v_1) > \Delta_1 \tag{12}$$

Figure 4 (Fig. 2 in Katz & Shapiro, 1986) shows the socially optimal outcome for all possible values of Δ_1 and Δ_2. Since the problem is completely symmetric, the same type of analysis also holds for the case in which $\Delta_1 > 0$ and $\Delta_2 < 0$.

The private (equilibrium) outcome may lead to "stranding" or non-standardization when standardization is optimal. Even if standardization occurs, it may not be the socially optimal outcome. Figure 5 (Fig. 5 in Katz & Shapiro, 1986) compares the market equilibrium and the socially optimal outcomes. The upper case letters indicate the equilibrium adoption patterns while lower case letters indicate the social optima. The areas in the figure that are marked with $*$ indicate that the equilibrium outcome makes for stranding (*AB*) when standardization (*aa*) is optimal. The reverse too is sometimes the case and is illustrated in the area marked with #, where standardization (*BB*) occurs and stranding (*ab*) is optimal.

There is a general bias towards the sponsored technology. The area marked $ shows that the sponsored technology *B* is adopted in both stages (*BB*) when it is optimal to adopt *A* (*AA*). The most extreme form of this is the case in which *B* is costlier in both stages. Here the consumers adopt *B* because the sponsored seller builds up an installed base by penetration pricing in stage 1 and creating network externalities that make the rival technology less attractive (this is referred to by Katz & Shapiro, 1986, as the "weakened rival effect").

3. EXPERIMENTAL DESIGN

3.1. Environment and Procedures

Each session uses nine subjects, four of whom are stage 1 buyers and four are stage 2 buyers. Each repetition of the two-stage game within a treatment is a period. A ninth subject is a seller of technology *B*. The experimenter provides the other technology (*A*) at a fixed price (equal to its marginal cost) in both stages of the game. The instructions emphasize that the price of *A* is fixed and no action on the part of the buyers or the seller of B can alter it. To approximate a game of *complete information* the sellers know the buyers' (identical) value function for the goods and the other seller's costs, while the buyers know the sellers' production costs in every period and are aware that all the buyers have identical values.[13]

Buyers and sellers interact through a computer program that uses a web browser interface. The experimental instructions in the appendix explain how this program works. This market operates for several periods in each experimental session (see Table 2). At the beginning of each period, the four stage 1 buyers, four stage 2 buyers and the seller of B are randomly picked by the program from among the participants. This randomization is done in order to minimize repeated game effects that would arise if one person were the seller throughout (the theoretical model assumes one shot interaction). At the start of the period, *all* subjects see the sellers' costs in both stages and the buyer value schedule on their computer screens. Both sellers submit a (stage 1) price, which is posted on the screens of all participants. The stage 1 buyers then make their purchase decisions. After the four buyers have submitted their choices, these are posted on the interface for all participants to see. The sellers then enter their stage 2 prices, which are likewise seen by all. The stage 2 buyers now choose the technology they want to buy. At the end of the period, the program calculates buyer and seller profits and displays them to the subjects. The computer also keeps a cumulative total of profits for a subject over all periods in a session, at the bottom of his screen. Please note that in the instructions the two technologies have been referred to as "goods" which is accurate given that the network is for a single product. Subjects use Table 1 to calculate their value for either technology. This table is based on the linear function

$$v(N) = 10 + 5N. \tag{13}$$

Table 1. Buyer's Values.

No. of Buyers Who Buy the Same Good (Including You)	Value
1	15
2	20
3	25
4	30
5	35
6	40
7	45
8	50

Table 2. Design Parameters.

Sessions/No. of Periods	Stage	Marginal Cost (*A*)	Marginal Cost (*B*)	Equilibrium Outcome	Maximum Price (*B*) in Equilibrium	Maximum Seller *B* Profit in Equilibrium (Total)	Minimum Buyer Profits in Equilibrium	Socially Optimal Outcome
Treatment 1 (*PU0221A* (15),	1	28	32	*B*	48		2	*B*
PU0323C (18))	2	28	5	*B*	48	236	2	*B*
Treatment 2 (*PU0221C* (15),	1	20	15	*B*	20		30	*A* or *B*
PU0323B (18), *PU0327A* (21))	2	20	25	*B*	40	80	10	*A* or *B*
Treatment 3 (*PU0221D* (15),	1	10	14 (11)[a]	*B*	10		40	*A*
PU0323A (18), *PU0327B* (19))	2	10	12 (17)[a]	*B*	30	56	20	*A*

[a] Values in parentheses are marginal cost values from session *PU0327B*.

This is the value obtained by a subject when N buyers over both stages (including him) make the same technology choice as him. N represents the total number of buyers who purchase the same technology. A buyer's earning is the gross value (from Table 1) less the price of the technology he buys. Table 2 lists parameters for three forms (treatments) of the technology adoption game.

For each treatment it displays the session names along with the number of periods run, marginal costs of the technologies, the equilibrium predictions on price and adoption, the agent profits in equilibrium and the socially optimal adoption pattern.

The experimental sessions last between 90 and 120 minutes. The experimenter reads the instructions aloud while subjects follow along on their booklets. The session begins only after the subjects fully comprehend how to use their computers to buy and sell and how profits are calculated. For the experienced sessions, the instructions are not read aloud. Instead, participants are given a summary of instructions to read and refer to. The subjects are undergraduate students recruited from classes in the schools of Management and Liberal Arts at Purdue University. All the cost and value parameters are in units of laboratory currency (*Kroners*), which are converted to US$ at a rate which varies from session to session but is equal for all subjects within a session. All subjects can expect to make between US$15 and US$25 including a (fixed) $5 fee for showing up.

3.2. Treatments

In treatment 1 (the cost parameters are chosen from the area represented by *BB* and *bb* in the second quadrant of Fig. 5), the unsponsored technology (A) is cheaper in stage 1 whereas the sponsored technology (B) is cheaper in stage 2. We see that the perfect equilibrium has the seller of B pricing just below 48 in both the stages. This can be understood by referring to Table 1, which gives the values redeemed by buyers from buying a unit based on the total number of adopters of the same technology. Making the assumption that either *all* stage 1 consumers buy A or *all* stage 1 consumers buy B, the loss in network externalities for a stage 1 consumer from adopting B when A is going to be adopted in the second stage is $v(8) - v(4) = 50 - 30 = 20$. Seller B knows that he can win stage 2 sales as he can set a lower price than A, given that his stage 2 costs are lower than that of technology A. He also knows that stage 1 buyers know this. So if he sets any price up to 20 above technology A's price, buyers will be willing to buy B as they would get a higher return from the network given that all buyers in stage 2 buy B. In equilibrium the seller can price just below 48 (the same as in stage 1) in stage 2. Given that the stage 1 consumers have all chosen B, all stage 2 consumers purchase B. If they went for A instead, they would have to pay 28 for technology A plus a penalty of 20 in network benefits lost because they "stranded" the first stage consumers. In this case the seller of B makes a large profit by building up a network in stage 1 and exploiting it in stage 2. Buyers in both stages make very low profits in equilibrium. Notice that in this treatment, even if *all* stage 1 buyers buy A, seller B can still credibly promise to win stage 2 by setting a price less than 8.

Treatment 2 (the cost parameters lie on the line given by $\Delta_1 N_1 - \Delta_2 N_2 = 0$, in the second quadrant of Fig. 5) has the sponsored technology cheaper in stage 1 and more expensive in stage 2. In equilibrium, seller B prices just below technology A's price in stage 1 to build a customer base. It then raises its price in stage 2, taking advantage of the fact that the later arriving consumers stand to lose considerable network benefits by "stranding" the stage 1 consumers. In this case the seller of B does not make as high a profit as in treatment 1. Buyers in stage 1 do well compared to their counterparts in stage 2.

Treatment 3 (the cost parameters for this treatment lie in the area *BB* and *aa*, in the third quadrant of Fig. 5) represents the most interesting form of this game and investigates the case where network externalities override technological advantages of one product over another. Here technology B is more expensive to produce in both stages. Seller B's equilibrium strategy in this case is to undercut technology A's price and *take a first stage loss*, in order to build a customer base. His stage 2 strategy is to raise his price up to three times his stage 1 price because he now has an installed base of customers that he can exploit. Notice that the *PU0327B* session has different marginal costs for the seller of B but the same equilibrium prices and outcomes as the other two sessions.

The last column of Table 2, labeled the socially optimal outcome, represents the adoption pattern that entails the maximum possible gains from trade and is calculated using Eqs (8), (9) and (10). For treatment 1, the equilibrium (*BB*) outcome is also socially optimal. For treatment group 2 the equilibrium and non-equilibrium standardization outcomes yield identical (maximum) social surplus and for treatment group 3, the non-equilibrium standardization outcome (*AA*) yields a higher level of social welfare.

3.3. Hypotheses

This subsection details the specific hypotheses that I will test in the next section by using the data obtained from the experimental sessions. The first four hypotheses (H1–H4) test whether the data from the experimental sessions are qualitatively consistent with the predictions of Katz and Shapiro (1986).

H1. Stage 1 buyers in *treatment* 1 buy technology *B* even when it is more expensive.

This hypothesis tests whether stage 1 buyers exhibit "forward looking" behavior in treatments 1 and 3. Alternatively, if the consumers do not take into account *B*'s ability to take over the market in stage 2 regardless of their purchase decision in stage 1, they should buy the cheaper technology (*A*).

H2. The number of buyers in stage 2 of a certain technology is positively correlated with the number of buyers of the same technology in stage 1.

This is a direct test for the presence of network externalities. I use a logistic model to test whether controlling for its price, the number of units of a technology purchased in stage 1 positively impacts its choice probability among stage 2 buyers.

H3. There is a positive correlation between stage 1 sales and the stage 2 price for a particular technology.

This tests whether seller *B* exploits his network from stage 1. I use an OLS regression model of sellers' price in stage 2 to determine the extent of this exploitation.

H4. In *treatment* 3, the stage 1 price of *B* is below marginal cost.

The theory predicts that in stage 1 the seller of *B* prices considerably below her cost in this treatment and recoups her losses in stage 2 once their network is established. I investigate whether the sponsored seller (*B*) is willing to compete and sustain stage 1 losses in order to sponsor her technology.

H5. Prices and quantities sold do not differ significantly from the equilibrium predictions of Katz and Shapiro (1986) summarized in Table 2.

Since the Katz and Shapiro price and sale predictions are point predictions, it seems almost certain that H5 will not be satisfied for most of the data. However the deviation of actual play from predicted values is important to explore as it offers insights into behavior that may actually lead to refinements of the existing theory.

4. RESULTS

This section evaluates the prices and decisions observed in the experimental sessions in the light of the informal hypotheses presented in the last section. The next four subsections deal with these hypotheses in detail. In the statistical tests I have assumed that observations on prices or adoption choices in a period are independent of those in other periods. This is not an unreasonable assumption to make in this study where agent roles are shuffled every period. However, there may be learning effects carried over from one period to the next. The regression analysis has utilized lagged variables wherever possible in order to characterize these learning effects.

4.1. Hypothesis 1

This hypothesis is supported for treatment 1. In session *PU0221A*, *B*'s stage 1 price is higher than *A*'s in 13 out of 15 periods.[14] The average number of stage 1 buyers who buy *B* is 3.54 per period in these situations, indicating that buyers are forward looking and recognize the fact *B* has the cost advantage to be stage 2 leader.

4.2. Hypothesis 2

Figures 6, 7 and 8 indicate that the buyers' behavior in the laboratory strongly supports this hypothesis.

The graphs plot a frequency distribution of stage 1 outcomes (subgames) on the left axis and the average number of buyers who buy technology *B* every period on the right axis. The average number of units of *A* may be obtained by subtracting the average number of *B* from four. All the sessions within a treatment have been pooled together and the negatively sloped lines on the graphs indicate that more

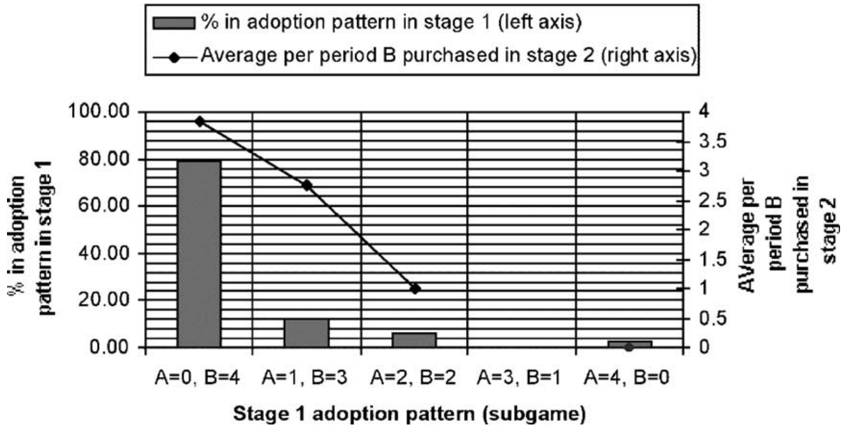

Fig. 6. Treatment 1 (Pooled) Buyers.

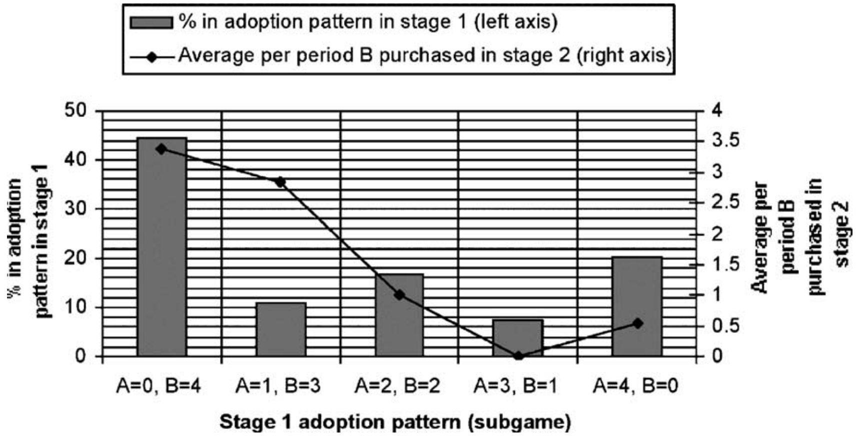

Fig. 7. Treatment 2 (Pooled) Buyers.

of a technology is purchased in stage 2 when it has a strong installed base from stage 1. A logistic model for stage 2 adoptions illustrates this relationship more formally. The model takes the form

$$pr(B_2) = \frac{e^{\alpha_0+\alpha_1 B_1+\alpha_3 P_2^B}}{1+e^{\alpha_0+\alpha_1 B_1+\alpha_2 P_2^B}} \tag{14}$$

$B_i (i = 1, 2)$ is the number of units of B purchased in stages 1 and 2. P_2^B represents the price charged by seller B in stage 2. This model is exploratory in nature and is

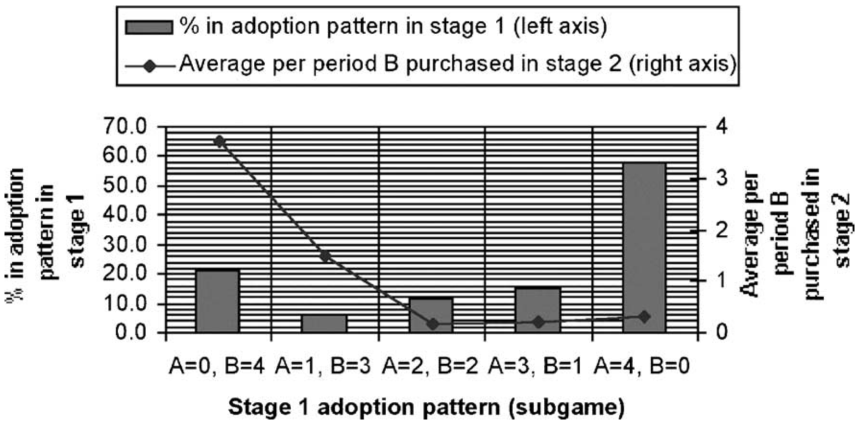

Fig. 8. Treatment 3 (Pooled) Buyers.

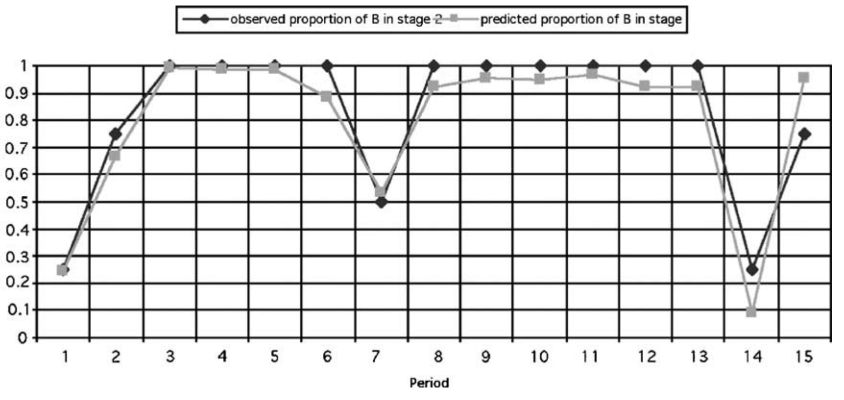

Fig. 9. Observed Proportion vs. Predicted Proportion *PU0221A* (Treatment 1).

not derived from a structural form. Since logistic models do not possess an absolute goodness-of-fit measure like the R^2, the predicted probabilities have been plotted against the observed proportions of *B* purchased in stage 2 (Figs 9–13).

The graphs indicate that this reduced form model fits the data well. Table 3 presents the regression coefficients from each of the sessions. Except for sessions *PU0221C* and *PU0221D*, the number of units of *B* purchased positively and significantly affects its choice probability in stage 2 at the 1% level of significance.[15]

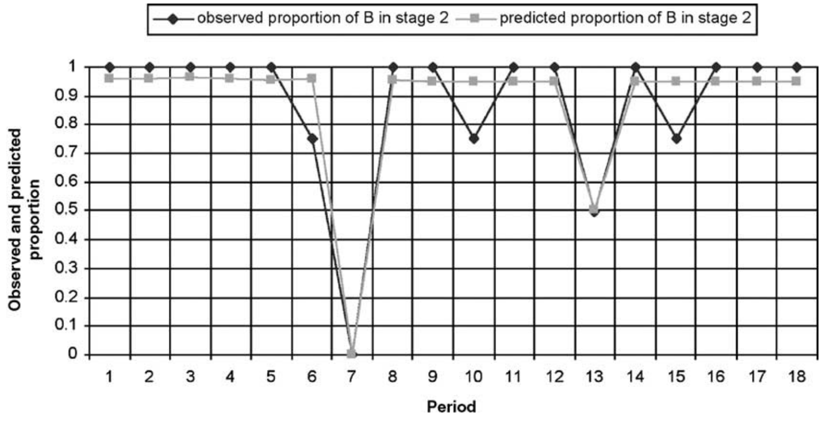

Fig. 10. Observed Proportion vs. Predicted Proportion *PU0323C* (Treatment 1).

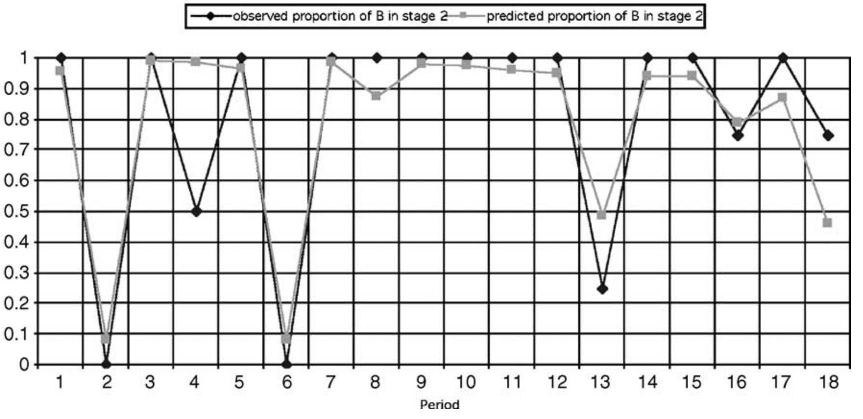

Fig. 11. Observed Proportion vs. Predicted Proportion *PU0323B* (Treatment 2).

4.3. Hypothesis 3

In all the treatments, seller B can charge a price that is significantly higher than its unit cost, provided it wins an installed base of more than 2 buyers in stage 1. Equation (15) models seller B's stage 2 price P_2^B as a function of the stage 1 installed base (B_1) and the lagged profit of the seller of B from one period ago (π_{t-1}^B).[16] T_t is the number of the period and is used to account for the time trend in the data.

$$P_2^B = \beta_0 + \beta_1 B_1 + \beta_2 \pi_{t-1}^B + T_t + \varepsilon \tag{15}$$

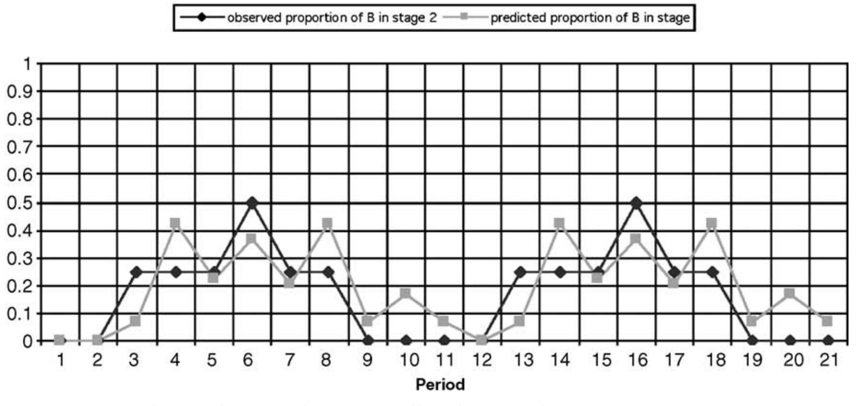

Fig. 12. Observed Proportion vs. Predicted Proportion *PU0327A* (Treatment 2).

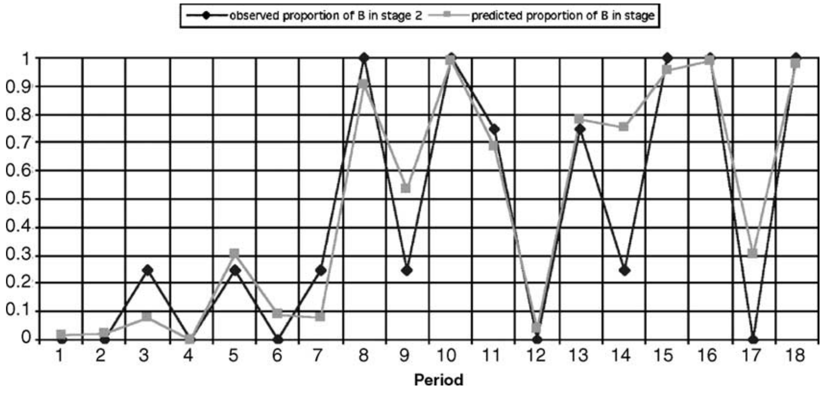

Fig. 13. Observed vs. Predicted Proportions *PU0323A* (Treatment 3).

Table 3. Logistic Regressions of Stage 2 Purchase Decision.

Variable	0221[a]	0323	0327
Treatment 1			
Intercept	−0.396 (4.495)	−8.375 (5.547)	
B bought in stage 1	2.408 (0.640)***	3.063 (1.191)***	
Stage 2 price of *B*	−0.192 (0.140)	−0.020 (0.1071)	
Akaike information criterion	39.422	35.728	
Schwartz criterion	45.705	42.558	
Number of observations	60	72	
Treatment 2			
Intercept	−43.491 (244)	2.362 (2.382)	23.548 (10.089)***
B bought in stage 1	14.641 (243.6)	2.165 (0.534)***	1.160 (0.445)***
Stage 2 price of *B*	0.904 (0.403)**	−0.2773 (0.089)***	−1.048 (0.423)***
Akaike information criterion	38.205	44.983	73.973
Schwartz criterion	44.488	51.813	81.266
Number of observations	60	72	64
Treatment 3			
Intercept	1.180 (13.039)	7.223 (2.808)***	
B bought in stage 1	20.810 (76.114)	0.966 (0.279)***	
Stage 2 price of *B*	−3.377 (12.689)	−0.805 (0.2701)***	
Akaike information criterion	16.047	50.475	
Schwartz criterion	21.400	57.305	
Number of observations	44	72	

Notes: Dependent variable = 1 if technology *B* is chosen, = 0 if technology *A* is chosen.
Standard errors are shown in parentheses. *, **, *** indicate that the coefficient estimate is significantly different from zero at the 10, 5, 1% level of significance.

[a] The model fit here is questionable as there may not be MLE due to the dependent variable taking on identical values over most of the dataset.

I have also estimated an alternative form with the number of units of B purchased in $(t-1)$, B_{t-1} replacing π^B_{t-1}. The two variables have not been used together as they are highly collinear. I expect that the coefficients on B_1 and B_{t-1} (π^B_{t-1}) positively impact the price of B in stage 2. Furthermore, I have estimated a form of the equation where B_1 is replaced by a dummy variable that takes the value 1 when the number of units of B bought in stage 1 is greater than two and 0 otherwise.[17] Table 4 presents the OLS regression results. I have pooled my data using session intercepts in order to increase the number of observations.[18]

The coefficient on *B bought in stage* 1 is insignificant in all the regressions except one of the formulations in treatment 2. Thus hypothesis H3 is very weakly supported by the data. Section 4.5.3 discusses briefly why sellers may not be exploiting their networks to the fullest extent. The number of observations for some of the OLS regressions is small. A few of the models have been estimated with only 17 observations. This may contribute to inflating standard errors and making coefficients appear less significant than they may otherwise be.

4.4. Hypothesis 4

The data from treatment 3 reveals that sellers of B charge a stage 1 price that is lower than unit cost 43% of the time over all sessions. In fact in all three sessions, the average observed markdown is greater than the theoretically predicted markdown. Table 5 presents the number of times sellers of B price below unit cost in each session in treatment 3. It also provides the observed average markdown (the average of the absolute difference between the observed price and the marginal cost in the periods when the seller uses penetration pricing) and the equilibrium markdown (the absolute difference between the equilibrium price and the marginal cost).

The average observed markdowns are higher than the theoretical predictions and indicate that sellers of B are willing to use penetration pricing in order to establish their technology in stage 1.

4.5. Hypothesis 5

Though the results are for most part qualitatively consistent with Katz and Shapiro (1986) as seen in the four earlier subsections, the observed behavior in the laboratory differs considerably from theoretical benchmarks. The next two subsections compare observed price and purchase decisions from stage 1 and stage 2 with theoretical point predictions and discuss the extent and probable causes of these deviations. Figures 14–21 display period by period, the purchase and pricing

Table 4. OLS Regression of Stage 2 Prices.

Variable								
	Treatment 1							
	Pooled With Session Intercepts							
B bought in stage 1		−0.517 (0.822)		−0.447 (0.792)				
Dummy for $B_1 > 2$						−1.252 (2.239)		−1.363 (2.169)
B bought in $(t-1)$		−0.131 (0.336)				−0.122 (0.335)		
Profit from *B* in $(t-1)$				−0.037 (0.033)				−0.039 (0.033)
Time		0.805 (0.158)***		0.916 (0.187)***		0.789 (0.152)***		0.913 (0.185)***
PU0221A		26.509 (3.829)***		27.444 (3.378)***		25.867 (3.267)***		27.281 (3.016)***
PU0323B		22.818 (3.637)***		21.382 (2.882)***		22.234 (3.146)***		21.104 (2.366)***
R^2		0.55		0.57		0.55		0.57
No. of observations		31		31		31		31
	Treatment 2							
	0221C				Pooled 0323 and 0327 With Session Intercepts			
Intercept	33.869 (1.741)***	34.009 (1.654)***	34.386 (1.055)***	34.426 (1.103)***				
B bought in stage 1	0.258 (0.306)	0.209 (0.323)			1.839*** (0.523)	0.432 (0.464)		
Dummy for $B_1 > 2$			0.516 (0.613)***	0.417 (0.645)***			4.683 (2.055)**	−0.653 (1.654)
B bought in $(t-1)$	−0.096 (0.086)		0.209 (0.323)		−0.952 (0.308)***		−0.836 (0.355)**	
Profit from *B* in $(t-1)$		−0.017 (0.016)	−0.096 (0.086)	−0.017 (0.016)		0.179 (0.064)***		0.211 (0.066)***
Time	0.037 (0.051)	0.036 (0.052)	0.037 (0.052)	0.036 (0.052)	0.511 (0.116)***	−0.0002 (0.186)	0.471 (0.127)***	−0.055 (0.188)
PU0323B					22.983 (2.039)***	22.892 (2.657)***	24.871 (2.049)***	24.837 (1.851)***
PU0327A					24.782 (1.368)***	18.442 (3.082)***	23.626 (1.035)***	25.560 (1.257)***
R^2	0.22	0.22	0.22	0.22	0.55	0.55	0.46	0.46
No. of observations	14	14	14	14	37	37	37	37
	Treatment 3							
	Pooled With Session Intercepts							
B bought in stage 1		−0.456 (0.984)		−0.68 (1.005)				
Dummy for $B_1 > 2$						0.327 (3.619)		−0.238 (3.710)
B bought in $(t-1)$		−0.438 (0.534)				−0.436 (0.536)		
Profit from *B* in $(t-1)$				0.167 (0.169)				0.144 (0.171)
Time		0.188 (0.263)		0.289 (0.287)		0.159 (0.261)		0.240 (0.285)
PU0221D		18.964 (3.515)***		16.172 (3.481)***		17.521 (3.448)***		15.757 (3.447)***
PU0323A		11.34 (3.710)***		11.026 (3.519)***		10.784 (3.684)***		10.266 (3.473)***
PU0327B		18.666 (3.35)***		17.518 (3.556)***		18.875 (3.368)***		17.896 (3.592)***
R^2		0.24		0.23		0.24		0.24
No. of observations		45		45		45		45

Notes: Dependent variable = Stage 2 price of *B*.
Standard errors are shown in parentheses. *, **, *** indicate that the coefficient estimate is significantly different from zero at the 10, 5, 1% level of significance.

Table 5. The Number of Times Seller *B* Prices Below Cost in Stage 1 of Treatment 3 and the Markdowns.

Treatment 3 (Total Number of Periods)	Number of Times $Price_B < MC_B$	Observed Average Markdown for *B* $\lvert Price_B\text{-}MC_B \rvert$	Equilibrium Markdown for *B*
PU0221D (15)	6 of 15	4.83	4
PU0323A (18)	10 of 20	4.1	4
PU0327B (19)	7 of 19	1.58	1

outcomes from all the sessions. The graphs show the observed prices for good *B* as well as the optimum upper bounds for these prices.[19] The graphs also show the number of units of the sponsored good *B* sold in both stages of each period.

4.5.1. Stage 1

In treatment 1 we have two sessions *PU0221A* and *PU0323C*. Here the sponsored technology *B* is less efficient (higher marginal cost) in stage 1 and much more efficient in stage 2. In equilibrium, the seller can price the good just below the equilibrium upper bound of 48 and use stage 1 buyer expectations regarding stage 2,

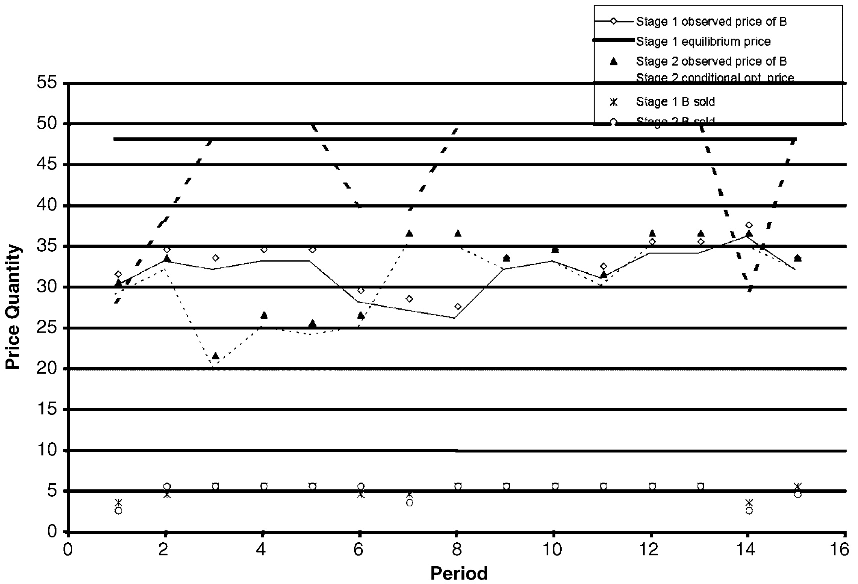

Fig. 14. Session *PU0221A* Observed Outcomes vs. Equilibrium Outcomes.

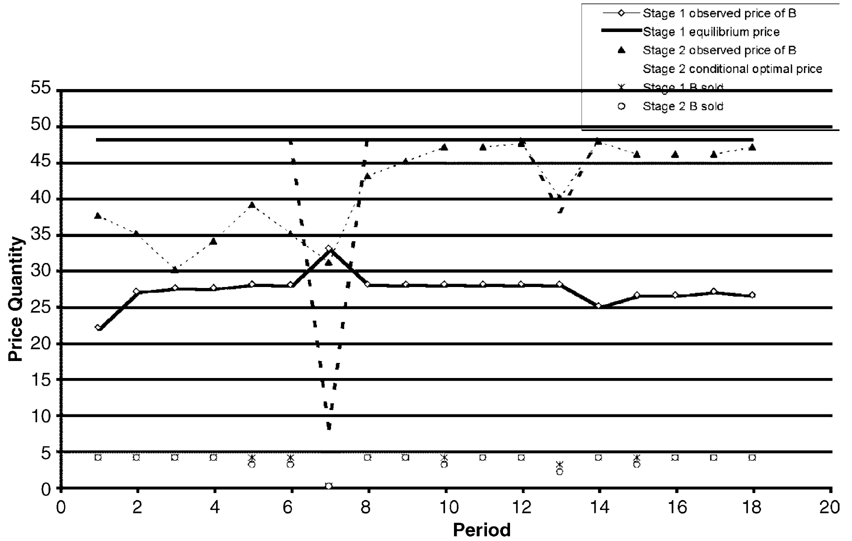

Fig. 15. Session *PU0323C* Observed Outcomes vs. Equilibrium Outcomes.

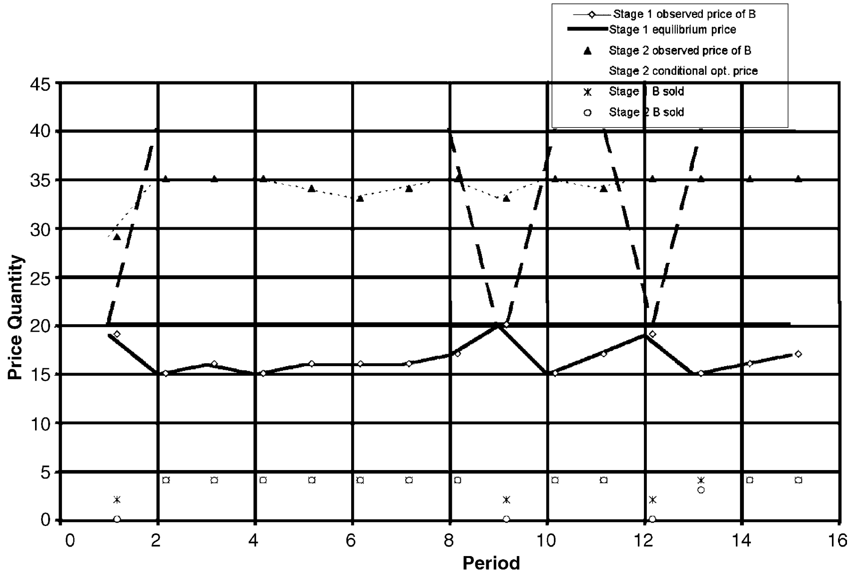

Fig. 16. Session *PU0221C* Observed Outcomes vs. Equilibrium Outcomes.

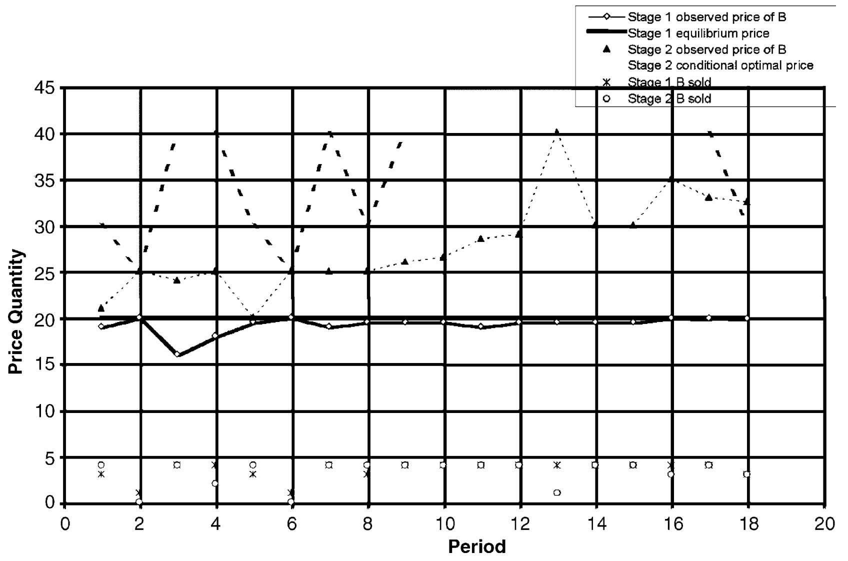

Fig. 17. Session *PU0323B* Observed Outcomes vs. Equilibrium Outcomes.

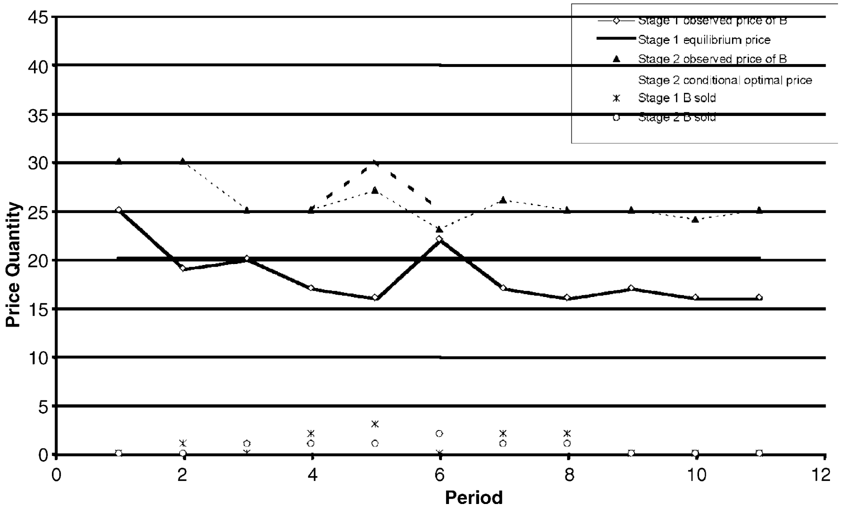

Fig. 18. Session *PU0327A* Observed Outcomes vs. Equilibrium Outcomes.

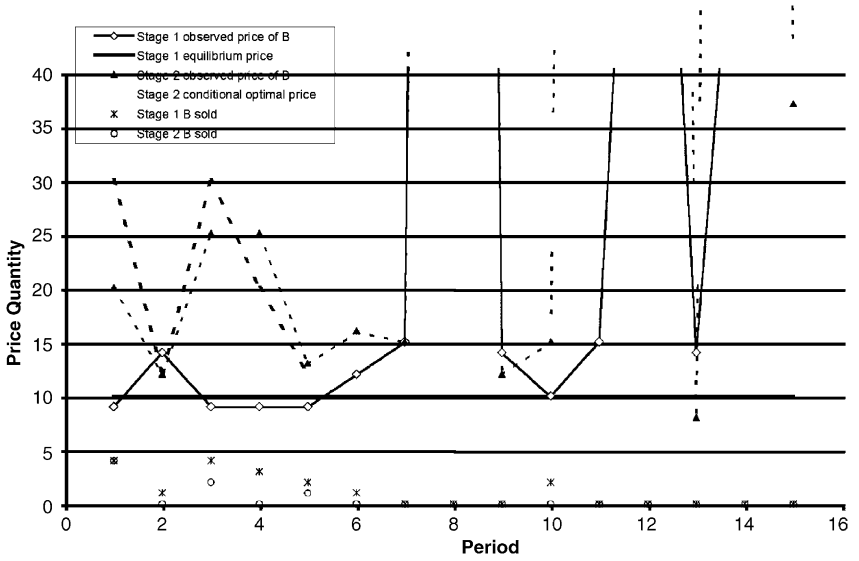

Fig. 19. Session *PU0221D* Observed Outcomes vs. Equilibrium Outcomes.

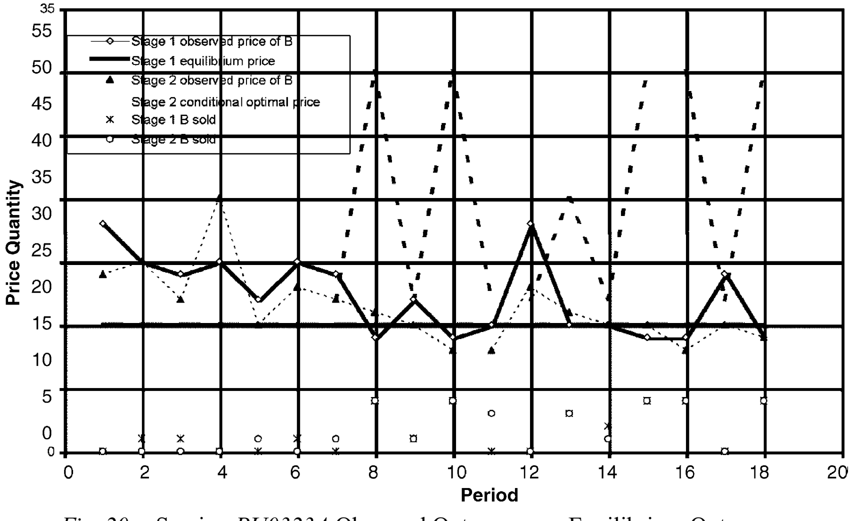

Fig. 20. Session *PU0323A* Observed Outcomes vs. Equilibrium Outcomes.

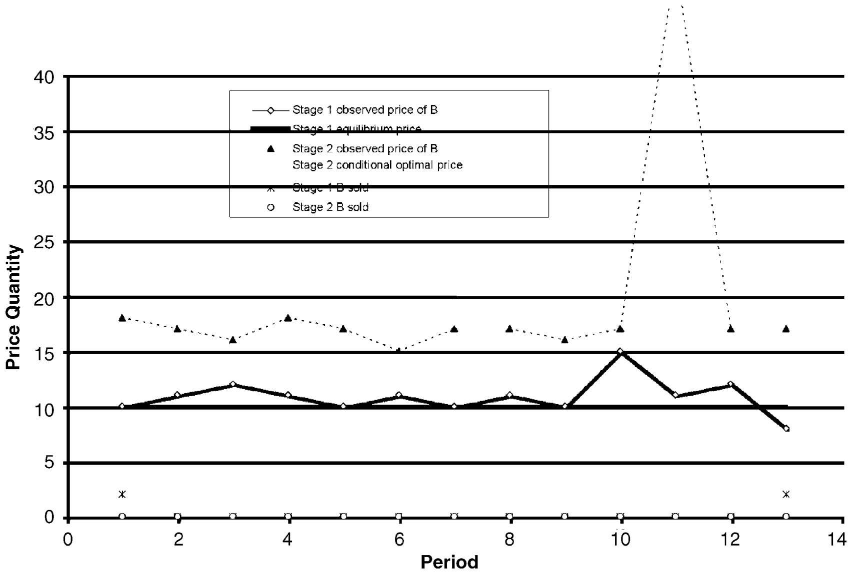

Fig. 21. Session *PU0327B* Observed Outcomes vs. Equilibrium Outcomes.

to build a network and subsequently exploit it by not reducing the price. Table 6 shows that in both the sessions, the average price charged by *B* is well below the equilibrium upper bound and in fact the average price for both sessions is lower than *B*'s unit cost.

In session *0323C*, seller *B* undercuts *A* in all but one of the 18 periods. This may arise from sellers' doubts regarding the rationality of buyers, where they may feel that buyers may not be forward looking and choose the cheaper technology. In session *0221*, the stage 1 price often exceeds the price of *A*, indicating that sellers are aware of the expectations of current buyers regarding the behavior of future consumers. In this treatment, buyers make few coordination errors and over 90% of the buyers over both sessions buy technology *B* in stage 1.

In treatment 2 we have the sessions *PU0221C*, *PU0323B* and *PU0327A*. In all of these, the sponsored technology is more efficient in stage 1 and less so in stage 2. In equilibrium, the sponsor undercuts the seller of *A* (prices at ϵ below 20) in stage 1 to establish the network and then realizes a large profit in stage 2 by raising price to just below 40. The second stage buyers tend to go with the network as it is costly for them to forego network benefits. In sessions *0221* and *0323*, seller *B* undercuts *A* in stage 1 and gets over 85% of the buyers to buy his technology. In contrast, session *0327* has the buyers coordinating on the pareto

Table 6. Stage 1 Prices and Quantities, Observed and Predicted.

Sessions	Price Predictions		Marginal Costs		Mean Observed Prices		Predicted Quantities		Mean Observed Quantities	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Treatment 1										
PU0221A (15)	28	48	28	32	28	**31.60**	0	4	0.47	3.53
PU0323C (18)	28	48	28	32	28	**27.35**	0	4	0.28	3.72
Treatment 2										
PU0221C (15)	20	20	20	15	20	16.6	0	4	0.4	3.6
PU0323B (18)	20	20	20	15	20	19.27	0	4	0.56	3.44
PU0327A (21)	20	20	20	15	20	17.95	0	4	3.05	0.95
Treatment 3										
PU0221D (15)	10	10	10	14	10	**11.54**	0	4	2.87	1.13
PU0323A (18)	10	10	10	14	10	**12.33**	0	4	2.45	1.55
PU0327B (19)	10	10	10	11	10	11.00	0	4	3.68	0.32

Note: Boldface indicates that the average price was below marginal cost.

dominated outcome (standardization on *A*). This is interesting and my conjecture is that the surplus promised to buyers by the sellers of *B* is not substantial enough to offset the uncertainty arising from the effect of strategic pricing on buyer behavior in stage 2. Stage 1 buyers may prefer to forego this surplus and buy *A*, because its stage 2 price is fixed and known. There may be uncertainty regarding *B*'s pricing behavior and/or the buyers' purchasing behavior in stage 2. More specifically, the stage 1 buyers may be afraid that seller *B* will raise his price once a network is established, and not be able to sell to all stage 2 buyers. Thus, fear of irrational behavior of other subjects may lead to subjects choosing the "safer" strategy of "buy *A*" compared to "buy *B*."

In treatment 3 we have sessions *PU0221D, PU0323A* and *PU0327B*. The price/purchase outcomes have been presented in Figs 19, 20 and 21. In this treatment, the sponsored technology is less efficient in both stages. The equilibrium involves seller *B* incurring a stage 1 loss as an investment to be recouped by exploiting the network in stage 2. Very little evidence of equilibrium behavior is observed in any of the sessions. In fact the equilibrium adoption outcome is observed in *only 2* out of the 15 periods in *PU0221D*, 4 out of the 18 periods in *PU0323A* and in *none* of the 13 periods in *PU0327B*. The buyers coordinate on *A* (the non-equilibrium, socially optimal technology) in 60% of the periods in the treatment. The markdowns from marginal cost for *B* usually exceed the theoretical predictions. However all four stage 1 buyers coordinate on *B* only 30% of the time *B* prices below *A*, possibly highlighting the unwillingness of stage 1 buyers to rely on the rationality of the seller of *B* and the other buyers.[20] Stage 1 buyers are aware that *B* will need to charge a high stage 2 price to recoup his stage 1 losses and may be apprehensive of *B* charging a price higher than the Nash equilibrium or of stage 2 buyers choosing *A* because they perceive *B*'s price to be "too high" even though their payoff is higher with *B*.

4.5.2. Stage 2

In treatment 1, prices for technology *B* stay well below the optimal Nash bound for most of the two sessions. In the latter half of *PU0323C* however, we do observe the sellers exploiting the network appreciably by pricing close to the optimal upper bound. Complete standardization on *B* occurs in 9 out of 15 periods in *0221A* and 12 out of 18 periods in *0323C*. However the buyers make coordination errors on several occasions. This tends to affect pricing in the periods following these instances of sub-optimality and we find sellers unwilling to price aggressively in order to realize full benefits from the network.

In treatment 2, sellers of *B* do manage to exploit the network in most periods to some degree though they approach the upper bound in only one or two periods in either session. This may be as a result of buyers being much more aggressive and ready to reject a price offer they consider "unfair." The sellers, realizing that the buyers may not be strictly "rational" in the game theoretic sense, opt to charge a lower price and share some of their surplus with the buyers.[21]

In treatment 3, seller *B* sells very few units in stage 2. This is as a result of approximately 76% of all stage 1 buyers in the treatment buying technology *A*. Even when *B* charges a lower price than *A*, 70% of stage 1 buyers prefer to buy *A*. Seller *B* sells only 18% of the total number of the units in stage 2.[22]

4.5.3. Rejection of Hypothesis 3

The rejection of hypothesis 3 (i.e. a high stage 1 installed base for *B* positively and significantly impacts the price the seller of *B* sets in stage 2) implies that sellers are not raising their price appreciably in stage 2 even when they know that buyers can potentially get more value from buying *B* instead of *A* because of the higher installed base of *B*. In period 7 of *PU0323C*, *none* of the first stage buyers purchase *B* even though the price of 33 is well below the maximum price that the seller of *B* can charge in equilibrium. This hints at the possibility that buyers may sacrifice some potential surplus and boycott a seller who they feel is charging a price that is "too high" even though the seller may be charging a price that is lower than the theoretically predicted upper bound. The buyer/seller interaction may be loosely interpreted as an ultimatum game[23] where the strategic seller *B*, offers a buyer a certain portion of the maximum surplus (price less marginal cost). The buyer has an outside option of purchasing *A*, which is provided at marginal cost. Results from the experimental literature on ultimatum games show that acceptance or refusal of an ultimatum offer often depends on the difference in payoffs between the proposer (in this case the seller of *B*) and the responder (in this case the buyer). In general, responders often reject offers in which the proposer keeps an asymmetrically high share of the pie.[24] Thus, contrary to game theoretic wisdom, ultimatum offers often have the proposer and responder splitting the surplus more evenly than in the Nash equilibrium outcome.[25] The data from this experiment is not very suitable for analyzing ultimatum bargaining behavior for 2 main reasons. Firstly, the size of the pie is not stationary from period to period as sellers set different prices and the buyers' value from purchase of *A* or *B* is different for different stage 1 outcomes. Secondly, payoffs depend on how the four buyers coordinate their purchases. However the coefficient on the variable *Stage 2 price of B* in Table 5 provides a measure of the degree to which the propensity to buy *B* (given as a probability) is impacted by a rise in the price of *B* (which proxies for the share of the pie that the seller keeps for himself) controlling for the outside option of purchasing *A* (which is proxied by the variable *B bought in stage 1*.[26]) A negative sign on the price of *B* indicates that buyers are sensitive to amount of surplus that is extracted by the seller of *B*. In treatment 1 this variable is insignificant, indicating that buyers rarely switch to *A*, even if *B* raises his price. In treatments 2 and 3 (except in sessions *0221C* and *0221D* where reliable estimates are unobtainable), the stage 2 price of *B* does negatively and significantly impact its stage 2 choice probability indicating that buyers may be sensitive to the amount of surplus that sellers tried to extract. This in turn may lead to sellers not wanting to raise their price all the way up to the Nash upper bound. This behavior is observed in a similar market when both technologies are sponsored. Chakravarty (2002) finds that sellers in a position to exploit the installed base do not in fact do so in a majority of the sessions.

4.6. Efficiency

Market efficiency is the observed market surplus as a percentage of the maximum possible surplus that can be realized. The market surplus in the different equilibrium outcomes is calculated using equation *8*, *9* or *10* of the theoretical background section. The observed surplus may be different from this and depends on the actual number of buyers who adopt the different technologies in a period. The socially optimal adoption outcome is one that has the highest market surplus. The equilibrium outcome may or may not be socially optimal depending on the treatment group we are in.

Table 7 presents the period-by-period observed efficiencies as well as the average observed efficiencies for all the sessions. In treatment 1, the socially optimal outcome is all buyers adopting *B* in both stages (*BB*). Thus the equilibrium outcome also yields the highest market surplus. The average efficiencies for the two sessions *PU0221A* and *PU0323C* are 78 and 86% respectively.

In treatment 2, market efficiency is maximum regardless of whether standardization occurs in *A* or *B*, i.e. the equilibrium outcome (*BB*) yields a market surplus equal to the non-equilibrium standardization outcome (*AA*). The average market efficiencies in the sessions *PU0221C* and *PU0323B* are 89 and 82% respectively. *PU0327A* has a very low average efficiency of 68%. This is not surprising given the level of sub-optimal behavior that characterized this session.

In treatment 3, standardization on the unsponsored technology (*A*) is socially optimal and the market equilibrium is only 93% efficient for the parameters in *0221D/0323A* and 90% efficient in the *0327B* session. In these sessions, the observed market efficiency is high, on average equal to 84.1, 85.4 and 94.1% respectively. This is not surprising, as the equilibrium outcome is not observed in most periods of these sessions.

All three treatments have a few periods in which the observed efficiencies are below 50%. These correspond to periods in which no technology enjoy a clear dominance i.e. the eight buyers are divided equally between *A* and *B*.

Table 7. Observed Efficiency.

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Ave.
Treatment group 1																			
PU0221A (NE = 100)	16	74	100	100	100	74	24	100	100	100	100	100	100	16	63				77.8
PU0323C (NE = 100)	100	100	100	100	63	63	70	100	100	63	100	100	24	100	63	100	100	100	85.9
Treatment group 2																			
PU0221C (NE = 100)	54	100	100	100	100	100	100	100	54	100	100	54	73	100	100				89
PU0323B (NE = 100)	69	73	100	54	69	73	100	69	100	100	100	100	44	100	100	73	100	50	81.8
PU0327A (NE = 100)	100	73	69	40	38	46	40	40	100	100	100								67.6
Treatment group 3																			
PU0221D (NE = 93)	93	77	56	49	50	77	100	100	100	60	100	100	100	100	100				84.1
PU0323A (NE = 93)	100	78	78	100	77	78	77	93	61	93	49	100	57	51	93	93	100	93	81.5
PU0327B (NE = 90)	62	100	100	100	100	100	100	100	100	100	100	100	62						94.1

5. CONCLUSIONS

The qualitative results from this laboratory study indicate that network externalities *are* an important driving force in shaping buyers' and sellers' decisions in a market with network effects. Stage 1 buyers buy the more expensive technology in periods when it can credibly promise to be the stage 2 market leader. The technology that establishes a strong network in stage 1 (three or more of four buyers) usually sells to all stage 2 buyers. The data also indicate that the sponsor (seller *B*) is willing to use penetration pricing in stage 1, in order to establish his technology. However, the sponsor does not exploit his installed base as laid out in the theory. In fact the number of buyers buying *B* in stage 1 does not impact its stage 2 price significantly. This is a strong departure from the theoretical predictions of Katz and Shapiro (1986) but supports the results obtained from the experimental market with network effects and two sponsored technologies investigated by Chakravarty (2002). I conjecture that this may be because they fear punishment from buyers who are less rational than predicted by theory.

NOTES

1. David's contention that the Dvorak (patented in 1936 by August Dvorak) is a superior design has been subject to some criticism. Liebowitz and Margolis (1999) argue that the support for this claim is scant and unreliable.

2. Arthur models "chance" or "historical events" in this manner.

3. Katz and Shapiro (1986) follow Arthur's (1983) definition. The expression "sponsor" is used in this work to denote the ability of a patent protected seller to invest some capital in order to establish his technology in the market. If a seller does not have defined property rights for his technology, he has no incentive to "sponsor" and establish it in the marketplace. "Non-sponsorship" refers to this lack of incentive on the part of a seller.

4. Under monopoly, they find that the inefficiency due to early adoption is exacerbated. The monopolist ex-post appropriates any positive value created via waiting by the current consumers. Therefore her power to extract surplus acts against her own interests in this dynamic setting. Farrell and Gallini (1988) and Shepard (1987) consider licensing as a commitment device for a monopolist in this situation.

5. Examples of pioneering studies of laboratory coordination games include Cooper et al. (1990, 1992) and Van Huyck et al. (1990, 1991).

6. A "classroom" experiment is one that is performed in order to introduce or reinforce concepts of economics to students. The student subjects are typically not paid in currency but given extra credit points, food coupons to be redeemed at the cafeteria or not paid at all. This may introduce biases caused by decision costs that outstrip incentives or behavior that is not related to the incentives dictated by the experimental design. For a survey on incentives and individual choice behavior in economics experiments see Roth (1995). Thus, the results from classroom sessions are not considered as important as regular data collection

experiments (where subjects are recruited from a general population and paid in currency for making salient decisions). They are however important pedagogical tools and are often vital to the development of a new experimental design.

7. This work operationalizes the *two-sponsored seller* case from Katz and Shapiro (1986).

8. In such a situation, seller B can price below cost to set up a network and recoup his investment from later arriving buyers by pricing substantially above cost.

9. The assumption underlying this behavioral restriction (which is not explicitly stated) may be that generic technologies have a large number of competing manufacturers who bid price down to cost. Given that the market environment has just two firms, this exogenous and simplifying restriction on A's behavior seems artificial. In fact, the Bertrand prediction, that oligopoly sellers of identical goods with constant and equal marginal costs set their price at marginal cost, has received mixed evidence in the laboratory. Dufwenberg and Gneezy (1998) find that a pair of randomly matched Bertrand competitors tends to price higher than the Nash equilibrium. With more than two price competitors (as in the market for non-sponsored technologies), prices were above the Nash prediction and converged only after repeated play over several periods.

10. From Katz and Shapiro (1986), in stage 2, for technology A the "no switch" condition for a consumer is

$$v(x_1 + x_2) - p_2 \geq v(y_1 + y_2 + 1) - q_2 \qquad \text{(i)}$$

For technology B the "no switch" condition is

$$v(x_1 + x_2 + 1) - p_2 \leq v(y_1 + y_2) - q_2 \qquad \text{(ii)}$$

If $v(\cdot)$ is assumed to be an increasing function, (i) and (ii) cannot be satisfied simultaneously and thus no consumer purchasing a technology has any incentive to switch to the other and therefore one of the two technologies will sell to all the buyers in stage 2. In other words $x_2 = 0$ or $x_2 = N_2$, where N_2 is the total number of consumers. Similar logic shows that all stage 1 consumers will be identical in terms of the technology they purchase.

11. However, Cooper et al. (1990), Van Huyck et al. (1990) and Cooper et al. (1992) provide some experimental evidence that a Pareto dominant equilibrium in a coordination game may not be a natural focal point as laid out in the theory (Harsanyi & Selten, 1988; Schelling, 1960). Strategic uncertainty (in the Cooper et al., 1992; Van Huyck et al., 1990 studies) and the presence of "cooperative" dominated strategies which are themselves not played in equilibrium (in the Cooper et al., 1990 study) are cited as the main sources of coordination failure.

12. Expression (3) is a composite of $v_2 - c_2 = v_b + c_2$ and $v_2 - d_2 = v_b + c_2$, which denotes that the value to a representative consumer from everyone buying either technology in both stages dominates the value obtained from buying a technology in only one of the two stages, when B prices at marginal cost. Thus, if technology B is bought in stage 1, the seller of B can provide a higher value than that from purchasing A by pricing at marginal cost in stage 2. Similarly, the seller of A can provide more value to the consumer if everyone has bought A in stage 1.

13. Strictly speaking, it is not possible to implement a game of complete information in practice because utility functions are not observable.

14. In session *PU0323C* seller B never set a price higher than that of seller A. So it has not been used to test this hypothesis.

15. A logistic model could not be fitted on the data from *PU0327B* (treatment 3) as the dependent variable takes only one value (0) for *all* observations.

16. The seller of technology B in period $t - 1$ is most likely not the current seller of B, as roles are randomly reshuffled every period. Thus, if learning affects seller behavior significantly, it is primarily observational learning. Learning from the behavior of others who faced a similar decision problem in the past has been investigated by Bikhchandani et al. (1998) who find the presence of informational cascades (situations in an agent's optimal action does not depend on her private information) which stops the accumulation of public information. Observational learning has been investigated in the laboratory by Garvin and Kagel (1994) in the context of common value auctions, who find that hypothetical losses (suffered by other subjects in the in previous periods) tend to lower bids in subsequent periods. In the technology adoption game, I expect that losses made by a previous seller of B affects the price charged in the current period negatively.

17. As pointed out by an anonymous reviewer, since I am attempting to gauge the impact of the installed base on stage 2 prices and the strategic seller raises his price provided he wins more than two sales in stage 1, it would be interesting to use a dummy variable as these are more flexible at picking up non-linearities in the causal relationship.

18. I have used Chow's (1960) test of structural change to verify that the regression on pooled data with fixed effects is valid.

19. It may be noted from the figures that the optimum upper bound for the price of B in stage 2 of the two-stage game is *not necessarily* the equilibrium upper bound for all periods. This is because the maximum price that the seller of B can set in stage 2 is contingent upon the stage 1 outcome. If either the buyers or the seller had deviated from equilibrium strategy in stage 1, it would not make sense to use the Nash prediction as a meaningful pricing benchmark in a disequilibrium subgame in stage 2. Accordingly, the upper bound of price for stage 2 lies weakly below the equilibrium bound, being equal to it when equilibrium behavior is observed in stage 1. However this adjusted "contingent" price bound no longer applies if it lies below the stage 2 marginal cost for the seller of B. In this case the seller would not price below his unit cost, as it would be impossible for him to make up for this later by pricing in excess of marginal cost. In such a situation seller B ends up pricing at marginal cost and allowing A capture the market.

20. This conjecture supports the results from Beard and Beil (1994). Their study confirms Rosenthal (1981), who argues that when the stakes are sufficiently high, reasonable people may be reluctant to play a strategy which relies on the hypothesis that others are utility maximizers.

21. A reason for the lack of confidence in buyers on the part of the seller agents and vice versa may be due to common knowledge of bounded rationality. Several studies in the literature investigate this phenomenon in games with more than a trembling hand bound on rationality, i.e. there is a possibility that the performance of players deteriorates considerably as the complexity of a task exceeds some threshold. The ideas of cognition/deliberation costs and alternatives to a rational – agent hypothesis have been examined in the pioneering works of Simon (1955), Kahnemann and Tversky (1974), Camerer et al. (1994) and Gabaix and Laibson (2000). McKinney and Van Huyck (2000) estimate bounded rationality in an experimental setting and find that most subjects have a very limited ability to visualize the extensive form of the game. It is quite plausible that in the product adoption game, less than perfectly rational subjects make for observed behavior to deviate considerably from the backward induction outcome.

22. In *PU0327A*, seller of *B* did not sell a single unit in stage 2 over the entire session.

23. An ultimatum bargaining game is one of two agents, in which a proposer (who moves first) proposes to split a pie in a certain fraction. The responder (second mover) then either accepts or rejects the split. If he accepts, both agents get their shares. If the responder refuses his share none of them get anything.

24. See Guth, Schmittberger and Schwarz (1982).

25. In an ultimatum bargaining game the theoretical equilibrium occurs where the proposer retains $(1 - \varepsilon)$ of a pie of size 1, and offers the respondent ε share (where ε is small and positive).

26. The price of *A* is given. Payoff from buying *A* depends only on the network size, which is given by 4 – *B bought in stage 1*).

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APPENDIX
EXPERIMENTAL INSTRUCTIONS

This is an experiment in the economics of decision making. If you follow these instructions carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment. The currency we will use in this experiment is Kroners (Kr.). Your earnings from the experiment will be in this currency which will be converted into US$ at the end of the experiment at the rate given by 1 Kr. = US$____, and given to you to take home. Please remember that the more Kr. you earn in this experiment, the more US$ you get to take home at the end. All participants in this experiment have the same exchange rate between Kr. and US$.

The experiment deals with a computerised market for **two goods** and will consist of a series of decision-making **periods**. **Each period** will have two separate **stages**. These instructions will show you how to use your computer terminal to buy and sell units. The sellers of these two goods will be the same people throughout the period and each will be required to make a pricing decision (i.e. -set a price) in **both stages** of the period. The total number of participants (9) will be divided each period in a **purely random manner** by the computer into 2 groups with four 4 buyers each, and 1 seller (for good Y). **Good X will be provided at a fixed price that is equal to cost per unit by the experimenter in every stage of a period**. The price of Good X is always fixed (at a price equal to its unit cost) **regardless of the actions of the buyers or seller of Y**. As a seller of Y or a buyer, you cannot influence its price any way. The 2 groups of buyers will be designated "**Stage 1**" buyers and "**Stage 2**" buyers and this will determine the stage of the period in which they make their purchase decision (i.e. – whether to buy X or Y). **Only one group** of 4 buyers will make a purchase decision at a particular stage of a period. Please observe that there are no fixed roles in this experiment. There is a one in nine chance that you will be a seller in a certain period. For the buyers there is equal chance of being assigned to either stage each period.

At the beginning of the experiment you will point your web browser to a certain URL (Uniform Resource Locator) provided to you by the experimenter. You will then enter the session name and login ID in order to participate in the experiment. The experimenter will announce the session name to all the participants. Your login ID for this experiment is ____. After you have entered these, you will be randomly assigned the role of a "**stage 1 buyer**," a "**stage 2 buyer**," or a "**seller of good Y**" by the computer.

INSTRUCTIONS FOR BUYERS

As a buyer in this experiment, your task is to choose one of the two goods labelled X or Y in the stage to which you have been assigned. Depending on the good you choose, its price and the actions of the other participants, you will receive profits in Kr. at the end of the period. After you log in, you will see a screen resembling one of the two shown above (Figs A1 and A2). On the left is your redeemed value table telling you the value in Kr. you get by "consuming" the unit of good you

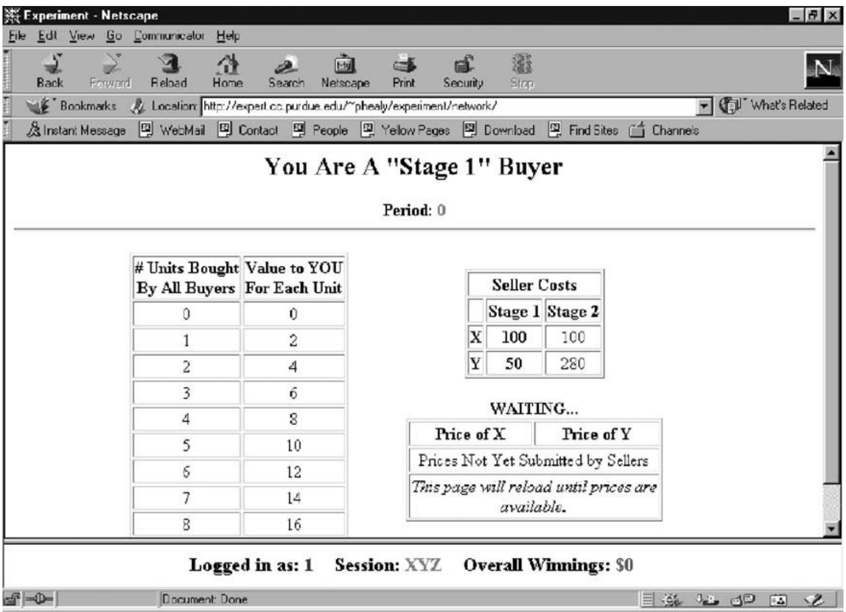

Fig. A1.

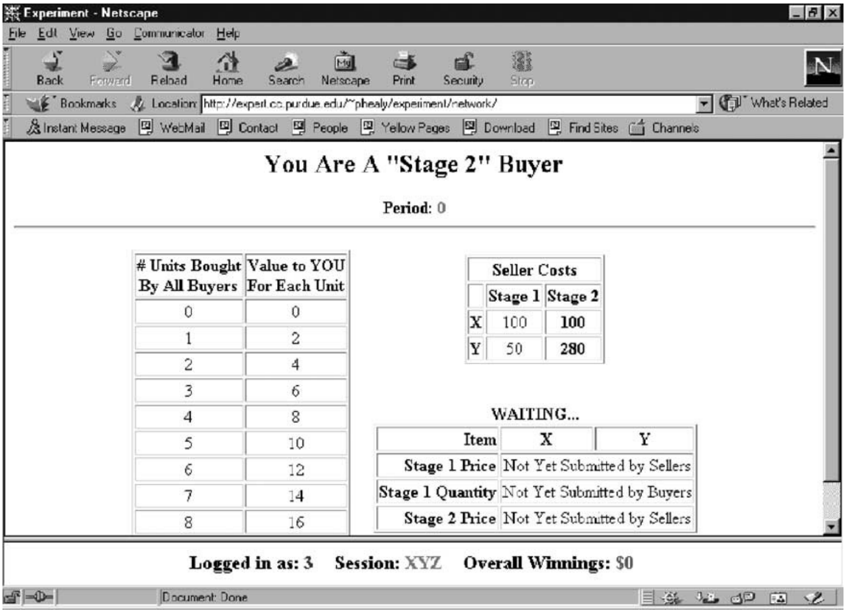

Fig. A2.

bought by reselling it to the experimenter at the end of the period. **All buyers in this experiment have the same redeemed value table. This schedule does not change throughout the experiment. It is also important to note that both sellers have this schedule on their screens and thus have full information about buyer valuations**. You will calculate your profit at the end of the period (profit calculations will be discussed a little later in more detail) by subtracting the price you paid for the good from your value for the good.

The consumption value of the unit you bought depends on the total number of buyers who bought it over ***both*** *the phases of the period*. **More specifically, the value a buyer gets from "consuming" the good he/she bought increases as the total number of buyers of that good increases**. In the figures above for example, if you bought good X and four people in total (including you) bought good X, the consumption value you get from your unit of X is 8 Kr. If instead, five people in total bought X, the consumption value of your unit would be 10 Kr.

Notice that the two goods are not inherently different in terms of value to a buyer, i.e. – the same schedule can be used regardless of whether you bought X or Y. The difference between the two goods lies in their **different per unit cost of production**, which all buyers and sellers see on their computer-screens under

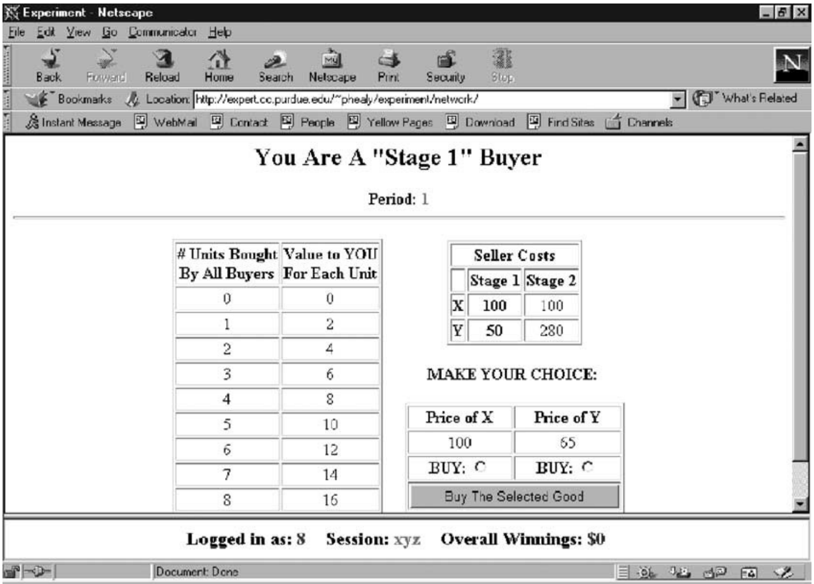
Experiment - Netscape
File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
Bookmarks Location: http://expert.cc.purdue.edu/~phealy/experiment/network/
What's Related
Instant Message WebMail Contact People Yellow Pages Download Find Sites Channels
You Are A "Stage 1" Buyer
Period: 1
Units Bought By All Buyers
Value to YOU For Each Unit
0 0
1 2
2 4
3 6
4 8
5 10
6 12
7 14
8 16
Seller Costs
Stage 1 Stage 2
X 100 100
Y 50 280
MAKE YOUR CHOICE:
Price of X Price of Y
100 65
BUY: BUY:
Buy The Selected Good
Logged in as: 8 Session: xyz Overall Winnings: $0
Document: Done

Fig. A3.

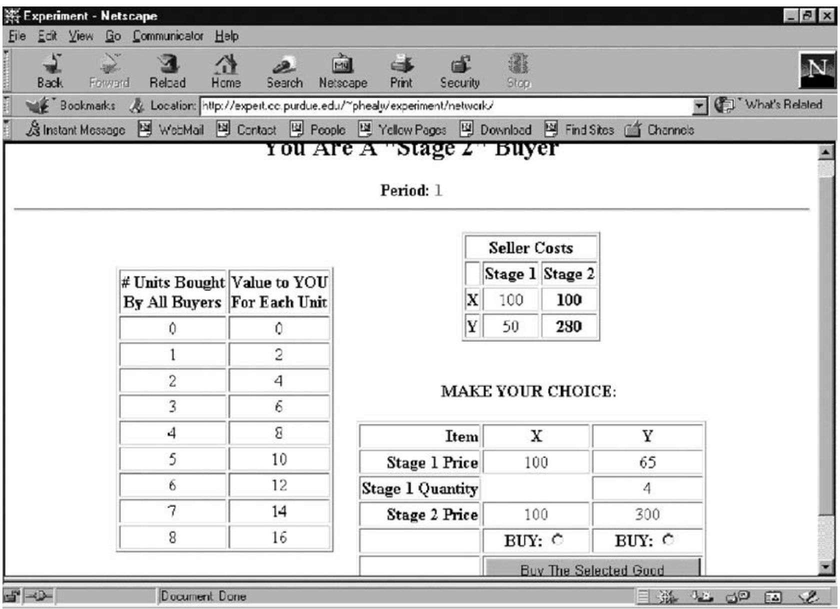
Experiment - Netscape
File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Stop
Bookmarks Location: http://expert.cc.purdue.edu/~phealy/experiment/network/
What's Related
Instant Message WebMail Contact People Yellow Pages Download Find Sites Channels
Period: 1
Seller Costs
Stage 1 Stage 2
X 100 100
Y 50 280
Units Bought By All Buyers
Value to YOU For Each Unit
0 0
1 2
2 4
3 6
4 8
5 10
6 12
7 14
8 16
MAKE YOUR CHOICE:
Item X Y
Stage 1 Price 100 65
Stage 1 Quantity 4
Stage 2 Price 100 300
BUY: BUY:
Buy The Selected Good
Document: Done

Fig. A4.

# Units Bought By All Buyers	Value to Buyer For Each Unit
0	0
1	2
2	4
3	6
4	**8**
5	10
6	12
7	14
8	16

Fig. A5.

the heading "**Seller Costs**." The unit cost of both goods for both periods is shown to **all participants** right at the beginning of the period. At the beginning of the first stage of a period, the sellers submit prices for X and Y, which appear on the computer screens of all buyers. Figure A3 shows the type of screen that a first stage buyer now observes. He makes his decision (whether to purchase X or Y) on the computer screen by checking one "**BUY**" button and clicking on "**Buy the selected good**." While the stage 1 buyers make their decisions, the second stage buyers get a "waiting" screen. After all the stage 1 buyers have made their purchase decisions, these decisions appear on the screen for **all** participants to observe. The computer then asks the sellers to post their second stage prices. These are likewise shown to all buyers and the stage 2 buyers are asked to make a purchase decision. Figure A4 shows the screen that a stage 2 buyer observes. After all the four buyers have chosen either X or Y, these too are posted on the computer screen for all participants to see.

Note from Fig. A4 that a buyer in the 2nd stage sees on his screen the decisions taken by all participants in stage 1 before he makes his purchase

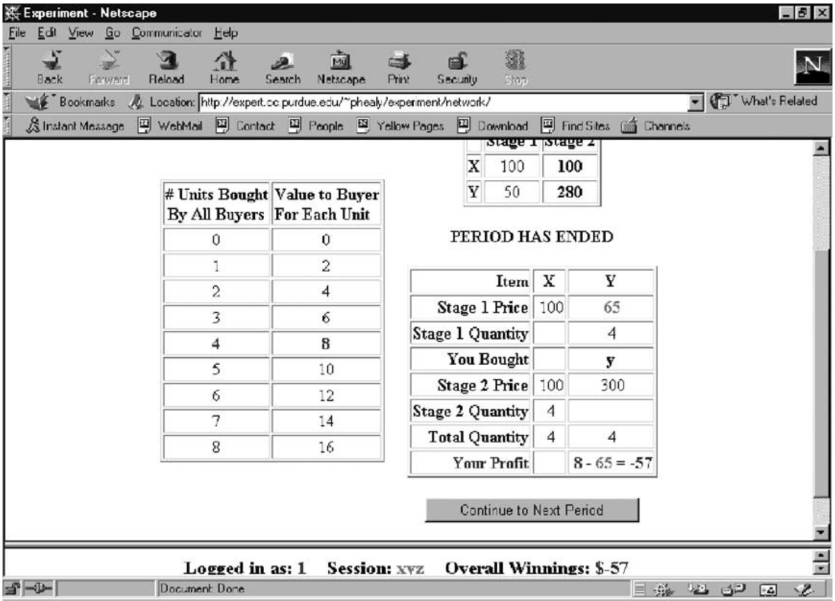

Fig. A6. Period Ending Screen, for Stage 1 Buyer.

decision. The period is now over and the buyers observe their profits. We will talk a little bit about what these profits are for buyers before we go on to show what you will see on your computer screens at the end of the period.

Profit is the difference between the redeemed (consumption) value of the good purchased and the price that is paid for it. This redeemed value depends on the **total number** of buyers from both stages who purchased the same good.

The calculation should become clearer through an example, which is given below. The table used for the calculations (Fig. A5) is the same as that which is on the computer screens in the earlier figures.Suppose that as a buyer in stage 1 of a certain period, you buy a unit of X for 6 Kr. After all the other buyers in stages **1 and 2** have made their purchase decisions you see that 4 people in total **including you** have bought X in the period. Go to the schedule and look at the value corresponding to the number of buyers equal to 4. It is 8 Kr. This is your consumption value for X. Your profit for the period is –

$$\text{PROFIT} = \text{VALUE} - \text{PRICE} = 8 - 6 = 2\text{Kr.}$$

To take another example, if six people instead bought X in the period, your consumption value would be 12 and you would therefore earn $12 - 6 = 6$Kr.

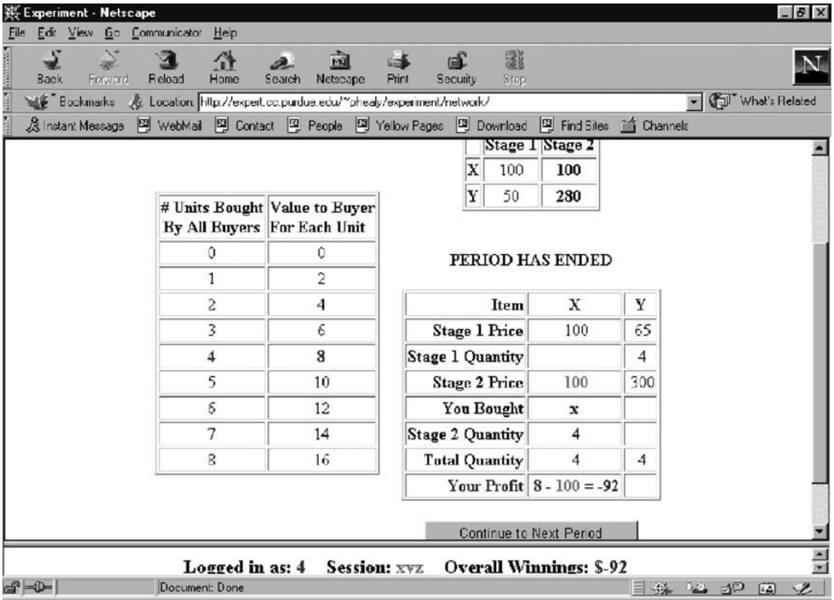

Fig. A7. Period Ending Screen, for Stage 2 Buyer.

Notice that if you buy a good for a higher price than the consumption value, you will make a loss on the purchase.

However you **do not** have to calculate these values by hand. The computer does them for you. At the end of the period, the buyers will get screens on the computer which resemble the ones in Figs A6 and A7 above. The computer calculates the buyer profit (as shown above) based on the redeemed value it obtains from the schedule on the left and subtracts from it the price paid by a buyer for the unit. This is seen in the "**Your Profit**" row in Figs A6 and A7.

INSTRUCTIONS FOR SELLERS

If you are a seller in a certain period you have enough Y to sell to the whole market consisting of eight buyers (4 in the 1st stage and 4 in the 2nd stage). You know the buyers' value schedule and per-unit cost of production for you and the seller of X (i.e. – the experimenter) in each of the two stages of the period right at the beginning of the period. **Be aware that the buyers have this exact same information**.

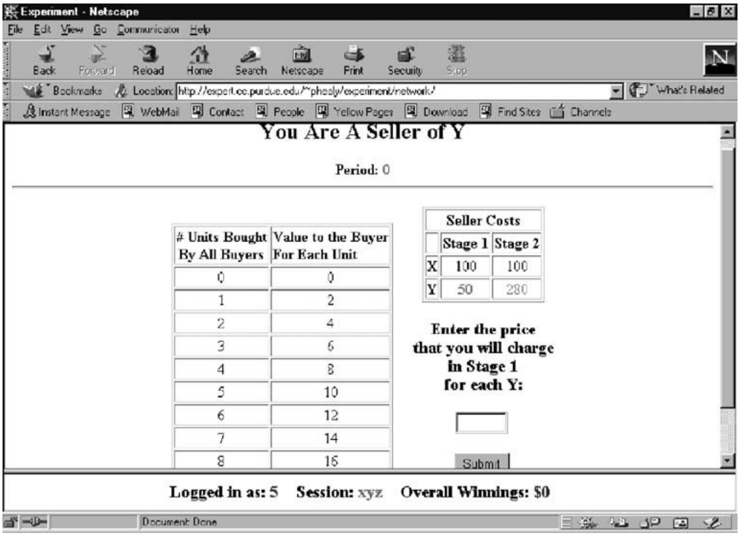

Fig. A8.

As shown on Fig. A8, in the first stage of a period you have a box on the bottom right corner of the screen where you have to type in the price at which you want to sell your good. You will enter the per-unit price at which you want to sell and "**send this price**" by clicking below. At the same time, the other seller too will enter a per-unit price on her computer screen. The prices are then posted on the computer screens of all buyers to observe. After all four stage 1 buyers have made their decisions; these decisions will be displayed to both sellers and **all the buyers**. Now you will get a screen resembling Fig. A9.

Note that in the screen above, all 4 buyers in stage 1 have bought Y. This is found in the "**Stage 1 Quantity**" row in the above screen. There is also a box in which you can enter the per-unit price you want to charge in stage 2. After you submit this stage 2 price, stage 2 buyers get a chance to make their purchase decisions. After all stage two buyers have made their decisions the period is over and you are now in a position to observe your profits.

Your total profit will be the sum of the profit you make from each unit of good you sell in the period. The profit on each unit sold is given below.

$$\text{PROFIT ON A UNIT SOLD} = \text{PRICE} - \text{COST}$$

The price in the equation above is the price you decide to sell at in each phase of a period. Suppose your unit cost of Y is 120 for the 1st phase of a period and 100 for

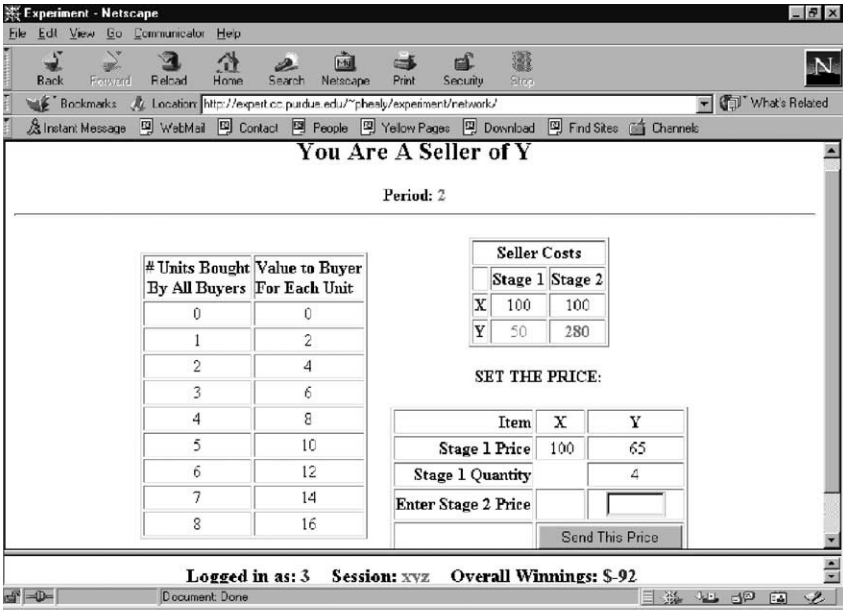

Fig. A9.

the 2nd phase, and you sell 2 units at the rate of 140 in the 1st phase and 2 more for 180 in the 2nd phase. Your total profit for the period is –

= PRICE – PRODUCTION COST for each unit sold in the period

____ stage 1_____ ____stage 2____

= 2(140–120) + 2(180–100) = 200 Kr.

Note that you do not bear the cost of a unit unless you sell it to a buyer. If you sell nothing in a period your total profit is zero. Again you do not have to calculate profits by hand. The computer will calculate them and display them for you at the end of the period on a screen resembling Fig. A10.

Note that in this example, the seller of Y has managed to sell only 4 units of Y in stage 1 and nothing in stage 2. His total quantity sold in each stage is given on the above screen. His profit is calculated in the "**Seller Profits**" row in exactly the same way as in our earlier numerical example.

Once all buyers and sellers click on the "**Continue to Next Period**" button, a new period begins and the profit from the current period is added on to the overall

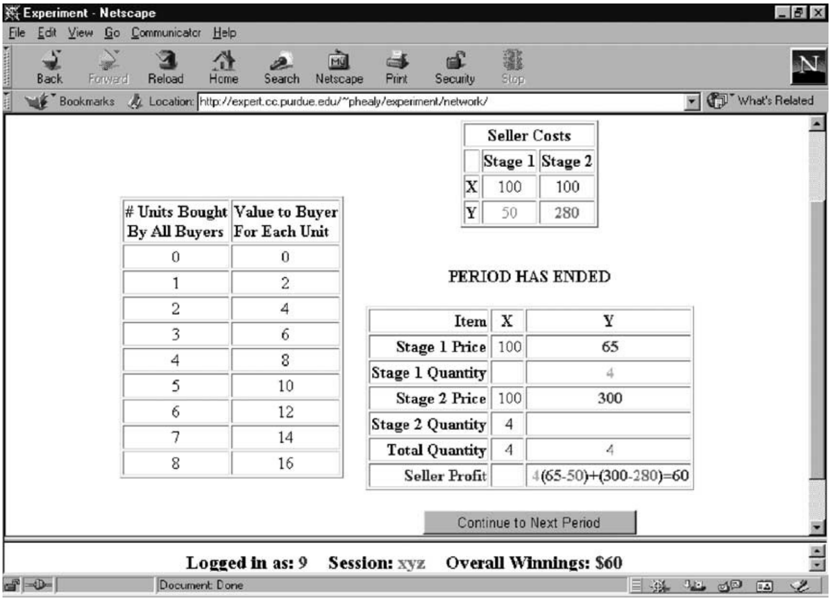

Fig. A10.

(cumulative) profit tally in the lower frame. Remember that all nine participants will be randomly reassigned to the buyer and seller roles each period.

Due to a software-related difficulty, sometimes the cumulative profit tally may not update properly. Thus a sheet has been provided to you to keep track of your cumulative earnings throughout the experiment. Please copy the profit from your screen onto this sheet and keep a running total of your earnings in the last column.

Please note that all the values in the figures above were used for illustration only. The screens you will observe in the experiments will be different. The very first period of this experiment will be a "practice" period and will not contribute towards your earnings from the experiment. Does anybody have any questions at this point?

INTERGENERATIONAL PRODUCT COMPATIBILITY AND PRICE COMPETITION

Dong Chen

ABSTRACT

This paper considers firms' incentive to preserve compatibility between product generations in a duopoly setting. A firm may or may not maintain backward compatibility depending on its first period market share. Firms' compatibility choices consequently will affect their pricing behaviors. Specifically, it is shown that under certain conditions both firms will preserve compatibility and act as local monopolist in the second period. Hence, backward compatibility becomes a tool for firms to relax second period price competition.

1. INTRODUCTION

It's common for firms to introduce product updates from time to time. Very often these new-generation products offer more features, either because of better design or the availability of more advanced technologies. One important issue that arises with the introduction of the new-generation products is the backward compatibility between the new versions and their predecessors.

Compatibility between product generations can take different forms. For example, if the product is a system software, say a computer operating system (OS), then compatibility is achieved if files can be easily shared across platforms

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or/and the same application software can work on both platforms. If the product consists of multiple components, for instance, a computer system with hardware and software or a camera with a body and a lens, then compatibility is achieved when components of different generations are interchangeable. Backward compatibility can also refer to the case where products of different versions share the same user interface and so on.

The issue of backward compatibility is important because the compatibility is usually valued by consumers but not always provided by firms. Several reasons may explain why backward compatibility is valuable. First, backward compatibility allows consumers to save on complementary products. This is the case for the operating system example. If the new-version operating system is backward compatible, then a consumer who upgrades to the new system can enjoy the new features and does not need to purchase all the application software again. Second, consumers' valuation of backward compatibility can also come from network externalities. When the surplus that consumers obtain by purchasing a certain product depends positively on the number of total users, then this product is said to exhibit network externalities (or demand-side scale economies). For computer operating systems, network externalities are very likely to be present, although they might work in an indirect way. If an operating system has a large number of users (i.e. a larger network), then application developers are more willing to design software for this operating system, which in turn gives the consumers more choices and thus increases the consumers' valuation of the operating system. If backward compatibility is preserved for an operating system, then users of all generations of the operating system can be considered as being in the same network. This means each consumer will put a greater valuation on the operating system than if backward compatibility is not preserved. Third, backward compatibility reduces learning cost. For example, the user of an earlier-version word processor will find it much easier to transit to the new version if they both share the same user interface and have common short-cut keys, etc. Last, backward compatibility can be valuable because of the interchangeability it brings. In the camera example, the interchangeability between bodies and lenses of different generations can bring consumers some extra surplus because mixing and matching components allows a consumer to use the products under circumstances where the original systems are not the best fit.[1]

Although backward compatibility is usually valuable to consumers, it is not always maintained when firms introduce their new-generation products. More interestingly, very often firms competing in the same markets do not make the same decision on compatibility. One example is the personal digital assistant (PDA) market, in which backward compatibility is mainly an issue about the operating system. PalmSource, the producer of the most popular operating system in the PDA market today, has managed to maintain the backward compatibility among its product generations to a very large extent. For example, PalmSource introduced its latest operating system Palm OS 5.0 in June 2002. The new operating system features stronger data encryption and Secure Socket Layer service for secure E-mail and online transactions. It also features built-in support for Bluetooth and 802.11b wireless communication standards. According to the executives from the company, the new version operating system is fully compatible with the application software that was written for the previous version Palm OS 4.0. Also the majority of software products that were developed for Palm OS 3.5 should work with the latest operating system. This means among a total of over 13,000 software written for Palm OS, a large portion of them can be installed directly on the new devices featuring the latest OS. It is noted that this level of compatibility is achieved when Palm, the parent firm of PalmSource,[2] decided to make some major changes to the hardware part of their PDA. Specifically, Palm OS 5.0 was designed to run on the ARM-based processor designed by England's ARM (formerly Advanced RISC Machines) and manufactured by Intel and others, while all earlier versions of the operating system were designed specifically for Motorola's Dragonball processor. This transition of processor architecture made the task of preserving such a high level of backward compatibility particularly difficult.[3]

In contrast, PDAs produced by some other manufactures fail to provide their users with such compatibility. For example, Nokia's 9210 Communicator is a PDA combined with wireless communication capabilities.[4] This device runs on the Symbian OS version 6.0 developed by a joint venture owned by Nokia and several other major cell phone manufacturers.[5] Unlike Palm OS 5.0, Symbian OS 6.0 is not backward compatible with its predecessors. This means if a consumer owns a PDA powered by some earlier-version Symbian OS (e.g. Psion, Diamond, and Ericsson range of handheld computers) and wishes to upgrade to a device installing Symbian OS 6.0, then he has to buy all the application software again (if these applications have the Symbian 6.0-compatible versions available) instead of installing what he already has on the new device.[6]

Another example is the 35mm single-lens-reflex (SLR) camera industry, which illustrates the issue of backward compatibility among product components. The basic features of 35mm SLR did not change much since its invention in the 1940s and the issue of backward compatibility had never been a major concern until the mid-1980s when the whole industry faced the transition from manual-focusing (MF) to auto-focusing (AF) technology. Minolta introduced the world's first truly body-integrated AF SLR camera, Maxxum 7000, in 1985. By so doing, Minolta dropped its older MD lens mount and introduced the brand-new "A"-type bayonet mount. The consequence is that the consumers who had purchased Minolta's manual-focus lens with the MD mount cannot use them on the new AF camera body. Also the new AF lenses that were designed specifically to fit the Maxxum series cameras cannot be put on the old MF camera bodies either. While Minolta pioneered the AF technology, other major camera manufacturers soon followed suit. Canon introduced its EOS series AF cameras in late 1986, which adopted a new EOS lens mount and made its previous FD mount obsolete.

Interestingly, when Nikon, which is one of the most renowned 35mm SLR producers, introduced its AF SLR F-501 in 1986, the AF lenses shared the same F bayonet-type mount with all its previous manual-focusing lenses.[7] This means Nikon users can put their old MF lenses on the automatic camera body and take advantage of the new features like focusing aid. Also the new AF Nikkor lenses can be put on most of the MF Nikon camera bodies as well. Although compared to Minolta's Maxxum series, F-501 has a noticeably slower auto-focusing speed, it became very popular upon its release.[8]

One reason that firms do not always preserve compatibility among product generations is that it is often costly to do so. The requirement for backward compatibility poses certain (and sometimes very difficult) constraints for the engineers who try to add new features or incorporate new technologies into the existing product. The difference in firms' compatibility decisions may simply be driven by the different technological constraints the firms faced. For example, it could be the case that the intrinsic structures of the two operating systems determines that it is easier for PalmSource to preserve backward compatibility than for Symbian. Or it could be that Nikon, just by pure luck, had designed a lens mount that can be more easily adapted to the AF technology than its competitors'. However, economists are more interested in the economic forces behind these decisions. We would like to ask besides any possible technological reasons, are there any economic considerations that drive these firms' backward compatibility decisions? Also, once these decisions are made, what are the implications for the market outcome? These are the questions that the present paper tries to answer.

Although the issue of product compatibility has been widely studied, previous research focuses on the compatibility between products sold by different firms (see, for example, Boom, 2001; Farrell & Saloner, 1986, 1992; Katz & Shapiro, 1985; Matutes & Regibeau, 1988; Mariñoso, 2001). The issue of backward compatibility within the same firm's product line has drawn much less attention. Usually this problem is considered implicitly in the context of planned obsolescence (e.g. Bulow, 1986; Choi, 1994). Backward compatibility effectively enhances the durability of the old-generation product and thus discourages consumers to upgrade to the new version. Hence, backward compatibility (or incompatibility) becomes a tool for firms to control the durability of its product and to avoid the time-inconsistency problem associated with a durable good as pointed out by Coase (1972). Bulow (1986) made this point clear by writing, "planned obsolescence is much more than a matter of durability; it is also and perhaps primarily about how often a firm will introduce a new product, and how compatible the new product will be with older versions" (Bulow, 1986, p. 747).

Choi (1994) examines a monopolist's decision on backward compatibility in the presence of network externalities. While compatibility increases the value of a product through network externalities, to attract the old customers to purchase again, the firm needs to lower its price significantly. The balance between selling to more consumers (by discarding compatibility and thus making the old version obsolete) at a lower price and selling to the new consumers only (by making the product compatible so increasing its value through network externalities) but at a higher price determines the monopolist's decision on compatibility.

The present paper addresses the issue of backward compatibility from a different perspective. Instead of focusing on the durable good problem, we argue that firms may use compatibility as a tool to soften price competition. Unlike Choi assuming a monopolistic market, the present paper develops a model of duopoly, where the driving force is the strategic interactions between firms. Our model predicts that firms' second period choice on backward compatibility is determined by firms' first period market share. In general, the firm that enjoys a greater market share in the first period is more likely to preserve backward compatibility in the second period and thus will charge a higher price accordingly. Here, maintaining compatibility allows firms to extract more surplus from the consumers and at the same time softens price competition in the second period. When firms take into consideration the effect of the first period market share on their second period profit, they compete more aggressively at the early stage in order to establish a larger consumer base. However, if it is too costly to exclude one's competitor from the market, then it is possible that the firm with cost advantage would price "softly" in the first period to make sure its rival's market share is not too small so that fierce price competition won't occur in the period that follows.

The present paper is closely related to the switching cost literature (e.g. Banerjee & Summers, 1987; Gabszewicz et al., 1992; Klemperer, 1987a, b, 1995). In our model a consumer faces switching cost in the second period if he is a first period customer of a firm which preserves backward compatibility. Instead of assuming the presence of switching cost to be exogenously given, as in the papers just cited, in our model firms introduce switching costs through their compatibility choices as part of the profit-maximizing decisions.

The rest of the paper is organized as follows. The next section outlines the model. Section 3 through Section 5 characterize the market equilibrium, and Section 6 contains the concluding remarks.

2. THE MODEL

Consider a linear city of length 1. A continuum of consumers of unit mass is distributed uniformly along the city. Two firms are located at the two ends of the city, with Firm 1 at location $x = 0$ and Firm 2 at $x = 1$. Each firm produces a product which brings a gross surplus (gross of the price and any potential travel cost) of v to a consumer who makes a purchase. It is assumed that the two firms' products are not mutually compatible although the gross surplus they bring to a consumer is the same. An example is the SLR camera market. Cameras of different brands have the same functionality (i.e. taking pictures) and thus give a consumer the same gross surplus. However, lenses and camera bodies from different manufacturers are generally not interchangeable.[9]

The market exists for two periods, and in each period firms produce a product of a different generation. We assume that the products produced by the two firms are not infinitely durable and, for simplicity, assume that the products last for only one period.[10] Firms' second-generation products may be upgraded versions of their predecessor products, but for simplicity we assume the gross surplus that each new product brings to the consumers is equal to v. It is assumed that in each period a consumer buys at most one product, which may be due to the income constraint.

At the start of the second period, each firm makes the decision whether or not to make its second-generation product compatible with its first-generation product. If the products are compatible, consumers who have bought from Firm i in both periods obtain some extra surplus δ. That is, the surplus a consumer obtains by purchasing the new version from the same firm is $v + \delta$. In contrast, if a firm decides not to make its new product compatible with the old version, then a consumer obtains surplus v by buying from the same firm again, which is the same as in the case when the consumer buys from different firms in each successive period.[11]

It is assumed that preserving backward compatibility is costly. Since the product of the new generation usually offers new features and often utilizes new technology, we assume that making the new product compatible requires an additional fixed engineering cost $F > 0$.

To purchase the product, consumers incur cost t per unit of length traveled. So a consumer located at point x incurs travel cost $T_1 = xt$ if he purchases from Firm 1 and $T_2 = (1 - x)\,t$ if he purchases from Firm 2. It is assumed that $(1/9)(6v + 11\delta - 4\sqrt{4\delta^2 + 6\delta v}) \leq t \leq (v + \delta)/2$.[12]

Now we are ready to characterize consumers' purchasing behavior. It is assumed that consumers are myopic in the sense that they make their first period purchase decision based on their payoffs of the first period only and do not consider whether the firm they purchase from would make its second-generation products compatible.[13] Hence, in the first period a consumer buys from Firm i if

$$v - p_{i1} - T_i \geq 0,$$

and

$$v - p_{i1} - T_i \geq v - p_{j1} - T_j,$$

where p_{i1} and p_{j1} are Firm i and j's first period prices respectively.

In the second period, when Firm i's products are compatible, its first period customers will repurchase from it if: (1) the net surplus from purchasing is non-negative; and (2) the net surplus from buying from Firm i again is at least as great as that from switching to Firm j. That is,

$$v + \delta - p_{i2} - T_i \geq 0,$$

and

$$v + \delta - p_{i2} - T_i \geq v - p_{j2} - T_j,$$

where p_{i2} and p_{j2} are Firm i and j's second period prices, respectively.

When Firm i's products are incompatible, consumers' behaviors are the same as in the first period except that purchase decisions depend on the firms' second period prices.

Note that when backward compatibility is preserved, with the presence of the extra surplus coming from buying the same firm's products, the firms' demands are discontinuous in the second period. In particular, a firm's demand is higher when trying to sell to their first period customers than when trying to induce the rival firm's customers to switch. This discontinuity in the second period demand is a key factor that affects each firm's pricing behavior and its compatibility choice.

Finally, we describe the firms' problems. From each firm's point of view, our model can be considered as a three-stage game. In the first stage firms choose their first period prices; in the second stage they decide whether or not to incur the fixed cost F to make their second-generation products backward compatible; and in the third stage, given the compatibility decisions, each firm sets its second period price. It is assumed that in the second period firms are not able to price discriminate among consumers. That is, a firm is not able to charge different prices for those who purchased from it in the first period and those who didn't. Firms face constant marginal production costs. For Firm i, the first period unit cost is $c_i \geq 0$, and in the second period, we assume both firms have an identical unit cost k, where $k \leq \min\{c_1, c_2\}$.[14] For simplicity, we can normalize k to be zero and assume there is no discounting so that firms maximize each period's profit.

We assume that in equilibrium the market is fully covered in the first period. For the moment let's also assume that neither firm monopolizes the market in the first period. Hence, there exists a point in the open interval (0, 1) such that the first period market is partitioned between the two firms, and let that point be α. Therefore, in the first period the consumers located in the region $[0, \alpha]$ buy from Firm 1 and the consumers located in $(\alpha, 1]$ buy from Firm 2. Note that our assumption on t ensures that in the second period, if Firm i operates as a local monopolist over its first period customers and produces a compatible product, it is willing to serve all of them for any $\alpha \in (0, 1)$.[15] Hence, the market must be fully covered in the second period as well.

3. THIRD-STAGE PRICE COMPETITION

3.1. Market Configurations

To generate a subgame perfect Nash equilibrium, we solve the model by backward induction. In the third stage, firms choose their second period prices given their compatibility choices and the first period market partition point α.

In the second period, the possible market configurations are the following. (1) Both firms sell to their first period customers only. (2) Firm 1 serves both its own previous customers and some of Firm 2's. (3) Firm 2 serves both its own previous customers and some of Firm 1's.[16] These observations lead to the following general result.

Lemma 1. In the second period, the firm that produces a backward compatible product will only sell to its first period customers in equilibrium.

Proof: Suppose in the second period that Firm i producing a compatible product and selling to some of Firm j's first period customers is part of an equilibrium. Then Firm j's first period customers who purchase from Firm i in period 2 do not obtain any extra surplus. Hence, given any price charged by Firm j, Firm i's second period best response function must be the same as it would be if Firm did not preserve compatibility. Hence, for any cost $F > 0$, Firm i making its product compatible is strictly dominated. This contradicts with the assumption of equilibrium. □

Lemma 1 says that in the second period if a firm ends up competing for its rival's first period customers, then maintaining compatibility is not worthwhile no matter how small the (positive) cost of compatibility is. The reason is that if a firm is not able to charge different prices for its own and its rival's previous customers, then in order to sell to the latter group, it has to lower its price significantly. However, if the firm successfully attracts some of its rival's old customers, then all of its own first period customers must buy from it again as well. By making its product backward compatible this firm only increases the surplus that its first period customers obtain but does not increase its profit because the firm cannot charge a higher price to extract the extra surplus. Hence, for any positive cost associated with preserving compatibility a firm would strictly prefer not to do so if it decides to compete for its rival's old customers in the second period.

Let us consider the cases in which one firm serves some of its rival's first period customers (and the other only sells to its own old customers) in period 2. The scenario where neither firm makes its second-generation product compatible is trivial because in this case consumers' second period purchasing choice is independent of their behavior in period 1. So in this section, we only outline the case where one firm does make its products compatible. (By Lemma 1 the scenario where both firms preserve backward compatibility and one firm serves its rival's previous customers is not an equilibrium.)

Case 1. Firm 1 (the incompatible firm) serves both its own and some of Firm 2's (the compatible firm's) first period customers.

In this case, there exists one first period customer of Firm 2 who is indifferent between purchasing from either firm in the second period. Let this consumer's location be x', then we have

$$v - p_{12} - x't = v + \delta - p_{22} - (1 - x')t,$$

which implies

$$x' = \frac{p_{22} - p_{12} + t - \delta}{2t}. \tag{1}$$

Firm 1's market demand is given by x' and Firm 2's is given by $1 - x'$. For a given price charged by Firm 2, Firm 1 maximizes the following profit function.

$$\pi_{12} = \left[\frac{p_{22} - p_{12} + t - \delta}{2t}\right] p_{12}.$$

Optimization yields

$$p_{12} = \frac{p_{22} + t - \delta}{2}. \tag{2}$$

Substituting Eq. (2) into Eq. (1), we have $x' = (t - \delta + p_{22})/4t$. By the assumption that Firm 1 serves some of Firm 2's first period customers, we need to require

$x' > \alpha$, which implies

$$p_{22} > 4\alpha t - t + \delta. \tag{3}$$

For a given price charged by Firm 1, Firm 2 optimizes the profit function

$$\pi_{22} = \left\lfloor \frac{p_{12} - p_{22} + t + \delta}{2t} \right\rfloor p_{22} - F.$$

The first order condition yields

$$p_{22} = \frac{p_{12} + t + \delta}{2}. \tag{4}$$

Similarly, we can express x' in terms of p_{12}, which is $x' = (3t - \delta - p_{12})/4t$. The condition $x' > \alpha$ yields

$$p_{12} < -4\alpha t + 3t - \delta. \tag{5}$$

The expressions (2) and (4) are Firms 1 and 2's respective best response functions under the condition that Firm 1 serves some of Firm 2's first period customers. However, these best response functions can yield an interior equilibrium only if conditions (3) and (5) are satisfied.

Solving Eqs (2) and (4), we have

$$p_{12} = t - \frac{\delta}{3},$$

and

$$p_{22} = t - \frac{\delta}{3}.$$

Conditions (3) and (5) are satisfied if a $\alpha < (3t - \delta)/6t$. We see that $p_{22} > p_{12}$. The price difference is the premium that Firm 2 enjoys by preserving backward compatibility.

Case 2. Firm 2 (the incompatible firm) serves both its own and some of Firm 1's (the compatible firm) first period customers.

In this case, there exists one of Firm 1's first period customers who is indifferent between the two firms' second period products. Symmetric to the solutions in Case 1, we have the following best response functions.

$$p_{12} = \frac{p_{22} + t + \delta}{2}, \tag{6}$$

and

$$p_{22} = \frac{p_{12} + t + \delta}{2}. \tag{7}$$

Solving Eqs (6) and (7), we have

$$p_{12} = t + \frac{\delta}{3},$$

and

$$p_{22} = t - \frac{\delta}{3}.$$

These prices are valid if $\alpha > (3t + \delta)/6t$. As in Case 1, we see that the compatible firm charges a higher price than the incompatible firm.

3.2. Equilibrium of the Third-Stage Subgame

3.2.1. Neither Firm's Product is Backward Compatible

Consider first the simplest case in which neither firm makes their second-generation products compatible with their respective predecessors. In this case, since consumers do not obtain any extra surplus from buying from the same firm, their purchase decision is independent of what they did in the first period. Therefore, neither firm enjoys any advantage from the first period customer base. Recall that by our assumption the market is fully covered and not monopolized in the second period. Let x be the location of the consumer who is indifferent between buying from Firm 1 and Firm 2 in the second period. Consumers located in the interval $(0, x)$ will buy from Firm 1 and consumers located in the interval $(x, 1)$ will buy from Firm 2. The definition of x gives rise to the following equation,

$$v - p_{12} - x't = v - p_{22} - (1 - x)t,$$

which implies,

$$x' = \frac{p_{22} - p_{12} + t}{2t}.$$

Given the market demand, Firms 1 and 2 maximize the following second period profit functions respectively,

$$\pi_{12} = \left(\frac{p_{12} - p_{22} + t}{2t}\right) p_{12}, \tag{8}$$

and

$$\pi_{22} = \left(\frac{p_{12} - p_{22} + t}{2t}\right) p_{22}. \tag{9}$$

Maximizing Eq. (8) over p_{12} and Eq. (9) over p_{22} yields

$$p_{12} = \frac{1}{2}(p_{22} + t), \tag{10}$$

and

$$p_{22} = \frac{1}{2}(p_{12} + t), \tag{11}$$

Solving Eqs (10) and (11) yields $p_{12} = p_{22} = t$ and $x = 1/2$ and both firms' second period profits are $t/2$.

3.2.2. Both Firms' Products are Backward Compatible

Next we consider the case in which both firms make their second-generation products compatible with their first-generation products. By Lemma 1, it immediately follows that either firm serving some of its rival's first period customers cannot be part of an equilibrium. Hence, we are going to focus on the last case, i.e. both firms serve their first period customers only. It is convenient to define the following pricing strategies.

Definition 1 *(Monopolizing Strategy)*. Let α be the point of first period market partition. Given a price p_{j2} charged by Firm j, Firm i is said to play a monopolizing strategy if it charges a price such that its first period customer who is located at point α obtains zero net surplus by purchasing from it again. We call this price the local monopoly price.

Definition 2 *(Competing Strategy)*. A firm is said to play a competing strategy if it charges any price lower than the local monopoly price. These prices are called competing prices.

Based on the definitions, we have the following lemmas.

Lemma 2. In the second period, Firm i will play monopolizing strategy only if its rival sells to its first period customers only.

Proof: Suppose Firm j sells to some of Firm i's first period customers. This implies there exists one of Firm i's first period customer who is indifferent between the two firms' products in the second period. Hence, given Firm j's price, p_{j2}, Firm i's profit is maximized by charging a price according to its best response function $p_{i2} = (p_{j2} + t + \delta)/2$ if its product is compatible and $p_{i2} = (p_{j2} + t)/2$ if its product is incompatible, which contradicts with the assumption that local monopoly price is optimal. □

Lemma 3. If both firms make their second-generation products compatible with their respective predecessors, then in the third-stage subgame either firm charging a competing price cannot be part of an equilibrium.

Proof: Since both firms make their second-generation products compatible, we learn from Lemma 1 that in the second period both firms must sell to their first period customers only. Let α be the first period point of market partition. Suppose in equilibrium at least one firm charges a competing price. This implies the compatible firm's first period customer who is located at point α must obtain positive net surplus from purchasing from the same firm again. Also this net surplus must be at least as great as what he can obtain by purchasing from the other firm. Let ϕ be the net surplus that the consumer located at point α obtains by purchasing from the same firm again. Also denote the difference between the net surplus that this consumer can get from purchasing from the two firms by $\Delta \geq 0$. If this is the case then the firm which charges the competing price can raise its price by ε such that $\varepsilon \leq \min\{\phi, \Delta\}$ and sell to the same group of consumers, which strictly increases its profit. This contradicts with the assumption of equilibrium. □

Lemma 2 states that a firm will acts as a local monopolist in the second period only if its rival does not try to "invade" into its "turf". Otherwise it should price optimally according to its best response functions. Lemma 3 says that if both firms decide to preserve backward compatibility, then the subgame perfect equilibria (if there exist any) must involve both firms playing monopolizing strategy. This is because if a firm ends up competing for its rival's old customers, then it doesn't pay for this firm to make its product compatible in the first place.

Given the compatibility choices, however, firms' second period pricing decisions are determined by the size of their existing consumer bases. Whether to charge the local monopoly price over its first period customers only or to charge a competing price and grab a larger market share depends on how large a firm's consumer base is. We have the following proposition.

Proposition 1. Let α be the first period market partition point. If both firms make their second-generation products compatible with their respective predecessors, then Firm 1 and Firm 2 both charging the local monopoly price is a unique Nash equilibrium in the third-stage subgame if and only if $\alpha \in [\alpha_l, \alpha_h]$, where $\alpha_l \equiv (4\delta + 3v - 2\sqrt{4\delta^2 + 6\delta v})/9t$ and $\alpha_h \equiv 1 - \alpha_l$.

Proof: First note that the assumption $t \geq (6\delta + 11\delta - \sqrt{4\delta^2 + 6\delta v})/9$ implies $\alpha_l \leq (3t - \delta)/6t$ (or $\alpha_h \geq (3t - \delta)/6t$), so the interval $[\alpha_l, \alpha_h]$ is non-empty.

In the second period, firms' local monopoly prices are given by

$$p_{12}^m = v + \delta - \alpha t, \tag{12}$$

and

$$p_{22}^m = v + \delta - (1-\alpha)t. \tag{13}$$

Suppose Firm 1 charges p_{12}^m. If Firm 2 charges the local monopoly price p_{22}^m as well, it has second period profit $\pi_{22}^m = [v + \delta - (1-\alpha)t](1-\alpha) - F$. If, however, Firm 2 decides to sell to some of Firm 1's first period customers, it would charge a price p_{22} according to its best response function (Eq. (7)). Hence, we have $p_{22} = (v + (1-\alpha)t)/2$.These prices yield a market demand for Firm 2 given by $(v + (1-\alpha)t)/4t$ and Firm 2's profit is

$$\pi_{22}^c = \left\lfloor \frac{v + (1-\alpha)t}{2} \right\rfloor \left\lfloor \frac{v + (1-\alpha)t}{4t} \right\rfloor - F = \frac{[v + (1-\alpha)t]^2}{8t} - F.$$

Given p_{12}^m, Firm 2 also charging the local monopoly price yields higher profits if

$$[v + \delta - (1-\alpha)t](1-\alpha) \geq \frac{[v + (1-\alpha)t]^2}{8t}. \tag{14}$$

Inequality (14) implies,

$$\alpha \leq 1 - \frac{3v + 4\delta - 2\sqrt{4\delta^2 + 6\delta v}}{9t}. \tag{15}$$

Next suppose Firm 2 charges its local monopolist price p_{22}^m. Given Firm 2's price, the condition under which Firm 1 earns higher profit by playing monopolizing strategy instead of competing can be found as symmetric as Eq. (15), which is

$$\alpha \geq \frac{3v + 4\delta - 2\sqrt{4\delta^2 + 6\delta v}}{9t}. \tag{16}$$

Define $\alpha_l \equiv (3v + 4\delta - 2\sqrt{4\delta^2 + 6\delta v})/9t$ and $\alpha_h \equiv 1 - \alpha_l$. We have established that when $\alpha \in [\alpha_l, \alpha_h]$, given Firm j charging the local monopoly price p_{j2}^m, Firm i's profit is maximized by charging p_{i2}^m as well. Hence, the price pair (p_{12}^m, p_{22}^m) constitutes a Nash equilibrium in the third-stage pricing game. The uniqueness follows directly from Lemma 3. □

Proposition 1 states that given that both firms make their second-generation products compatible, if neither firm's market share is too small, then there exists a unique Nash equilibrium in the second period such that both firms act as local monopolists. The intuition is clear: Being a local monopolist is profitable for a firm only if there is a large enough market to monopolize over. Otherwise pricing aggressively so as to grab a greater market share will be desirable.

3.2.3. Only One Firm's Product is Backward Compatible

If in the second period market only one firm makes its product backward compatible, then firms' pricing behaviors will be very different from the case in which compatibility is preserved by both firms. This is because without compatibility and the associated extra surplus it brings, the incompatible firm's incentive to be a local monopolist in the second period is eliminated. As a consequence, this firm will charge a competing price in the second period and try to attract its rival's first period customers. Given the incompatible firm's pricing strategy, its rival, whose product is compatible, will not charge the local monopoly price either because the optimal price is then given by the best response function as described in Section 3.1. Therefore, with one firm not preserving backward compatibility, price competition in the second period becomes much more intense because in the equilibrium neither firm will be local monopolists regardless of the first period market outcome. The following proposition formally summarizes this intuition.

Proposition 2. If only one firm makes its second-generation product compatible, then in the second period neither firm charging the local monopoly price can be part of an equilibrium.

Proof: See Appendix. □

4. SECOND-STAGE COMPATIBILITY DECISION

By making its products compatible, a firm is able to extract more surplus from its first period customers at the cost of F. However, compatibility is valuable only for those consumers who purchase from the same firm in both periods. If in the second period a firm ends up competing for its rival's previous customers, then it does not pay for the firm to maintain the compatibility in the first place. It naturally follows that firms' first period market share may play an important role in determining firms' compatibility choice. In particular, the firm with a greater consumer base in the first period is more likely to invest F and preserve backward compatibility because it is less likely for this firm to compete into its rival's turf. The following proposition confirms this intuition.

Proposition 3. Let $\alpha \in (0, 1)$ be the first period point of market partition and let s_i and s_j be Firms i and j's first period market shares, respectively. Let $s^* = \min\{s_i, s_j\}$.

(1) If $\alpha \in [\alpha_l, \alpha_h]$ and $F \leq \min\{F^*, F^{**}\}$, where $F^* = s^*(v + \delta - 3s^*t)$ and $F^{**} = s^*(v + \delta - s^*t) - ((3t - \delta)^2/18t)$, then in the second period both firms making their products backward compatible and charging the local monopoly prices is the unique Nash equilibrium of the last two stage subgames.
(2) If $\alpha \in (0, \alpha_l)$ and $F \leq (\delta^2 + 6\delta t)/18t$, then the unique Nash equilibrium of the last two stage subgames involves only Firm 2 preserving backward compatibility and firms charging $p_{12} = t - (\delta/3)$ and $p_{22} = t + (\delta/3)$.
(3) If $\alpha \in (\alpha_h, 1)$ and $F \leq (\delta^2 + 6\delta t)/18t$, then the unique Nash equilibrium of the last two stage subgames involves only Firm 1 preserving backward compatibility and firms charging $p_{12} = t + (\delta/3)$ and $p_{22} = t - (\delta/3)$.

Proof: See Appendix. □

The above proposition says that if the difference between firms' first period market shares is not too large and if the cost associated with maintaining compatibility is not too high, then both firms will do so. Here backward compatibility becomes a tool for the firms to soften price competition. By making their products compatible in the second period, both firms are able to act as local monopolist over their first period customers and earn higher profits. However, if a firm's first period market share is too small, then the monopoly profit from a small customer base is less than that of competing aggressively for the other firm's old consumers. As a consequence, preserving compatibility is not worthwhile. Note that in this case, the firm with the greater first period market share will still make its products compatible as long as the cost is low enough. The reason is that even if both firms charge competing prices, the extra surplus from compatibility still allows a firm to command a price premium. So if the market leader's first period consumer base is sufficiently large, compatibility can still be justified. In what follows, we will assume $F \leq \alpha_l(v + \delta - \alpha_l t) - ((3t - \delta)^2/18t)$, which ensures that for any $\alpha \in [\alpha_l, \alpha_h]$, both firms will preserve compatibility in the second period.

This result is consistent with our observations in the earlier examples. PalmSource, as the leader of the PDA operating system market, has the largest consumer base. In 2001, among all handheld devices sold worldwide, 57% were powered by Palm OS and in the enterprise market, Palm OS had a market share of 51%.[17] As a result, the benefit it enjoys by preserving backward compatibility is far greater than that for Symbian, which has a much smaller share in the handheld device market.[18] By making its new-generation operating system compatible with the older versions, Palm is able to charge a price premium for its latest PDAs. Although achieving compatibility is costly, Palm's large consumer base ensures the investment to be profitable. For Symbian, however, backward compatibility is of less importance because the number of consumers who value compatibility is too small and thus the extra surplus that can be extracted does not justify the investment.

Similar explanations can be applied to the camera industry. Among the 35mm SLR manufactures, Nikon enjoyed an absolute advantage in the professional 35mm camera market over Canon and Minolta until the mid-1980s. For Nikon, the benefit of maintaining compatibility of its products was substantial. This is because the flexibility brought by the interchangeability between two generation of lenses and camera bodies was a great attraction to Nikon's older customers, especially for the professional photographers who had much greater demand for a second or even third camera system. In contrast, Canon and Minolta's existing customer base was much smaller, and accordingly their incentive to keep their products compatible was much lower.[19] So they chose not to make their new generation products compatible with their older versions when preserving compatibility is costly.

Since firms' first period market shares play an important role in determining the market outcome in the period that follows, it is not hard to imagine that forward-looking firms will try to manipulate these outcomes to their best interest through strategically setting their prices in the first period. For example, if firms envision that a certain set of conditions will lead to a second period market occupied by two local monopolists, then they may compete more aggressively in the first period because a greater consumer base increases a firm's monopoly profits. On the other hand, under certain conditions a firm that otherwise would compete aggressively in the first period may refrain from doing so if it realizes that leaving its rival too little a market share will result in more intense price competition in the second period. Hence, the strategic consideration of the possible market outcomes of the future will affect a firm's current behavior. In the next section, we will consider firms' first period pricing strategy.

5. FIRST-STAGE PRICE COMPETITION

In the first stage, firms compete in the first period price to maximize their two-period profit. Without loss of generality, we assume $c_2 \geq c_1$. Denote the cost difference $c_2 - c_1$ by Δc.

First, consider the case when both firms choose to make their products compatible and both charge the monopoly prices in the second period. In this case, firms' total profits are affected by two forces that work in opposite directions. Since a larger market share means greater monopoly profit in the second period, firms have the incentive to compete aggressively for market share in the first period. This aggressive price competition, however, sacrifices first period profits.

Hence, firms' first period pricing decision will be based on the balance of the two forces.

Suppose α^* is the location of the indifferent consumer in the first period. Hence, we have $\alpha^* = (p_{21} - p_{11} + t)/2t$. Firm 1 maximizes the following profit function by choosing p_{11}.

$$\pi_1 = \left(\frac{p_{21} - p_{11} + t}{2t}\right)\left\{(p_{11} - c_1) + \left\lfloor v + \delta - \left(\frac{p_{21} - p_{11} + t}{2t}\right) t \right\rfloor\right\} - F. \tag{17}$$

Firm 2 chooses p_{21} to maximize its total profit

$$\pi_2 = \left(\frac{p_{11} - p_{21} + t}{2t}\right)\left\{(p_{21} - c_2) + \left\lfloor v + \delta - \left(\frac{p_{11} - p_{21} + t}{2t}\right) t \right\rfloor\right\} - F. \tag{18}$$

The first order conditions for Eqs (17) and (18) are, respectively,

$$p_{11} = \frac{1}{3}[2p_{21} + 2t + c_1 - (v + \delta)], \tag{19}$$

and

$$p_{21} = \frac{1}{3}[2p_{11} + 2t + c_2 - (v + \delta)]. \tag{20}$$

Solving Eqs (19) and (20), we find

$$p_{11} = \frac{3c_1 + 2c_2}{5} + 2t - (v + \delta), \tag{21}$$

and

$$p_{21} = \frac{2c_1 + 3c_2}{5} + 2t - (v + \delta). \tag{22}$$

The first period market will be partitioned at point $\alpha^* = (1/2) + (\Delta c/10t)$. Assuming $\Delta c < 5t$, we have $\alpha^* \in (0,1)$.

It is interesting to compare these prices with the ones that will be generated if firms don't take into consideration the impact of the first period price on their second period profit. Denote these prices by p'_{11} and p'_{21} and we have

$$p'_{11} = \frac{2c_1 + c_2}{3} + t, \tag{23}$$

and

$$p'_{21} = \frac{c_1 + 2c_2}{3} + t. \tag{24}$$

Taking the difference between p_{11} and p'_{11} and between p_{21} and p'_{21}, we have

$$p_{11} - p'_{11} = \frac{\Delta c}{15} + t - (v + \delta),$$

and

$$p_{21} - p'_{21} = -\frac{\Delta c}{15} + t - (v + \delta).$$

Given our assumption $t \leq (v + \delta)/2$, the expression $t - (v + \delta)$ is negative. Hence, it immediately follows that Firm 2 (the high-cost firm), after taking into account of the impact on second period profit, sets a lower price than it would if this consideration were absent. For the low-cost firm, the price difference under the two scenarios will be negative if $\Delta c < 15(v + \delta - t)$, which is satisfied under the assumption $\Delta c < 5t$ and $v + \delta \geq 2t$. Hence, both firms' first period prices are lower if the total profit is of the concern. This result confirms our intuition that when first period market shares positively affect firms' second period profits, firms compete more aggressively to establish their installed bases in the first period. Comparing the price changes between the two firms, we find that the high-cost firm cuts its price more than the low-cost firm. This is not surprising because the net marginal benefit from price cutting is greater for the firm with the smaller market share than the other.

Recall that the above results are based on the assumption that both firms make their products compatible and charge monopoly price in the second period. By Proposition 2 this can be an equilibrium only if the first period market partition point α^* falls within the interval $[\alpha_l, \alpha_h]$. Hence, the above solutions for p_{11} and p_{21} is valid only if $\alpha_l \leq (1/2) + (\Delta c/10t) \leq \alpha_h$, or $10t(\alpha_l - (1/2)) \leq \Delta c \leq 10t(\alpha_h - (1/2))$. Since $\alpha_l \leq (3t - \delta)/6t$, which is strictly less than 1/2, the first part of the inequality is satisfied universally. The second part states that our solutions from Eqs (19) and (20) are valid only if the difference between two firms' marginal cost is sufficiently small.

If $\Delta c > 10t(\alpha_h - (1/2))$, charging prices according to Eqs (21) and (22) cannot be optimal because with the market partition point $\alpha^* > \alpha_h$, in the second period Firm 2 will choose not to make its products compatible and the third-stage price competition will yield an equilibrium that involves both firms charging competing prices. Hence, the objective functions Eqs (17) and (18) are not proper in the first place. When $\alpha^* > \alpha_h$, the second period market equilibrium yields $p_{12} = t + (\delta/3)$ and $p_{22} = t - (\delta/3)$. The market is partitioned at the point $(3t + \delta)/6t$. Note that in this case firms' second period prices and market shares are independent of α^*. Also note that if firms only maximize their first period profit, the market partition point is given by $(p'_{21} - p'_{11} + t)/2t$. Because the price difference $p'_{21} - p'_{11}$ is smaller than that when firms take into account their second period profits, given any c_1 and c_2 such that $c_2 \geq c_1$, the market partition point must be greater (closer to 1) when firms maximize their first period profits only.

If in the second period firms end up charging competing prices, both firms' profits are lower than they would be in equilibrium in which both play monopoly strategy. Hence, Firm 1, the cost leader, may consider some other pricing strategy to improve its profit. Particularly we note that by charging a higher price in the first period, Firm 1 can manipulate the first period market shares to the extent that Firm 2 will preserve backward compatibility and play monopoly strategy in the second period.

Consider the following pricing strategies. Firm 1 charges a first period price such that the consumer located at point α_h is just indifferent between buying from either firm and Firm 2 prices according to Eq. (20). That is,

$$p^*_{11} = p_{21} + (1 - 2\alpha_h)t, \tag{25}$$

and

$$p^*_{21} = \frac{1}{3}[2p_{11} + 2t + c_2 - (v + \delta)]. \tag{26}$$

Solving for p^*_{11} and p^*_{21} we have,

$$p^*_{11} = c_2 + (5 - 6\alpha_h)t - (v + \delta), \tag{27}$$

and

$$p^*_{21} = c_2 + (4 - 4\alpha_h)t - (v + \delta). \tag{28}$$

At these prices, the market is partitioned just at point α_h and the two firms' total profits are respectively,

$$\pi_1 = \alpha_h[\Delta c + (5 - 7\alpha_h)t] - F,$$

and

$$\pi_2 = 3t(1 - \alpha_h)^2 - F.$$

As the following proposition shows, under certain conditions the pricing strategies described above can be part of a subgame perfect equilibrium.

Proposition 4.

(1) If $\Delta c \leq 10t(\alpha_h - (1/2))$, then firms' first period prices given by Eqs (21) and (22) and in the second period both firms making their products

compatible with their respective predecessors and both charging the local monopoly prices constitute a subgame perfect Nash equilibrium.

(2) If $\Delta c > 10t(\alpha_h - (1/2))$, then firms' first period prices given by Eqs (27) and (28) respectively, and in the second period both firms making their products compatible with their respective predecessors and both charging the local monopoly prices constitute a subgame perfect Nash equilibrium if $F \leq 3t\alpha_l^2 - ((6t\alpha_l - v - \delta)^2/8t) - ((3t - \delta)^2/18t)$.

Proof: See Appendix. □

The above proposition says that if the cost differential between the two firms is small, then both firms will compete aggressively in the first period in order to establish a larger consumer base. This allows them to extract more surplus in the following period by charging local monopoly prices. However, if the cost differential between the two firms is large, then the firm that enjoys the cost advantage actually may price "softly" in the first period. This is because the cost leader rationally expects that if its rival is left with too small a market share in the first period, then maintaining backward compatibility is not desirable, which in turn will result in fierce price competition and lower profits for both firms in the second period. Hence, if the cost associated with preserving backward compatibility is sufficiently small, it pays the low-cost firm to sacrifice some of its first period profit to make sure its rival will "cooperate" in the period that follows, which will yield higher total profits for both firms.

6. CONCLUDING REMARKS

In this paper, we present a simple model of firms' compatibility choice between their product generations and the associated pricing behaviors. The product market is characterized by the feature that backward compatibility yields some extra benefit to a consumer if he purchases from the same firm again. It is shown that firms' decisions on compatibility depend crucially on their first period market shares. If a particular firm's products are compatible across generations but not with the product of the other firm, then consumers face a switching cost if they buy from different firms in the two periods. This makes it possible for firms to act as local monopolists in the second period. Therefore, firms can use backward compatibility as a tool to relax price competition in the second period.

However, maintaining backward compatibility is profitable only if a firm's first period market share is large enough. That is, a firm will choose to make its products compatible only if the monopoly profit over its first period consumer base is higher than what it can earn by competing for its rival's previous customers. If a firm's first period market share is too small, then it is not worthwhile to make the effort to maintain the compatibility if doing so is costly. In the latter case firms will end up in a situation where both firms earn lower profits than they would by following the monopolizing strategy.

Because the second period market outcome depends on the first period market share, firms' pricing behaviors will be altered in the first period due to their strategic consideration of their future profitability. In particular, I show that if the cost differential between firms is small, to increase the second period profits, competition in the first period is intensified because firms are more aggressive in competing for greater consumer bases. However, if the cost differential between firms is large, then the firm with a cost advantage may have the incentive to price "softly" in the first period so that its rival's market share is not too small and thus avoid intense price competition in the period that follows. This leads to a collusion-like situation in the first period.

There are several caveats to my analysis that need to be pointed out. First, I have assumed the products are not durable. Although this assumption greatly simplifies my analysis, it eliminates a very important aspect of the problem because in many market where backward compatibility is of importance, the products are durable. When firms make their decisions on backward compatibility, it's very likely that controlling the durability of earlier-generation products is part of the consideration. While in my model firms generally prefer compatibility because it softens price competition, a durable good manufacturer may consider otherwise because of the incentive of planned obsolescence. Second, I ignore the issue of network externality in my model although it partly motivates the idea that backward compatibility is valuable to consumers. Network externality is observed in many industries, especially those of information technology. The presence of network externality may change my results in two ways. On the one hand, as described in the introduction, preserving backward compatibility will enlarge the network size and thus increase each consumer's valuation on the compatible firm's product. This effect will strengthen each firm's incentive to preserve compatibility. On the other hand, however, with network externality the first period installed base becomes even more important to firms and this will lead to more intense competition in the first period. Note our last result that the firm with cost advantage may charge a higher price in the first period to encourage its rival to become a local monopolist depends on the assumption that no firm can profitably drive its rival out of the market in the first period. With the presence of network externality this assumption is more likely to be violated because the gain of being the single producer in the second period may outweigh the loss of first period profit. This then leaves the possibility that instead of pricing softly in the first period, the low-cost firm may actually compete more aggressively so that it can become a monopolist (instead of a local monopolist) in the second period.

Despite these caveats, I believe the fundamental insight of this paper is still valid. It provides a different view on firms' incentive to preserve backward compatibility and suggests that more research on this issue is still needed.

NOTES

1. Matutes and Regibeau (1988) have made the point that by mixing and matching product components and building their own systems, consumers can obtain higher surplus than if they only accept the systems assembled by the manufacturers. Matutes and Regibeau's paper focuses on the compatibility issue among products from different manufacturers instead of the backward compatibility issue.

2. As of June 2003, Palm Inc. is in the process of spinning off PalmSource, which after the transaction will become an independent company. The board of Palm Inc. announced the final approval for the spin-off on June 4, 2003.

3. Source of the Palm OS story: Vnunet.com hardware analysis, "Will New Palms Win Laurels?" by Maggie Williams, posted on 08/23/2002. The article is available at http://www.vnunet.com/analysis/1134570.

4. PDAs and cell phones historically belong to two totally different markets. Since the late 1990s, however, there started the trend of convergence of these two products with the development of wireless communication technology which allows for rapid data transimission between wireless devices. For example, Palm, Handspring (which has been acquired by Palm), Kyocera, Samsung, and Sony have introduced a wide range of PDAs with wireless communication capabilities (including traditional voice transmission and high-speed internet access) based on Palm OS platform. Microsoft also have introduced two operating systems, Pocket PC Phone edition and Smartphone OS, and licensed to wireless service providers including Orange from France. Currently these devices are known as either "communicators" or "smartphones" depending on the emphasis on the products' PDA functionality or as a high-end cell phone. However, this distinction is becoming increasingly obscure as the convergence continues.

5. The joint venture, Symbian, was established in 1998 and is now owned by Nokia, Ericsson, Mitsushita (Panasonic), Motorola, Psion, Samsung Electronics, Siemens and Sony Ericsson.

6. *Source:* Geek.com PDA review by Milan Tjioe, posted on 12/06/2001. The article is available at http://www.geek.com/hswrev/pda/nokia9210/index.htm.

7. To be accurate, in 1983 Nikon released its first AF camera model F3AF, which was a revised version of its third-generation flagship F3. However, the AF function of this camera was available only with two lenses that were specially designed for the model and these lenses were discontinued shortly after. Hence, F3AF is more like an experimental model instead of for commercial production on large a scale.

8. The Minolta Maxxum example was also cited by Choi (1994). The source of the Nikon story is the *Photography in Malaysia* website (http://www.mir.com.my/rb/photography/),

which contains a very detailed documentation of the history of several major Japanese brands for 35mm cameras.

9. The issue of compatibility between products by different manufacturers have been studied by many researchers, as cited in the text. Here we assume that the products by two firms are incompatible so that we can concentrate on each firm's compatibility decision between their own product generations.

10. This assumption allows us to emphasize firms' strategic considerations associated with backward compatibility other than planned obsolescence.

11. Recall our camera example. In this case, a consumer obtains some extra benefit if he purchases two cameras of different generations from the same firm when backward compatibility is preserved because this allows him to assemble two customized camera systems by switching the lens and the camera body. This extra benefit would be absent if backward compatibility is not preserved or if this consumer buys from a different firm in each period.

12. The interval $\lfloor(1/9)(11\delta + 6v - 4\sqrt{4\delta^2 + 6\delta v}), (v + \delta)/2\rfloor$ is non-empty if δ is not too small. Specifically it requires $\delta > 0.03v$, which will be assumed.

13. The same assumption is made by Gabszewicz et al. (1992). A more general approach should allow consumers to have rational expectation. However, the main point made in this paper is unaffected by this assumption because consumers' expectations will have a *direct* effect only on the first period market outcome, while the major result of this paper is concerned with firms' second period behaviors taking the first period market outcome as given.

14. This assumption is made for simplicity of the analysis. A more general assumption on firms' second period marginal costs will make the presentation more complicated but will not affect the main results of the model.

15. To see this, suppose Firm 1 sets the monopoly price and sells to its first period customers only. Denote the location of the consumer who is indifferent between buying from Firm 1 and not buying at all by x, we have $v + \delta - p_{12} - xt = 0$, which implies $x = (v + \delta - p_{12})/t$. Firm 1's profit maximization in the second period yields $p_{12} = (v + \delta)/2$ and $x = (v + \delta)/2t$. Firm 1 is willing to serve all of its first period customers if $x \geq \alpha$. In particular, since the supermum of α is 1, $t \leq (v + \delta)/2$ is sufficient for this condition. The same result applies to Firm 2 as well.

16. The assumption that the market is not monopolized in the first period plus $k \leq \min\{c_1, c_2\}$ ensures no firm will monopolize the market in the second period as well.

17. Pocket PC, developed by Microsoft, had a market share of 20%, and other operating systems, including Symbian, accounted for 23% of the market. Source: PalmSource, http://www.palmsource.com/includes/why_palmos.pdf.

18. The specific number for Symbian's worldwide market share is not available to the author. However, the total sales of devices installing operating systems other than Palm OS and Pocket PC together had a market share of 23% (see Note 17). Among the 2001 enterprise sales, Symbian OS accounts for only 1% of the market. Source: PalmSource, http://www.palmsource.com/includes/why_palmos.pdf.

19. To be precise, at the time under discussion, Canon had a very large share in the point-and-shoot camera market. However, in this market, lens and camera body compatibility is not an issue since almost all point-and-shoot cameras have integrated body and lens.

20. To see this, note that $F^* \geq F^{**}$ if $s^* \leq (3t - \delta)/6t$. The condition $\alpha = \alpha_h$ implies $s^* = s_2 = \alpha_l$. Given the assumption $t \geq (6v + 11\delta - 4\sqrt{4\delta^2 + 6\delta v})/9$, we have $s^* \leq (3t - \delta)/6t$. Therefore, the condition on F in Proposition 2 is satisfied if $F \leq F^{**} = \alpha_l(v + \delta - \alpha_l t) - (3t - \delta)^2/18t$.

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APPENDIX A

Proof of Proposition 2

Proof: We first prove that the firm that does not maintain compatibility will not charge the local monopoly price in equilibrium. Let α be the first period market partition point. Suppose in equilibrium Firm 2's product is compatible but Firm 1's is not. Let Firm 1 charge the local monopoly price $p_{12}^{m} = v - \alpha t$. This implies that the consumer located at point α obtains zero net surplus. For any price charged by Firm 2, no customer who purchased from Firm 2 in the first period will purchase from Firm 1 because doing so results in negative net surplus. Hence, in period two Firm 1 only sells to its first period customers. Also by Lemma 2, Firm 1 playing a monopolizing strategy in the second period implies Firm 2 only sells to its first period customers as well. Therefore, Firm 2 must be charging its local monopolist price p_{22}^{m}. This implies that the consumer located at point α obtains zero net surplus if purchasing from Firm 2. Hence, the consumer located at point α is indifferent between Firms 1 and 2's products in the second period. However, given Firm 2's price p_{22}^{m}, Firm 1's profit is maximized by charging a price according to its best response function $p_{12} = (p_{22}^{m} + t - \delta)/2$. This contradicts with the assumption that Firm 1 charging p_{12}^{m} is part of an equilibrium. The case where Firm 2's product is incompatible while Firm 1's is can be proved symmetrically.

Next we prove that the firm that does make its second-generation product compatible will not charge local monopoly price either. Again consider in equilibrium Firm 1's product is incompatible and Firm 2's is. Suppose Firm 2 charges the local monopoly price. Since Firm 2's product is compatible, by Lemma 1, in equilibrium Firm 2 only sells to its first period customers. Also because Firm 2 charges the local monopoly price, by Lemma 2, Firm 1 must also serve its first period customers only. Hence, the second period market partition point is exactly the same as that in the first period, which is α. Given Firm 2 charges the local monopoly price, it follows that its first period customer located at point α obtains zero net surplus from purchasing again in the second period. The fact that this particular consumer does not switch to Firm 1 in the second period implies that the net surplus he can obtain by purchasing from Firm 1 is no greater than zero. It then follows that Firm 1 must be charging the local monopoly price. However, we have already proved that Firm 1 charging local monopoly price cannot be part of an equilibrium, hence contradiction occurs. The case where Firm 2's product is incompatible while Firm 1's is can be proved symmetrically. □

Proof of Proposition 3

Proof: Part 1. Suppose $\alpha \in [\alpha_l, \alpha_h]$. Consider Firm 1's compatibility decision. Suppose Firm 2 makes its product compatible. If Firm 1 also preserves compatibility, then by Proposition 1, both firms charging the local monopoly prices is the unique Nash equilibrium in the third-stage pricing game. Firm 1 earns the second period profit $\alpha(v + \delta - \alpha t) - F$. If Firm 1 does not maintain compatibility, then it charges a competing price according to its best response function as given by expression (2). Here we need to consider two cases. (I) When $\alpha \in [\alpha_l, (3t - \delta)/6t]$, both firms' best response functions (2) and (4) yield the interior solution which implies a second period market partition point at $(3t - \delta)/6t$ and Firm 1 charging $p_{21} = t - (\delta/3)$. Hence, Firm 1's second period profit is $(3t - \delta)^2/18t$. Note that for $\alpha \geq \alpha_l$ and $F \leq s_1(v + \delta - s_1 t) - (3t - \delta)^2/18t$, we have $\alpha(v + \delta - \alpha t) - F > (3t - \delta)^2/18t$. (II)When $\alpha \in ((3t - \delta)/6t, \alpha_h]$, no interior solutions exist by solving (2) and (4) because the condition (3) and (5) are not satisfied. The equilibrium of the third-stage pricing game in this case involves Firm 1 charging a price p^*_{12} according to its best response (2) and Firm 2 charging

$$p^*_{22} = p^*_{12} + \delta - (1 - 2\alpha)t. \qquad (29)$$

This implies $p^*_{12} = 2\alpha t$ and $p^*_{22} = \delta + (4\alpha - 1)t$. The market is partitioned at point α.

To see that this constitutes a Nash equilibrium, first we note that Firm 1's price is optimal by the definition of best response. Next we will show the optimality of p^*_{22}. Note that when $\alpha > (3t - \delta)/6t$, for any price charged by Firm 1, p^*_{22} is higher than what its best response (4) commands. Suppose Firm 2 raises its price above p^*_{22}. In this case, Firm 1 will sell to some of Firm 2's first period customers and the market will be partitioned at some point $x^* > \alpha$. However, when $x^* > (3t - \delta)/6t$, Firm 2's profit is decreasing in its price. Hence, raising its price lowers Firm 2's profit. Next suppose Firm 2 charges a price below p^*_{22}. Then it will sell to some of Firm 1's first period customers and the second period market will be partitioned at some point $x^{**} < \alpha$. Denote this price by p'_{22}. Consider two cases. First, $\alpha \in ((3t - \delta)/6t, 1/2]$. In this case, p'_{22} is lower than what Firm 2's best response function (11) commands when it serves Firm 1's old customers. When $x^{**} \leq 1/2$, for any price charged by Firm 1, Firm 2's profit is increasing in its price. Hence, Firm 2 charging a price below p^*_{22} will result in a lower profit. Next consider $\alpha \in (1/2, \alpha_h]$. In this case, p'_{22} is optimally set according to (11), which yields $p'_{22} = t(2\alpha + 1)/2$ and the market is partitioned at $x^{**} = (3 - 2\alpha)/4$. Firm 2's profit in this case is given by $t(2\alpha{+}1)^2/8$. Note that $t(2\alpha + 1)^2/8$ is increasing in α. So given our condition it reaches the maximum when $\alpha = \alpha_h$ With our assumptions on t, we have $(t(2\alpha_h + 1)^2/8) < (1 - \alpha_h)[\delta + (4\alpha_h - 1)t]$. Hence, given Firm 1 charging $p^*_{12} = 2\alpha t$, Firm 2 earns high profit by setting a price according to (29) insteadof (11).

We just showed that when $\alpha \in ((3t - \delta)/6t, \alpha_h]$ the third-stage pricing game results in a market partition point exactly at α. Since firms' prices are bounded by the local monopoly price, Firm 1's profit, which is given by $2t\alpha^2$, must be lower than $\alpha(v + \delta - \alpha t)$. Note that given our assumption $t \leq (v + \delta)/2$, $\alpha(v + \delta - \alpha t)$ is increasing in α, $\forall\alpha\in(0, 1)$. Hence, the condition

$$F \leq \begin{cases} s_1(v + \delta - 3s_1 t) & \text{if } \alpha \leq \dfrac{1}{2} \\ s_2(v + \delta - 3s_2 t) & \text{if } \alpha > \dfrac{1}{2} \end{cases}$$

guarantees $\alpha(v + \delta - \alpha t) - F \geq 2t\alpha^2$ when $\alpha \in [(3t - \delta)/6t, \alpha_h]$.

We have established that when $\alpha \in [\alpha_l, \alpha_h]$ and if $F \leq \min\{F^*, F^{**}\}$, Firm 1 earns higher profit by preserving backward compatibility given that Firm 2's second-generation product is compatible. Symmetrically we can show that under the same conditions, Firm 2 will make its second-generation product compatible given that Firm 1 does so. Hence, if $\alpha \in [\alpha_l, \alpha_h]$ and $F \leq \min\{F^*, F^{**}\}$, in the second period both firms making their product backward compatible and charging local monopoly prices constitutes a Nash equilibrium for the last two stage subgames. The uniqueness follows directly from Proposition 1.

Parts 2 and 3. Suppose $\alpha \in (0, \alpha_l)$. Recall that the assumption $t \geq (6v + 11\delta - 4\sqrt{4\delta^2 + 6\delta v})/9$ implies $\alpha_l \leq (3t - \delta)/6t$. First, suppose Firm 2 preserves backward compatibility. As shown in Section 3.1, no matter whether Firm 1 decides to make its product compatible or not, in the second period the market will be partitioned at point $(3t - \delta)/6t$ and prices are $p_{12} = t - (\delta/3)$ and $p_{22} = t + (\delta/3)$. Since $F > 0$, Firm 1 will not preserve compatibility. Given Firm 1 discards compatibility, if Firm 2 does the same, it earns $t/2$ in the second period. If Firm 2 preserves compatibility, it earns $((3t + \delta)^2/18t) - F$. The condition $F \leq (\delta^2 + 6\delta t)/18t$ implies $((3t + \delta)^2/18t) - F \geq (t/2)$. Hence, we have shown that if $\alpha \in (0, \alpha_l)$ and $F \leq (\delta^2 + 6\delta t)/18t$, then only Firm 2 preserving backward compatibility and in the second period firms charging $p_{12} = t - (\delta/3)$ and $p_{22} = t - (\delta/3)$ respectively constitute a Nash equilibrium. The uniqueness follows from Proposition 1 and the fact that these prices are the solutions from firms' best response functions (2) and (4), which are both linear. The case where $\alpha \in (\alpha_h, 1)$ can be proved symmetrically. □

Proof of Proposition 4

Proof: Part 1. It directly follows from Proposition 3 and the fact that (25) and (26) are best response functions.

Part 2. First consider Firm 2's pricing behavior. Suppose Firm 1 charging a first period price p^*_{11} as given by (27). As we have shown in the text, if Firm 2 sets its price according to (26), which yields p^*_{21}, then the first period market will be partitioned exactly at point α_h. We first claim that given p^*_{11}, Firm 2 won't charge a price lower than p^*_{21} in the first period.

To see this, suppose Firm 2 charges some $\hat{p}_{21} < p^*_{21}$, given p^*_{11}, the first period market will be partitioned at some point $\alpha < \alpha_h$. By Proposition 3, in the second period both firms will make their products backward compatible and charge local monopoly prices. Given both firms charge local monopoly prices in the second period, however, $\hat{p}_{21}$ cannot be optimal for Firm 2 in the first period because the best response function (26) yields p^*_{21}. Hence, Firm 2's first period price must be at least as great as p^*_{21}. So given Firm 1 charges p^*_{11}, the first period market partition point, α, must be at least as great as α_h.

Suppose $\alpha = \alpha_h$. By Proposition 2, in the second period both firms are going to maintain backward compatibility and charge the local monopoly price if F is sufficiently small. Specifically, it's sufficient to have $F \leq \alpha_l(v + \delta - \alpha_l t) - (3t - \delta)^2/18t$.[20] Let's assume this condition on F is satisfied. In this case, Firm 2 maximizes its profit by charging a price according to (26), which yields p^*_{21}. Firm 2's total profit is $3t(1 - \alpha_h)^2 - F$. By definition, $\alpha_h = 1 - \alpha_l$, hence, we can rewrite the profit as $3t\alpha_l^2 - F$.

Suppose $\alpha > \alpha_h$. By Proposition 3, the equilibrium of the third-stage pricing game involves a second period market partition point at $(3t + \delta)/6t$ and Firm 2's second period profit is $(3t - \delta)^2/18t$. Note that when $\alpha > \alpha_h$, the second period market outcome is independent of α. Hence, Firm 2's problem of maximizing its total profit is equivalent to maximizing profits from two periods separately. Therefore, Firm 2 must set its first period price according to the best response function $p_{21} = (1/2)(p^*_{11} + c_2 + t)$, which implies $p_{21} = c_2 + 3t(1 - \alpha_h) - (v + \delta)/2$ and a first period market partition point at $(v + \delta + (6\alpha_h - 2)t)/4t$. Firm 2's first period profit is then $[6t(1 - \alpha_h) - v - \delta]^2/8t$. Hence, Firm 2's total profit is $[6t(1 - \alpha_h) - v - \delta]^2/8t + ((3t - \delta)^2/18t)$, which can be rewritten as $(6t\alpha_l - v - \delta)^2/8t + ((3t - \delta)^2/18t)$.

Note that $3t\alpha_l^2 > (6t\alpha_l - v - \delta)^2/8t + ((3t - \delta)^2/18t)$ given the assumptions on t and δ. Hence, there exists a positive constant $\hat{F} = 3t\alpha_l^2 - (6t\alpha_l - v - \delta)^2/8t - ((3t - \delta)^2/18t)$ such that for $F \leq \hat{F}$, $3t\alpha_l^2 - F \geq (6t\alpha_l - v - \delta)^2/8t + ((3t - \delta)^2/18t)$. Also we note that the condition $F \leq \hat{F}$ implies $F \leq$

$F^{**} = \alpha_l(v + \delta - \alpha_l t) - ((3t - \delta)^2/18t)$, which guarantees that Firm 2 indeed will preserve backward compatibility once it has a first period market share $s_2 = \alpha_l$. To see this, take the difference between $\hat{F}$ and F^{**} and we have

$$\hat{F} - F^{**} = [3t\alpha_l^2 - \alpha_l(v + \delta - \alpha_l t)] - \frac{(6t\alpha_l - v - \delta)^2}{8t}.$$

Note that $3t\alpha_l^2$ is Firm 2's total profit if it preserves compatibility and $\alpha_l(v + \delta - \alpha_l t)$ is Firm 2's second period monopoly profit. Hence, the term in the square bracket is Firm 2's first period profit when it charges a first period price p_{21}^* and has first period market share equal to α_l. The second term is Firm 2's *maximal* first period profit given Firm 1 charges p_{11}^*. Hence, $\hat{F} - F^{**} \leq 0$, which implies if we have $F \leq \hat{F}$, the condition on F in Proposition 3 is also satisfied.

Therefore, we have shown that if $F \leq \hat{F}$, then given Firm 1 charges p_{11}^*, Firm 2 maximizes its profit by charging p_{21}^* in the first period and in the second period it will preserve compatibility and charge the local monopoly price. □

DYNAMIC PRICING VIA FEES IN DUOPOLY WITH VARYING USAGE LEVELS

Krina Griva and Nikolaos Vettas

ABSTRACT

We examine a two-period, homogeneous product duopoly model. Consumers choose the supplier that demands the lowest two-part tariff payment. When per unit rates are given, firms' competition in fixed fees leads to an endogenous segmentation of the market, with positive profit for both firms and consumers self-selecting according to their usage levels. Consumers' usage levels vary between periods but switching suppliers is costly. Examining various possibilities (including price discrimination between old and new customers) reveals that switching affects the two suppliers asymmetrically, as the average usage level of a firm's clientele changes.

1. INTRODUCTION

In a variety of markets, pricing takes the form of a two-part tariff, that is, a fixed fee and a rate per unit of usage. In credit cards markets, banks typically charge a fixed (annual) fee and, in addition, set an interest rate to be applied to the amount each user borrows by using the card. For telecommunication services, the providers charge a fee (typically monthly) and also specify a payment per unit of the connection time to the network. In such cases, as usage levels differ

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in the population of consumers, some consumers may be directed to suppliers primarily on the basis of the fixed fee and others on the basis of the per unit rate. In addition, two features may be important when such markets are viewed dynamically, that consumers' usage levels may vary from period to period and that switching from one product or supplier to another involves a switching cost. This chapter presents a simple homogeneous products duopoly model where the population of consumers is heterogeneous with respect to usage levels and pricing has two parts, a rate (taken as given in the analysis) and a fee, the endogenous, strategic, variable for each firm and one that may be changed from one period to another.

While two-part tariff pricing is a general practice covering a wide range of markets, it appears particularly important in "new economy" markets. The key is that technology, especially for digital products, facilitates the measurement of the usage level of each customer and/or tracing the customer's identity over time. While in most cases the difference between "new" and "old" economy markets is not qualitative, but rather a matter of degree, it is true that in many markets the way customers purchase products and, especially, services has changed significantly over the last few years. Rather than having to visit a store and make a cash payment for the transaction, in many markets consumers can now obtain product and pricing information and also make a purchase via the internet or telephone. Payment may be done with a credit or a charge card where, in turn, the consumer has a number of choices as to how he or she will settle the financial obligation. In all of these stages, whether dealing with a supplier of telecommunication services, a company selling via the internet, a credit card company or a bank, consumers face pricing that takes various (typically non linear) forms. At the same time, each supplier can keep (at a very low cost) a record of each customer's transactions. While other factors are also important, the ability to charge a payment that is a function of the exact usage of the customer may be critical. As discussed above, markets for which these considerations are important include some that form the backbone of the "new economy," specifically credit cards and payment systems (financial and banking services, in general) and internet access and on-line services (telecommunication and information services, more generally).[1]

In this chapter, we set up a simple model to examine certain aspects of duopoly competition via fees when firms' rates differ, with emphasis on the dynamics, in particular on two-period competition with switching costs. The details are as follows. We assume the two firms' products are viewed by the consumers as perfectly homogeneous. Lack of product differentiation implies that, if firms can simultaneously choose both their fees and rates, competition results in pricing at cost. However, if rates have been set (by the firms or by some institutional mechanism) at levels that are not too close to each other, then firms' competition via fees leads to an equilibrium where both rivals enjoy positive profit. The key for this result is that the population of consumers is heterogeneous with respect to their usage level. The market then becomes segmented, with "light" users choosing the firm with a relatively low fee and high rate and "heavy" users opting for the firm with a high fee and low rate. Taking this observation as our starting point, we then focus on two-period competition. We examine the case when consumers' usage levels may change between periods (due to some exogenous shock), but a consumer that switches from one product to the other pays a switching cost. We examine the implications for firms' pricing (via fees) in each of the two periods. We consider a number of different settings. First, we assume that the change in the customers' usage levels is not anticipated by the firms: they simply react to the change after it takes place. We then turn to the case where the change is anticipated and trace the implications for the firms' strategies in each period. We study both the case where firms can change their fee between periods and that where firms have to charge a single fee in both periods. Finally, we examine the possibility of price discrimination between old (loyal) and new customers and compare the equilibrium with that when such discrimination is not possible.

In the two-period setting, what drives the main results is how the tendency of customers to self select in one of the two products (the one that represents the best fee and rate combination, given their personal usage levels) interacts with the inertia due to the switching cost. Given prices, firms' profits depend positively on the proportion of "heavy" users that they service, and thus, the implications of the change in each consumer's usage level are not neutral for the firms. Our main results are as follows. When firms are myopic, and when rates have been set at levels that are not too close to each other and consumers face switching costs that are not too large, the firm associated with the high rate has higher profit compared to the case of no switching costs, while the profit of the rival firm is lower. When firms are forward looking, first-period fees are smaller than the fees firms charge when they are myopic, whereas second-period fees are higher. Unlike the case of the one-period model, the market is no longer equally divided: the firm associated with the low rate attracts more customers in both periods. When firms are constrained to set the same fee in both periods, both fees are lower than the second-period fees that firms charge when they can price differently in the two periods. The fee that the high-rate firm charges (over both periods) exceeds the first-period fee of the same firm when it can price differently in the two periods; how the fee that the low-rate firm charges compares to its fee when fees can be changed, depends on the switching cost. Finally, when firms can price discriminate, in the second period, between new and old customers, the second-period fees are independent of the first-period fees. The high rate firm then sets a lower fee to its loyal (old) customers compared to when it does not price discriminate, while the rival firm sets a lower fee to its new customers. First-period fees for both firms are higher when firms are forward looking and price discriminate in the second period, compared to when firms do not price discriminate.

Our analysis is related to two important literatures, on two-part tariffs and on price competition with switching costs. Regarding two-part tariffs, there is an extensive literature studying various aspects of the issue (see e.g. Oi, 1971, for a classic reference and Varian, 1989, and Stole, 2001 for a review and references). Much of this literature, as also the main volume of the research on price discrimination, focuses on the monopoly case.[2] Despite the importance of the matter, the study of oligopoly competition with two-part tariffs has not received much attention, especially when compared to the volume of work on oligopoly with linear pricing. Important exceptions, where oligopolists compete for final consumers via nonlinear prices of course exist, including e.g. Spulber (1981), Oren et al. (1983), Hayes (1987), Stole (1995), Corts (1998), Armstrong and Vickers (2001) and Rochet and Stole (2002). Berstein (2002) models consumers as choosing between two products under two-part tariffs, like we do, but in a differentiated products market – importantly, we abstract away from any product differentiation and show that the market can be segmented even in the case of homogeneous products. What drives then our results is not consumers' preferences towards one product or the other, but heterogeneity with respect to usage levels. Regarding switching costs, the implications for (dynamic) pricing have been studied in various settings – see Klemperer (1995) for a review and Beggs and Klemperer (1992) and Padilla (1995) for examples of dynamic analysis. Chen (1997), Villas-Boas (1999), Fudenberg and Tirole (2000), Shaffer and Zhang (2000) and Taylor (2003) examine the important issue of pricing to induce customers to switch. An important difference of our work relative to this line of research is that, given the endogenous segmentation of the market between "heavy" and "light" users, we study how switching costs interact with the users' willingness to switch when their usage levels change.

The remainder of this chapter is organized as follows. In Section 2, we set up the basic model and describe the equilibrium in fees (for given rates) in the one-period case. In Section 3, we extend the basic model to study dynamics over two periods; first (as a benchmark) without and then with switching costs, assuming that, in the second period, there is an unexpected change in consumers' usage levels. Section 4 turns to the case where the change in usage levels is anticipated, that is, firms are forward looking. Section 5 presents the equilibrium when (forward-looking) firms are constrained to set the same fee in both periods. Section 6 examines the case where firms can price discriminate between old and new customers. Section 7 concludes.

2. THE BASIC (ONE-PERIOD) MODEL

We consider competition between two firms, A and B, selling products viewed by consumers as perfect substitutes – for ease of notation, we refer to product i as the one supplied by firm i, $i = \text{A, B}$. Pricing by each firm i has two parts, a fixed fee f_i, to be paid by each consumer that chooses product i, and a rate r_i, that is to be applied to the usage of the product. Demand is represented by a continuum of consumers with total mass normalized to 1. Consumers differ with respect to their usage levels. In particular, each consumer is represented by his level of usage, θ, where we further assume that θ is uniformly distributed on [0, 1].[3]

The goal of each firm is profit maximization – as we assume for simplicity zero costs for the firms, this amounts to maximization of the revenue from each product.[4] Each consumer, on the other hand, chooses the product that leads to the lowest total payment: a consumer that has a usage level θ will choose the product of firm A ("product A") if $f_A + \theta r_A < f_B + \theta r_B$ and product B otherwise. We assume that consumers choose to purchase one of the two products.[5] There is no uncertainty.

Let us first write the firms' profits as functions of the fees and rates charged. We need to distinguish three cases. Given the lack of product differentiation, for both firms to have a positive market share it should be that either both firms charge identical prices or, if they charge different prices, that one firm charges a higher fee and the other charges a higher rate. We consider the various possibilities:

Case 1: If a firm charges both a higher fee and a higher rate than its rival, no consumer chooses its product and that firm ends up with zero profit. In that case, the firm with the lower fee and lower rate captures the entire market. The profit of such a firm, say firm i, that captures the entire market by charging f_i and r_i is $\int_0^1 (f_i + \theta r_i)\,\mathrm{d}\theta = f_i + r_i \int_0^1 \theta\,\mathrm{d}\theta = f_i + (r_i/2)$.

Case 2: If both firms have equal fees and equal rates (say f and r), we assume that they split the market equally and have equal profits, $(f + (r/2))/2$.

Case 3: Suppose now one firm charges a higher fee and the other a higher rate. Without loss of generality, let firm A be the one that has the higher rate, that is, $r_A \geq r_B$. When $r_A > r_B$ and $f_A < f_B$, a consumer with usage level θ is indifferent between product A and product B if $f_A + \theta r_A = f_B + \theta r_B$. We call this indifference usage level,

$$\tilde{\theta} \equiv \frac{f_A - f_B}{r_B - r_A}. \tag{1}$$

Both firms will have positive market shares if $\tilde{\theta} \in (0, 1)$. Then, firm A sells to consumers with θ in $[0, \tilde{\theta}]$, firm B to those with θ in $[\tilde{\theta}, 1]$ and the profit functions are

$$\pi_A = \int_0^{\tilde\theta} (f_A + \theta r_A)\,\mathrm{d}\theta = f_A\tilde\theta + r_A\frac{\tilde\theta^2}{2}$$
$$= f_A\frac{f_B - f_A}{r_A - r_B} + r_A\frac{((f_B - f_A)/(r_A - r_B))^2}{2} \quad (2)$$

and

$$\pi_B = \int_{\tilde\theta}^{1} (f_B + \theta r_B)\,\mathrm{d}\theta = f_B(1-\tilde\theta) + r_B\left(\frac{1-\tilde\theta^2}{2}\right)$$
$$= f_B\left(1 - \frac{f_B - f_A}{r_A - r_B}\right) + r_B\frac{1 - ((f_B - f_A)/(r_A - r_B))^2}{2}. \quad (3)$$

If $\tilde\theta \geq 1$, firm A captures the entire market with profit equal to $\int_0^1 (f_A + \theta r_A)\,\mathrm{d}\theta = f_A + r_A\int_0^1 \theta\,\mathrm{d}\theta = f_A + (r_A/2)$, while firm B's market share and profit are zero. On the other hand, an important observation is that $\tilde\theta < 0$ can only occur when one firm has both a higher fee and a higher rate. If a firm sets a lower fee than its rival, it guarantees itself some positive market share; the reason a lower fee implies a positive market share, regardless of the rates, is that there are always some consumers with usage level θ close enough to zero. Consumers with θ equal to zero (and, by continuity, also these in a neighborhood of zero) only care about the fixed fees.

In summary, the profit functions when $r_A > r_B$ and $f_A < f_B$ are

$$\pi_A = \begin{cases} f_A\dfrac{f_A - f_B}{r_B - r_A} + r_A\dfrac{((f_A - f_B)/(r_B - r_A))^2}{2} & \text{if } \tilde\theta \in (0,1) \\ f_A + \dfrac{r_A}{2} & \text{if } \tilde\theta \geq 1 \end{cases}$$

and

$$\pi_B = \begin{cases} f_B\left(1 - \dfrac{f_A - f_B}{r_B - r_A}\right) + r_B\dfrac{1 - ((f_A - f_B)/(r_B - r_A))^2}{2} & \text{if } \tilde\theta \in (0,1) \\ 0 & \text{if } \tilde\theta \geq 1. \end{cases}$$

How would firms compete in this setting? When fees and rates are both chosen at the same time, the lack of product differentiation implies that the only equilibrium outcome is of the Bertrand type, with zero profit for both firms (see Griva & Vettas, 2003). The picture, however, changes dramatically if one of the two price instruments (fees or rates) can be considered set at some level and then firms compete in the other price instrument. In this chapter we proceed to analyze duopoly competition via fees, when firms take the rates as given. This approach can be understood in two ways. First, there may be various ways that the rates are set to some levels that cannot then be changed in the current period: this includes cases where the rates are set by some institution and cases where the rates have been set as a result of some (possibly collusive) agreement between firms. Second, this approach can be viewed as a first step that produces results and insights helpful for the analysis of a two-stage game where rates would be strategically chosen before the fees.[6] Below we state the main result in the one-period case (borrowed from Griva & Vettas, 2003). After we discuss the properties of the equilibrium, we then move to the dynamic (two-period) case, which is the focus of this chapter.

Proposition 1. Consider the one-period game where rates $r_A \geq r_B \geq 0$ are taken as given and firms choose their fees simultaneously. If $r_A \geq 2r_B$, the equilibrium fees are

$$f_A^* = -\frac{r_B}{2} \quad \text{and} \quad f_B^* = \frac{1}{2}(r_A - 2r_B), \tag{4}$$

the usage level of the indifferent consumer is

$$\tilde{\theta}^* = \frac{1}{2} \tag{5}$$

and the equilibrium profits are

$$\pi_A^* = \frac{1}{8}(r_A - 2r_B) \tag{6}$$

and

$$\pi_B^* = \frac{1}{8}(2r_A - r_B). \tag{7}$$

Proof: See Griva and Vettas (2003). □

Some important remarks on the equilibrium presented above are as follows. First, the market gets segmented, with the "light" users (relatively low θ) choosing the high rate and low fee firm (firm A) and the "heavy" users (high θ) choosing the low rate and high fee firm (firm B). Figure 1 presents the equilibrium fees and profits. Each of the two lines represents the total payment a consumer would make to obtain one of the two products. Thus, depending on their θ, consumers choose the product represented by the lower of the two lines. Indifference occurs where the two lines cross. From the viewpoint of the firms, for each customer they serve, the distance between the price line and the zero line represents the profit (or loss). Hence, the aggregate profits are given by the shaded areas.

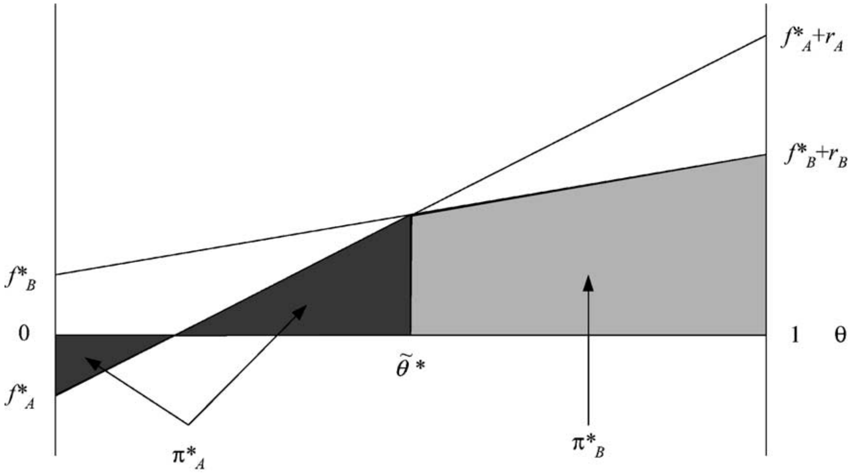

Fig. 1. Equilibrium Profits.

Second, both firms, in equilibrium, make strictly positive profit, despite the lack of product differentiation. Given users' heterogeneity with respect to usage levels and different rates, each firm prefers to share the market with its rival rather than to get engaged in aggressive pricing that would lead to low profit. Third, both firms' equilibrium profits are increasing in the difference between the two firms' rates. As in models of product differentiation (e.g. Shaked & Sutton, 1982), increasing differentiation (here via rates) increases equilibrium profits. Fourth, a condition for the equilibrium described in the above proposition to exist is that the difference between the rates is not too small. In the extreme case when the rates are equal, pricing (in fees) leads to the Bertrand outcome, while for $r_B < r_A < 2r_B$ a pure strategy equilibrium fails to exist.

A final remark is that what allows firms to gain positive profits via the endogenous market segmentation is that there is a single price pair (fee and rate) for each firm. If, instead, firms were able to (perfectly) price discriminate by charging a different fee for each user, competition would lead to zero profit. Thus, enriching the strategy space of the firms, would reduce their profit. Essentially, we would have Bertrand competition for each customer. The details are as follows. Taking as given the rates and the usage level θ of each particular user, each firm would charge a fee that makes the total payment for the user slightly lower than its rival's, in order to attract that user. In equilibrium, total payments would be zero, with $f_A^* = -\theta r_A$ and $f_B^* = -\theta r_B$. If any firm increased its fee, it would fail to attract the consumer, while if it decreased its fee it would make a loss equal to the negative payment the consumer makes. The same logic holds for every consumer in the line segment and in equilibrium, both firms end up with zero profit. We summarize.

Remark 1. In the one-period game where rates $r_A \geq r_B \geq 0$ are taken as given and firms can price discriminate between different users, both firms make zero profit.

Next, we turn to pricing in the two-period game.

3. A TWO-PERIOD GAME WITH VARYING USAGE LEVELS

In this section, we extend the static model to two periods and introduce a shock at the beginning of the second period. This shock alters the usage levels of consumers in the second period, while the aggregate distribution remains uniform on [0, 1]. Formally, in each period, each consumer's usage level is a random draw from [0, 1], with the draws being independent across periods. Thus, in the second period there is uncertainty about each consumer's usage level, but no aggregate uncertainty. Consumers learn their new usage level at the beginning of the second period. Because of the change in their usage levels, some consumers may find it optimal to change supplier in the second period. We assume in our analysis that the per unit rates are exogenously given and remain the same across both periods: $r_{1A} = r_{2A} = r_A$ and $r_{1B} = r_{2B} = r_B$. As before, we call firm A the one that charges the higher rate. Firms take the rates as given and choose their fees simultaneously at the beginning of each period in order to maximize their profit. First, we explore the equilibrium of the two-period game when there are no switching costs for consumers that switch products. Then we introduce switching costs and examine the properties of the equilibrium.

3.1. No Switching Costs

First, we consider, as a benchmark, a two-period game where consumers can change suppliers without having any switching cost. Since, in this case, there is no link between the two periods, the equilibrium is simply the repetition of the equilibrium in the one-period model twice. In the second period, consumers that choose the same product as in the first period are called "old," while the ones that have switched products are called "new." We obtain:

Proposition 2. In equilibrium, in the second period, each consumer chooses with probability 1/2 the same product he chose in the first period, and with probability 1/2 switches to the other product.

Proof: Since the equilibrium in the second period is a replica of the equilibrium in the first period and since we have shown in the one-period model that the indifference usage level is $\tilde{\theta}_1 = 1/2$ (where we now use an index to denote the period), we conclude that in the second period, the indifference usage level will also be $\tilde{\theta}_2 = 1/2$. As each consumer has probability $\tilde{\theta}_1$ to choose firm A in period 1 and probability $\tilde{\theta}_2$ to choose firm A in period 2, the following statements hold. Each consumer chooses firm A in period 1 and switches to firm B in period 2 with probability $\tilde{\theta}_1(1 - \tilde{\theta}_2) = 1/4$. Each consumer chooses firm B in period 1 and switches to firm A in period 2 with probability $(1 - \tilde{\theta}_1)\tilde{\theta}_2 = 1/4$. Each consumer chooses firm A in both periods with probability $\tilde{\theta}_1\tilde{\theta}_2 = 1/4$ and chooses firm B in both periods with probability $(1 - \tilde{\theta}_1)(1 - \tilde{\theta}_2) = 1/4$. The statement in the proposition follows immediately. □

In this case, each firm captures half of the market. Thus, in equilibrium, in period 2 half of each firm's clients will be old and half will be new.

3.2. Switching Costs

Now we turn to the case where there is a switching cost for consumers that switch suppliers between periods. We assume that every consumer that chooses in the second period a different supplier than the one he chose in the first period, pays a switching cost $s > 0$. Due to this switching cost, some consumers that would otherwise like to switch suppliers stick to their old supplier, since the benefit they would obtain from switching products is smaller than the switching cost. We maintain throughout the analysis the assumption that consumers are myopic and, thus, purchase in each period the product that minimizes their cost in that period. As a first step, in this section we also assume that firms are myopic: they do not take into consideration their future profits, when calculating their first-period equilibrium fees. Consequently, the equilibrium fees and profits for the first period are the same as in the one-period game. The pricing of firms in the second period, on the other hand, will be affected by the presence of switching costs.

A consumer who chose product A in period 1 and has usage level θ in period 2, will be indifferent between choosing product A or product B in period 2 if

$f_{2A} + \theta r_A = f_{2B} + \theta r_B + s$. We call this indifference usage level

$$\tilde{\theta}_A \equiv \frac{f_{2B} - f_{2A} + s}{r_A - r_B}. \tag{8}$$

Similarly, a consumer who chose product B in period 1 and has usage level θ in period 2, will be indifferent between choosing product A or product B in period 2 if $f_{2A} + \theta r_A + s = f_{2B} + \theta r_B$. We call this indifference usage level

$$\tilde{\theta}_B \equiv \frac{f_{2B} - f_{2A} - s}{r_A - r_B}. \tag{9}$$

It is immediate that $\tilde{\theta}_A > \tilde{\theta}_B$ for any $s > 0$ (and $\tilde{\theta}_A = \tilde{\theta}_B$, for $s = 0$). Given that consumers are myopic, the first-period's fees and profits are the same as in the basic model since the first-period variables are unaffected by the second-period values. Therefore, we know that in the first period the indifference usage level is $\tilde{\theta}_1^* = 1/2$. Given $\tilde{\theta}_1^*$, we now examine which consumers will choose product A in the second period (see Fig. 2).

If $\tilde{\theta}_A \leq 0$ (which also implies $\tilde{\theta}_B \leq 0$) no consumer buys product A in period 2, no matter which product he bought in period 1. If $0 < \tilde{\theta}_A < 1$ and $\tilde{\theta}_B \leq 0$, firm A attracts $\tilde{\theta}_A$ of the consumers that bought product A in period 1 (in total, this corresponds to a mass of $\tilde{\theta}_A \tilde{\theta}_1^*$ consumers). If $0 < \tilde{\theta}_A < 1$ and $\tilde{\theta}_B > 0$, firm A attracts $\tilde{\theta}_A$ of the consumers that bought product A in period 1 and $\tilde{\theta}_B$ of the consumers that bought product B in period 1 (in total, $\tilde{\theta}_B + (\tilde{\theta}_A - \tilde{\theta}_B)\tilde{\theta}_1^*$ consumers). If $\tilde{\theta}_A \geq 1$ and $0 < \tilde{\theta}_B < 1$, firm A attracts all the consumers that bought product A in period 1 and $\tilde{\theta}_B$ of the consumers that bought product B in period 1 (in total,

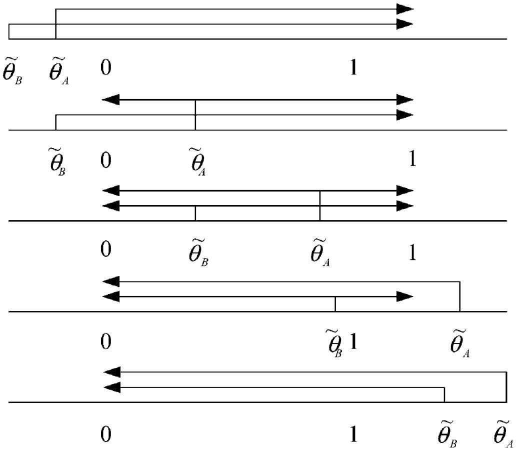

Fig. 2. Market Shares as Fees Change.

$\tilde{\theta}_1^* + (1-\tilde{\theta}_1^*)\tilde{\theta}_B$ consumers). Finally, if $\tilde{\theta}_B \geq 1$ (which also implies $\tilde{\theta}_A \geq 1$) all consumers choose product A, no matter which product they bought in period 1.

An analogous analysis can be done for the demand for product B in period 2. If $\tilde{\theta}_A \leq 0$ (which also implies $\tilde{\theta}_B \leq 0$) all consumers choose product B in period 2, no matter which product they chose in period 1. If $0 < \tilde{\theta}_A < 1$ and $\tilde{\theta}_B \leq 0$, firm B attracts all the consumers that bought product B in period 1 and $(1-\tilde{\theta}_A)$ of the consumers that bought product A in period 1 (in total, $(1-\tilde{\theta}_1^*) + \tilde{\theta}_1^*(1-\tilde{\theta}_A)$ consumers). If $0 < \tilde{\theta}_A < 1$ and $\tilde{\theta}_B > 0$, firm B attracts $(1-\tilde{\theta}_A)$ of the consumers that bought product A in period 1 and $(1-\tilde{\theta}_B)$ of the consumers that bought product B in period 1 (in total, $(1-\tilde{\theta}_A) + (1-\tilde{\theta}_1^*)(\tilde{\theta}_A - \tilde{\theta}_B)$ consumers). If $\tilde{\theta}_A \geq 1$ and $0 < \tilde{\theta}_B < 1$, firm B attracts no consumer that bought product A in period 1 and $(1-\tilde{\theta}_B)$ of the consumers that bought product B in period 1 (in total, $(1-\tilde{\theta}_1^*)(1-\tilde{\theta}_B)$). Finally, if $\theta_B \geq 1$ (which also implies $\tilde{\theta}_A \geq 1$) no consumer will buy product B in period 2, no matter what he bought in period 1.

It follows that the second-period profit functions are as follows.

$$\pi_{2A} = \begin{cases} 0 & \text{if } \tilde{\theta}_A \leq 0 \\ \tilde{\theta}_1^* \int_0^{\tilde{\theta}_A} (f_{2A} + \theta r_A)\, d\theta & \text{if } \tilde{\theta}_B \leq 0 < \tilde{\theta}_A < 1 \\ \int_0^{\tilde{\theta}_B} (f_{2A} + \theta r_A)\, d\theta + \tilde{\theta}_1^* \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} (f_{2A} + \theta r_A)\, d\theta & \text{if } 0 < \tilde{\theta}_B < \tilde{\theta}_A < 1 \\ \tilde{\theta}_1^*(f_{2A} + \frac{r_A}{2}) + (1-\tilde{\theta}_1^*) \int_0^{\tilde{\theta}_B} (f_{2A} + \theta r_A)\, d\theta & \text{if } 0 < \tilde{\theta}_B < 1 \leq \tilde{\theta}_A \\ f_{2A} + \dfrac{r_A}{2} & \text{if } \tilde{\theta}_B \geq 1 \end{cases} \tag{10}$$

and

$$\pi_{2B} = \begin{cases} f_{2B} + \dfrac{r_B}{2} & \text{if } \tilde{\theta}_A \leq 0 \\ (1-\tilde{\theta}_1^*)\left(f_{2B} + \dfrac{r_B}{2}\right) + \tilde{\theta}_1^* \int_{\tilde{\theta}_A}^1 (f_{2B} + \theta r_B)\, d\theta & \text{if } \tilde{\theta}_B \leq 0 < \tilde{\theta}_A < 1 \\ \int_{\tilde{\theta}_A}^1 (f_{2B} + \theta r_B)\, d\theta + (1-\tilde{\theta}_1^*) \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} (f_{2B} + \theta r_B)\, d\theta & \text{if } 0 < \tilde{\theta}_B < \tilde{\theta}_A < 1 \\ (1-\tilde{\theta}_1^*) \int_{\tilde{\theta}_B}^1 (f_{2B} + \theta r_B)\, d\theta & \text{if } 0 < \tilde{\theta}_B < 1 \leq \tilde{\theta}_A \\ 0 & \text{if } \tilde{\theta}_B \geq 1. \end{cases} \tag{11}$$

In our analysis, we restrict attention to the case where $0 < \tilde{\theta}_B < \tilde{\theta}_A < 1$, so there are some consumers switching from firm A to firm B and vice versa (of course, implicit to this restriction of attention are restrictions on the parameters, as

$\tilde{\theta}_B$ and $\tilde{\theta}_A$ are endogenous). Substituting $\tilde{\theta}_1^* = 1/2$ (determined in the first period), $\tilde{\theta}_A$ from (8) and $\tilde{\theta}_B$ from (9) into the relevant branch of (10), we obtain firm A's profit function in period 2:

$$\begin{aligned}\pi_{2A} &= \int_0^{\tilde{\theta}_B} (f_{2A} + \theta r_A)\,d\theta + \tilde{\theta}_1^* \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} (f_{2A} + \theta r_A)\,d\theta \\ &= f_{2A}\left(\frac{f_{2B} - f_{2A} - s}{r_A - r_B}\right) + r_A \frac{((f_{2B} - f_{2A} - s)/(r_A - r_B))^2}{2} \\ &\quad + \frac{1}{2}\left(f_{2A}\left(\frac{2s}{r_A - r_B}\right) + r_A \frac{(2s/(r_A - r_B))^2}{2}\right),\end{aligned}$$

or

$$\pi_{2A} = f_{2A}\left(\frac{f_{2B} - f_{2A}}{r_A - r_B}\right) + r_A\left(\frac{s^2 + (f_{2A} - f_{2B})^2}{(r_A - r_B)^2}\right). \tag{12}$$

Similarly, firm B's profit function in period 2 is

$$\begin{aligned}\pi_{2B} &= \int_{\tilde{\theta}_A}^{1} (f_{2B} + \theta r_B)\,d\theta + (1 - \tilde{\theta}_1^*) \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} (f_{2B} + \theta r_B)\,d\theta \\ &= f_{2B}\left(1 - \frac{f_{2B} - f_{2A} + s}{r_A - r_B}\right) + r_B \frac{(1 - (f_{2B} - f_{2A} + s)/(r_A - r_B))^2}{2} \\ &\quad + \frac{1}{2}\left(f_{2B}\left(\frac{2s}{r_A - r_B}\right) + r_B \frac{(2s/(r_A - r_B))^2}{2}\right),\end{aligned}$$

or

$$\pi_{2B} = f_{2B} + \frac{r_B}{2} + \frac{s^2 + f_{2A}^2 - f_{2B}^2}{2(r_A - r_{B)}} - r_A\left(\frac{s^2 + (f_{2A} - f_{2B})^2}{2(r_A - r_B)^2}\right). \tag{13}$$

We then obtain:

Proposition 3. Given $r_A \geq 2r_B$ and $s < (r_A - r_B)/2$, the presence of switching costs leaves both firms' fees unchanged compared to the case where we have no switching costs, but increases the profit of firm A and decreases the profit of firm B.

Proof: We first check the second order conditions. We have $d^2\pi_{2A}/df_{2A}^2 = -(r_A - 2r_B)/(r_A - r_B)^2 < 0$, thus π_{2A} is concave for $r_A > 2r_B$. Similarly, $d^2\pi_{2B}/df_{2B}^2 = -(2r_A - r_B)/(r_A - r_B)^2 < 0$, thus π_{2B} is concave for $r_A > r_B$. To find the equilibrium fees we now take the first order conditions of both profit functions with respect to each firm's fee, and obtain the reaction functions

$$f_{2A} = R_{2A}(f_{2B}) = -\frac{f_{2B}r_B}{r_A - 2r_B} \tag{14}$$

and

$$f_{2B} = R_{2B}(f_{2A}) = \frac{f_{2A}r_A + (r_A - r_B)^2}{2r_A - r_B}. \tag{15}$$

By solving the system of (14) and (15), we find the equilibrium fees

$$f^*_{2A} = -\frac{r_B}{2} \quad \text{and} \quad f^*_{2B} = \frac{r_A - 2r_B}{2}. \tag{16}$$

Substituting the equilibrium fees into (12) and (13) we obtain the second-period equilibrium profits

$$\pi^*_{2A} = \frac{r_A - 2r_B}{8} + \frac{4s^2 r_A}{8(r_A - r_B)^2} \tag{17}$$

and

$$\pi^*_{2B} = \frac{2r_A - r_B}{8} - \frac{4s^2 r_B}{8(r_A - r_B)^2}. \tag{18}$$

When we compare (16) to (4), (17) to (6), and (18) to (7) we conclude that the presence of a switching cost does not alter the equilibrium fees but it does alter the profits. The profit of firm A increases compared to the case of no switching cost by $4s^2 r_A/8(r_A - r_B)^2$. The profit of firm B decreases compared to the case of no switching costs by $4s^2 r_B/8(r_A - r_B)^2$. □

In the equilibrium described above, the profit of firm A increases compared to the no-switching cost benchmark, because now firm A captures some customers with usage level above 1/2. These customers are trapped in this firm, because of the presence of switching cost, and therefore the average usage level of firm A's clients increases. On the other hand, the profit of firm B decreases because now firm B serves some customers with usage level below 1/2; these are also trapped in this firm because of the switching cost. The equilibrium values of $\tilde{\theta}_A$ and $\tilde{\theta}_B$ are

$$\tilde{\theta}^*_A = \frac{1}{2} + \frac{s}{r_A - r_B}$$

and

$$\tilde{\theta}^*_B = \frac{1}{2} - \frac{s}{r_A - r_B}.$$

For $0 < \tilde{\theta}_B^* < \tilde{\theta}_A^* < 1$ to hold, condition $s < (r_A - r_B)/2$ must be satisfied. Note that $\tilde{\theta}_A^*$ and $\tilde{\theta}_B^*$ are symmetrically located to the right and to the left of $\tilde{\theta}_2 = 1/2$ respectively. Firms A's market share is $\tilde{\theta}_B^* + (\tilde{\theta}_A^* - \tilde{\theta}_B^*)\tilde{\theta}_1^*$, while firm B's market share is $(1 - \tilde{\theta}_A^*) + (\tilde{\theta}_A^* - \tilde{\theta}_B^*)(1 - \tilde{\theta}_1^*)$. Substituting the equilibrium values, we conclude that the two firms continue to share the market equally in the second period.

4. FORWARD LOOKING FIRMS

Thus far, we have assumed that firms are myopic, in that the change in consumers' usage level takes them by surprise. In some cases, it may be more realistic to assume that, in the first period, firms have expectations about the shock in consumers' usage level in the second period. Accordingly, they consider how their expected second-period profits will be affected when they set their first-period fees. In this case, the second-period profits have to be also written as functions of the first-period indifference level, $\tilde{\theta}_1$. If $\tilde{\theta}_1 < 0$, then

$$\pi_{2A} = \begin{cases} 0 & \text{if } \tilde{\theta}_A \leq 0 \quad \text{or} \quad \tilde{\theta}_B \leq 0 < \tilde{\theta}_A < 1 \\ \int_0^{\tilde{\theta}_B} (f_{2A} + \theta r_A)\, d\theta & \text{if } 0 < \tilde{\theta}_B < \tilde{\theta}_A < 1 \quad \text{or} \quad 0 < \tilde{\theta}_B < 1 \leq \tilde{\theta}_A \\ f_{2A} + \dfrac{r_A}{2} & \text{if } \tilde{\theta}_B \geq 1 \end{cases}$$

and

$$\pi_{2B} = \begin{cases} f_{2B} + \dfrac{r_B}{2} & \text{if } \tilde{\theta}_A \leq 0 \quad \text{or} \quad \tilde{\theta}_B \leq 0 < \tilde{\theta}_A < 1 \\ \int_{\tilde{\theta}_B}^{1} (f_{2B} + \theta r_B)\, d\theta & \text{if } 0 < \tilde{\theta}_B < \tilde{\theta}_A < 1 \quad \text{or} \quad 0 < \tilde{\theta}_B < 1 \leq \tilde{\theta}_A \\ 0 & \text{if } \tilde{\theta}_B \geq 1. \end{cases}$$

For $0 < \tilde{\theta}_1 < 1$, the second-period profit functions are as in (10) and (11). For $\tilde{\theta}_1 > 1$ the second-period profit functions are

$$\pi_{2A} = \begin{cases} 0 & \text{if } \tilde{\theta}_A \leq 0 \\ \int_0^{\tilde{\theta}_A} (f_{2A} + \theta r_A)\, d\theta & \text{if } \tilde{\theta}_B \leq 0 < \tilde{\theta}_A < 1 \quad \text{or} \quad 0 < \tilde{\theta}_B < \tilde{\theta}_A < 1 \\ f_{2A} + \dfrac{r_A}{2} & \text{if } 0 < \tilde{\theta}_B < 1 \leq \tilde{\theta}_A \quad \text{or} \quad \tilde{\theta}_B \geq 1 \end{cases}$$

and

$$\pi_{2B} = \begin{cases} f_{2B} + \dfrac{r_B}{2} & \text{if } \tilde{\theta}_A \leq 0 \\ \int_{\tilde{\theta}_B}^{1} (f_{2B} + \theta r_B)\,d\theta & \text{if } \tilde{\theta}_B \leq 0 < \tilde{\theta}_A < 1 \quad \text{or} \quad 0 < \tilde{\theta}_B < \tilde{\theta}_A < 1 \\ 0 & \text{if } 0 < \tilde{\theta}_B < 1 \leq \tilde{\theta}_A \quad \text{or} \quad \tilde{\theta}_B \geq 1. \end{cases}$$

Again, we restrict attention to the case where both firms have some clients in both periods and there is switching from each firm to the other ($0 < \tilde{\theta}_1 < 1$ and $0 < \tilde{\theta}_B < \tilde{\theta}_A < 1$). Then firm A's profit function in period 2 is

$$\pi_{2A} = \int_0^{\tilde{\theta}_B} (f_{2A} + \theta r_A)\,d\theta + \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} \tilde{\theta}_1 (f_{2A} + \theta r_A)\,d\theta$$

and for firm B

$$\pi_{2B} = \int_{\tilde{\theta}_A}^{1} (f_{2B} + \theta r_B)\,d\theta + \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} (1 - \tilde{\theta}_1)(f_{2B} + \theta r_B)\,d\theta.$$

Let δ be the one-period discount factor. The expected profit for firm A over the entire two-period horizon, evaluated as of period one is then

$$V_A = \int_0^{\tilde{\theta}_1} (f_{1A} + \theta r_A)\,d\theta + \delta \pi_{2A}. \tag{19}$$

Similarly, for firm B we have

$$V_B = \int_{\tilde{\theta}_1}^{1} (f_{1B} + \theta r_B)\,d\theta + \delta \pi_{2B}. \tag{20}$$

We then obtain:

Proposition 4. Suppose firms are forward looking and conditions $r_A > 2r_B$ and $s^2\delta < (r_A - r_B)^2(2r_A - r_B)/(2r_A + 3r_B)$ hold. Then in the first period, firm B charges a lower fee compared to the case when firms are myopic, while firm A charges a lower fee if $r_A > 3r_B$. In the second period both firms' fees are higher when firms are forward looking, compared to when they are not.

Proof: We proceed via backwards induction. We first check the second order conditions for the second-period profit functions. We have $d^2\pi_{2A}/df_{2A}^2 = -(r_A - 2r_B)/(r_A - r_B)^2 < 0$ and therefore π_{2A} is concave for $r_A > 2r_B$, and $d^2\pi_{2B}/df_{2B}^2 = -(2r_A - r_B)/(r_A - r_B)^2 < 0$ for $r_A > r_B$. Next, the first order conditions lead to the reaction functions, and by solving the system of the two equations we obtain the equilibrium second-period fees, as functions of the first-period fees:

$$f_{2A} = f_{2A}^{*}(f_{1A}, f_{1B}) = -\frac{r_B}{2} + \frac{s r_B (r_A - r_B + 2(f_{1A} - f_{1B}))}{2(r_A - r_B)^2} \tag{21}$$

and

$$f_{2B} = f_{2B}^{*}(f_{1A}, f_{1B}) = \frac{r_A - 2r_B}{2} + \frac{s r_A (r_A - r_B + 2(f_{1A} - f_{1B}))}{2(r_A - r_B)^2}. \tag{22}$$

We substitute (21) and (22) into the expected profit functions of both firms, (19) and (20). We check that $d^2 V_A / df_{1A}^2 = -((r_A - r_B)^2 (r_A - 2r_B) + s^2 \delta (3r_A + 2r_B))/(r_A - r_B)^4 < 0$ for $r_A > 2r_B$, and $d^2 V_B / df_{1B}^2 = -((r_A - r_B)^2 (2r_A - r_B) + s^2 \delta (2r_A + 3r_B))/(r_A - r_B)^4 < 0$ for $s^2 \delta < (r_A - r_B)^2 (2r_A - r_B)/(2r_A + 3r_B)$. Taking the first order conditions and solving with respect to the first-period fees, we obtain the first-period reaction functions

$$f_{1A} = R_{1A}(f_{1B}) = -\frac{[s^2 \delta (3r_A + 2r_B)(r_A - r_B - 2f_{1B}) + (r_A - r_B)^2 (s\delta (r_A - 2r_B) + 2 f_{1B} r_B)]}{2s^2 \delta (3r_A + 2r_B) + (r_A - r_B)^2 (r_A - 2r_B)} \tag{23}$$

and

$$f_{1B} = R_{1B}(f_{1A}) = \frac{[s^2 \delta (2r_A + 3r_B)(r_A - r_B + 2f_{1A}) - (r_A - r_B)^2 (2(f_{1A} r_A + (r_A - r_B)^2)) - s\delta (2r_A - r_B)]}{2s^2 \delta (3r_A + 2r_B) + (r_A - r_B)^2 (r_A - 2r_B)}. \tag{24}$$

By solving the system of (23) and (24) we derive the first-period equilibrium fees

$$f_{1A}^{*} = -\frac{r_B}{2} - \frac{s\delta [(r_A - r_B)^2 (2r_A^2 - 7r_A r_B + 3r_B^2) + 2s^2 \delta (2r_A^2 + r_A r_B + 2r_B^2)]}{2(r_A - r_B)^2 (s^2 \delta + 2(r_A - r_B))^2} \tag{25}$$

and

$$f_{1B}^{*} = \frac{r_A - 2r_B}{2} - \frac{s\delta [(r_A - r_B)^2 (3r_A^2 - 7r_A r_B + 2r_B^2) + 2s^2 \delta (2r_A^2 + r_A r_B + 2r_B^2)]}{2(r_A - r_B)^2 (s^2 \delta + 2(r_A - r_B)^2)}. \tag{26}$$

Finally, we substitute (25) and (26) into (21) and (22) and obtain the equilibrium second-period fees:

$$f^*_{2A} = -\frac{r_B}{2} + \frac{s^2\delta r_B(r_A + r_B)}{2(r_A - r_B)(s^2\delta + 2(r_A - r_B)^2)} \tag{27}$$

and

$$f^*_{2B} = \frac{r_A - 2r_B}{2} + \frac{s^2\delta r_A(r_A + r_B)}{2(r_A - r_B)(s^2\delta + 2(r_A - r_B)^2)}. \tag{28}$$

If we compare the first-period equilibrium fee of firm A when firms are myopic and that when they are forward looking, we find that f^*_{1A} is lower when firms are forward looking when $r_A > 3r_B$. When $2r_B < r_A < 3r_B$, in order for f^*_{1A} to be lower when firms are forward looking, condition $s^2\delta > -(r_A - r_B)^2(2r_A^2 - 7r_Ar_B + 3r_B^2)/2(2r_A^2 + r_Ar_B + 2r_B^2)$ must hold. For firm B, the first-period fee when firms are forward looking is smaller than that when firms are myopic (since $r_A > 2r_B$). Finally, when firms are forward looking, both second-period fees are larger compared to when firms are myopic (since $r_A > r_B$). □

Next, we establish that:

Remark 2. When there are switching costs and firms are forward looking, firm B has a larger market share in both periods, compared to when firms are myopic.

Proof: To find the first-period indifference usage level, we substitute (25) and (26) into (1) and obtain

$$\bar{\theta}^*_1 = \frac{1}{2} - \frac{s\delta(r_A + r_B)}{2(s^2\delta + 2(r_A - r_B)^2)} < \frac{1}{2}. \tag{29}$$

Therefore, in the first period, firm B has a larger market share than firm A. Note that condition $s\delta(r_A + r_B) < s^2\delta + 2(r_A - r_B)^2$ must hold in order for both firms to be in the market.

Further, we substitute (27) and (28) into (8) and (9) and find that the equilibrium values for $\tilde{\theta}_A$ and $\tilde{\theta}_B$ are

$$\bar{\theta}^*_A = \frac{1}{2} + \frac{s^2\delta(r_A + r_B)}{2(r_A - r_B)(s^2\delta + 2(r_A - r_B)^2)} + \frac{s}{r_A - r_B}$$

and

$$\bar{\theta}^*_B = \frac{1}{2} + \frac{s^2\delta(r_A + r_B)}{2(r_A - r_B)(s^2\delta + 2(r_A - r_B)^2)} - \frac{s}{r_A - r_B}.$$

In order for $0 < \bar{\theta}_B^* < \bar{\theta}_A^* < 1$ to hold, condition $(r_A - r_B)(s^2\delta + 2(r_A - r_B)^2) > s(4(r_A - r_B)^2 + s\delta(r_A + r_B + 2s))$ must be satisfied. The market share of firm A in the second period is $\bar{\theta}_B^* + \bar{\theta}_1^*(\bar{\theta}_A^* - \bar{\theta}_B^*)$, which is equal to

$$\text{A's market share} = \frac{1}{2} - \frac{s^2\delta(r_A + r_B)}{2(r_A - r_B)(s^2\delta + 2(r_A - r_B)^2)}. \tag{30}$$

The market share of firm B in the second period is $(1 - \bar{\theta}_A^*) + (1 - \bar{\theta}_1^*)(\bar{\theta}_A^* - \bar{\theta}_B^*)$, which is equal to

$$\text{B's market share} = \frac{1}{2} + \frac{s^2\delta(r_A + r_B)}{2(r_A - r_B)(s^2\delta + 2(r_A - r_B)^2)}. \tag{31}$$

We observe that firm A's market share in the second period is below 1/2 and, therefore, is lower than that in the case of myopic firms. On the other hand, firm B's market share in the second period in now larger than 1/2, so firm B's share increases when the firms are forward looking. □

We conclude this section with some remarks. When firms are myopic, the difference of the fees is equal to $(r_A - r_B)/2$ in both periods. When firms are forward looking, firm B attracts more customers in the first period, by decreasing its fee more than firm A does. The difference of the fees now becomes $(r_A - r_B)/2 - s\delta(r_A + r_B)/2(s^2\delta + 2(r_A - r_B)^2)$. Since, because of the switching cost, some customers do not change suppliers in the second period, firm B increases its fee by more than firm A and still continues to attract more customers than firm A. The difference of the two fees in the second period now becomes $(r_A - r_B)/2 + s\delta(r_A + r_B)/2(s^2\delta + 2(r_A - r_B)^2)$.

5. FIRMS SET ONE FEE FOR BOTH PERIODS

To gain some additional insights about the dynamic effects, in this section, we modify the basic model by assuming that firms commit to a single fee across both periods. We maintain the assumption that the rates do not change: $r_{1A} = r_{2A} = r_A$ and $r_{1B} = r_{2B} = r_B$. In this case, firms know that in the second period consumers' usage levels will change, but they cannot adjust their fees to respond to the modified profit functions. Of course, when choosing their first-period fees, firms take into consideration that the usage levels of consumers will change in the second period. In this case, the period-two profit functions can be written as in (10) and (11) above, with the only modification that now we constrain fees to be the same across periods, thus we will have $f_{1A} = f_{2A} = f_A$ and $f_{1B} = f_{2B} = f_B$.

Again we focus on the case where $0 < \tilde{\theta}_B < \tilde{\theta}_A < 1$. The profit function of firm A across both periods, evaluated as of period one, is

$$V_A = \int_0^{\tilde{\theta}_1} (f_A + \theta r_A)\,d\theta + \delta \left(\int_0^{\tilde{\theta}_B} (f_A + \theta r_A)\,d\theta + \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} \tilde{\theta}_1 (f_A + \theta r_A)\,d\theta \right).$$

Similarly, for firm B we have

$$V_B = \int_{\tilde{\theta}_1}^{1} (f_B + \theta r_B)\,d\theta + \delta \left(\int_{\tilde{\theta}_A}^{1} (f_B + \theta r_B)\,d\theta + \int_{\tilde{\theta}_B}^{\tilde{\theta}_A} (1 - \tilde{\theta}_1)(f_B + \theta r_B)\,d\theta \right).$$

The indifference period-one usage level is as in (1) and the indifference period-two usage levels are as in (8) and (9) above, with the only modification that now fees are the same across periods. We obtain the following result.

Proposition 5. Consider a two-period model where fees are set once and for all at the beginning of period one and rates do not change over time. Each firm sets a fee lower than the corresponding second-period fee when firms can change fees across periods. Firm B serves more customers than firm A in both periods.

Proof: We first check that $\partial^2 V_A/\partial f_A^2 = 4s\delta r_B - (1+\delta)(r_A - 2r_B)(r_A - r_B)/(r_A - r_B)^3$ and $\partial^2 V_B/\partial f_B^2 = -4s\delta(2r_A - r_B) + (r_A - r_B)(2r_A - r_B - \delta(3r_A - 2r_B))/(r_A - r_B)^3$ are both negative for $r_A > 2r_B + 4s\delta r_B/(1+\delta)(r_A - r_B)$. Solving the system of the first order conditions then leads us to the equilibrium fees:

$$f_A^* = \frac{-r_B}{2} - \frac{[8s^2\delta^2(r_A - 2r_B) + 2s\delta(r_A - r_B)((2r_A - 3r_B) + \delta(2r_A - 5r_B)) - \delta(1+\delta)(r_A - r_B)^2 r_B]}{2(6s\delta + (2+3\delta)(r_A - r_B))(2s\delta + (1+\delta)(r_A - r_B))}$$

and

$$f_B^* = \frac{r_A - 2r_B}{2} - \frac{[4s^2\delta^2(3r_A - 5r_B) + 2s\delta(r_A - r_B)((3r_A - 4r_B) + \delta(4r_A - 7r_B)) + \delta(1+\delta)(r_A - r_B)^2(r_A - 2r_B)]}{2(6s\delta + (2+3\delta)(r_A - r_B))(2s\delta + (1+\delta)(r_A - r_B))}$$

Straightforward but tedious calculations establish that both fees are lower compared to the fees that firms would charge in the second period if they were allowed to adjust their prices in the second period.

To find the first-period equilibrium market shares, we substitute the equilibrium fees into (1) and obtain

$$\underline{\theta}_1^* = \frac{1}{2} - \frac{\delta(r_A - r_B + s)}{2(6s\delta + (2+3\delta)(r_A - r_B))}.$$

Since $0 < \underline{\theta}_1^* < 1/2$ for $s \geq 0$, we conclude that firm B serves more customers than firm A in period one. To calculate the second-period market shares we substitute the equilibrium fees into (8) and (9) and obtain

$$\underline{\theta}_A^* = \frac{1}{2} - \frac{\delta(2s + r_A - r_B)}{12s\delta + (4+6\delta)(r_A - r_B)} + \frac{s}{(r_A - r_B)}$$

and

$$\underline{\theta}_B^* = \frac{1}{2} - \frac{\delta(2s + r_A - r_B)}{12s\delta + (4+6\delta)(r_A - r_B)} - \frac{s}{(r_A - r_B)}.$$

For $0 < \underline{\theta}_B^* < \underline{\theta}_A^* < 1$ to hold, condition $(r_A - r_B)^2(1+\delta) > 6s^2\delta + s(r_A - r_B)(2+\delta)$ must be satisfied. Firm A's market share in period two is $\underline{\theta}_B^* + (\underline{\theta}_A^* - \underline{\theta}_B^*)\underline{\theta}_1^*$, which is equal to

$$\text{A's market share} = \frac{1}{2} - \frac{\delta(2s + r_A - r_B)^2}{2(r_A - r_B)(6s\delta + (2+3\delta)(r_A - r_B))}.$$

Firm B's market share in period two is $(1 - \underline{\theta}_A^*) + (\underline{\theta}_A^* - \underline{\theta}_B^*)(1 - \underline{\theta}_1^*)$, which is equal to

$$\text{B's market share} = \frac{1}{2} + \frac{\delta(2s + r_A - r_B)^2}{2(r_A - r_B)(6s\delta + (2+3\delta)(r_A - r_B))}.$$

A direct comparison reveals that, in period two, firm B serves more customers than firm A. □

In order to compare the fee that each firm charges when constrained not to change it in period two, to the first-period fees when fees can change across periods, we have performed some numerical comparisons. For parameter values $r_A = 6$, $r_B = 2$, $s = 0.7$ and $\delta = 0.7$ we have $f_A^* > f_{1A}^*$ and $f_B^* < f_{1B}^*$. The former inequality appears to hold as δ and s were allowed to vary. The latter inequality gets reversed for $s > 1.05$.

6. PRICE DISCRIMINATION BETWEEN NEW AND OLD USERS

In this section, we allow firms to price discriminate between old and new customers in the second period. This is a very common practice in many markets. For instance, in the credit card market firms often offer a lower interest rate and/or a lower fee in order to attract the customers of competing banks. Such "introductory pricing" offers are also common in other markets. They can be particularly important in "new economy" markets, where firms can have at low cost a record of the past purchasing decisions of (their) customers. Here we examine the case where firms set different fees to old and new customers in the second period.

In period two, each firm faces two different groups of consumers: consumers that bought product A in the first period and consumers that bought product B. The two market segments can be separated. Let us examine how firms compete for the $\tilde{\theta}_1$ consumers who bought product A in the first period (these are consumers with usage levels below $\tilde{\theta}_1$ in period one). A consumer that chose product A in the first period and has second-period usage level θ, will be indifferent between product A and product B in the second period if $f_{2A}^{L} + \theta r_A = f_{2B}^{N} + \theta r_B + s$, where f_{2A}^{L} is the fee that firm A sets to its loyal (old) clients and f_{2B}^{N} is the fee that firm B sets to its new clients. We call this indifference usage level

$$\hat{\theta}_A \equiv \frac{f_{2B}^{N} - f_{2A}^{L} + s}{r_A - r_B}. \tag{32}$$

For $0 < \hat{\theta}_A < 1$, firm A maximizes

$$\tilde{\theta}_1 \int_0^{\hat{\theta}_A} (f_{2A}^{L} + \theta r_A)\, d\theta \tag{33}$$

with respect to f_{2A}^{L}, while firm B maximizes

$$\tilde{\theta}_1 \int_{\hat{\theta}_A}^{1} (f_{2B}^{N} + \theta r_B)\, d\theta \tag{34}$$

with respect to f_{2B}^{N}.

Firms also compete for the consumers that bought product B in the first period. A consumer that chose product B in the first period and has usage level θ in period two, will be indifferent between the two products in the second period if $f_{2A}^{N} + \theta r_A + s = f_{2B}^{L} + \theta r_B$, where f_{2B}^{L} is the fee that firm B charges to its loyal clients and f_{2A}^{N} is the fee that firm A charges to its new clients. We call this indifference usage level

$$\hat{\theta}_B \equiv \frac{f_{2B}^L - f_{2A}^N - s}{r_A - r_B}. \tag{35}$$

There are $(1 - \tilde{\theta}_1)$ consumers that bought product B in the first period and for $0 < \hat{\theta}_B < 1$, firm A maximizes

$$(1 - \tilde{\theta}_1) \int_0^{\hat{\theta}_B} (f_{2A}^N + \theta r_A)\, d\theta \tag{36}$$

with respect to f_{2A}^N, while firm B maximizes

$$(1 - \tilde{\theta}_1) \int_{\hat{\theta}_B}^1 (f_{2B}^L + \theta r_B)\, d\theta \tag{37}$$

with respect to f_{2B}^L.

Firms' profit functions over both periods are then

$$V_A = \int_0^{\tilde{\theta}_1} (f_{1A} + \theta r_A)\, d\theta + \delta \left(\tilde{\theta}_1 \int_0^{\hat{\theta}_A} (f_{2A}^L + \theta r_A)\, d\theta + (1 - \tilde{\theta}_1) \int_0^{\hat{\theta}_B} (f_{2A}^N + \theta r_A)\, d\theta \right) \tag{38}$$

and

$$V_B = \int_{\tilde{\theta}_1}^1 (f_{1B} + \theta r_B)\, d\theta + \delta \left(\tilde{\theta}_1 \int_{\hat{\theta}_A}^1 (f_{2B}^N + \theta r_B)\, d\theta + (1 - \tilde{\theta}_1) \int_{\hat{\theta}_B}^1 (f_{2B}^L + \theta r_B)\, d\theta \right). \tag{39}$$

Proposition 6. Suppose firms are forward looking and in the second period can price discriminate between new and old customers. Then the second-period fees are independent of the first-period fees. Firm A sets a lower fee to its loyal customers compared to when it cannot price discriminate, while firm B sets a lower fee to its new customers. Both first-period fees are higher when firms are forward looking and price discriminate in the second period compared to when firms do not price discriminate. Firm A's first-period fee when firms are forward looking and price discriminate is lower than its fee when firms are myopic if $r_A > 3r_B$, and higher otherwise. Firm B's first-period fee is always lower when forward looking firms price discriminate compared to the case of myopic firms.

Proof: First, note that while firms' second period profits, (33), (34), (36) and (37), depend on firms' first-period behavior through $\tilde{\theta}_1$, the second-period fees that firms would choose are independent of $\tilde{\theta}_1$ (and independent of first-period behavior in general). Thus, we can determine the second-period equilibrium behavior separately. Proceeding to the optimization, we check that the profit functions in (33) and (36) are concave for $r_A > 2r_B$, while these in (34) and (37) are concave for $r_A > r_B$. Taking the first order conditions with respect to each firm's fees, we then obtain the following reaction functions:

$$f_{2A}^{L} = R_{2A}^{L}(f_{2B}^{N}) = -\frac{(s + f_{2B}^{N})r_B}{r_A - 2r_B}, \tag{40}$$

$$f_{2B}^{N} = R_{2B}^{N}(f_{2A}^{L}) = \frac{r_A^2 + r_A(-s + f_{2A}^{L} - 2r_B) + r_B^2}{2r_A - r_B}, \tag{41}$$

$$f_{2A}^{N} = R_{2A}^{N}(f_{2B}^{L}) = \frac{(s - f_{2B}^{L})r_B}{r_A - 2r_B} \tag{42}$$

and

$$f_{2B}^{L} = R_{2B}(f_{2A}^{N}) = \frac{r_A^2 + r_A(s + f_{2A}^{N} - 2r_B) + r_B^2}{2r_A - r_B}. \tag{43}$$

Solving as a system (40) and (41), and then (42) and (43) leads to the equilibrium fees:

$$f_{2A}^{*L} = -\frac{r_B}{2} - \frac{sr_B}{2(r_A - r_B)}, \tag{44}$$

$$f_{2A}^{*N} = -\frac{r_B}{2} + \frac{sr_B}{2(r_A - r_B)}, \tag{45}$$

$$f_{2B}^{*L} = \frac{r_A - 2r_B}{2} + \frac{sr_A}{2(r_A - r_B)} \tag{46}$$

and

$$f_{2B}^{*N} = \frac{r_A - 2r_B}{2} - \frac{sr_A}{2(r_A - r_B)}. \tag{47}$$

In order to find the first-period equilibrium fees, we substitute the equilibrium fees of the second period into (38) and (39). Checking the second order conditions, we see that both profit functions are concave with respect to the own first-period fees when $r_A > 2r_B$. The first order conditions then imply:

$$f_{1A} = R_{1A}(f_{1B}) = -\frac{s\delta r_A + 2r_B(-s\delta + f_{1B})}{2(r_A - 2r_B)} \tag{48}$$

and

$$f_{1B} = R_{1B}(f_{1A}) = -r_B - \frac{s\delta}{2} + \frac{r_A(f_{1A} + r_A)}{2(r_A - r_B)}. \tag{49}$$

By solving the system of (48) and (49), we obtain the first-period equilibrium fees

$$f^*_{1A} = -\frac{r_B}{2} - \frac{s\delta(r_A - 3r_B)(2r_A - r_B)}{4(r_A - r_B)^2} \tag{50}$$

and

$$f^*_{1B} = \frac{r_A - 2r_B}{2} - \frac{s\delta(3r_A - r_B)(r_A - 2r_B)}{4(r_A - r_B)^2}. \tag{50}$$

Comparing these fees with the second-period fees when firms are forward looking but do not price discriminate (expressions (27) and (28)) we find that $f^{*L}_{2A} < f^*_{2A}$ and $f^{*N}_{2B} < f^*_{2B}$ and that if $s\delta(r_A + r_B - s) < 2(r_A - r_B)^2$ then $f^{*N}_{2A} > f^*_{2A}$ and $f^{*L}_{2B} > f^*_{2B}$, otherwise $f^{*N}_{2A} < f^*_{2A}$ and $f^{*L}_{2B} < f^*_{2B}$. Next, comparing the second-period fees that firms charge in the case when they price discriminate between new and old customers to the second-period fees when firms are myopic (given by (16)) we find that f^{*L}_{2A} and f^{*N}_{2B} are lower than the fees firms charge when they are myopic, while f^{*N}_{2A} and f^{*L}_{2B} are higher. Thus, firm A "rewards" its loyal customers with a lower price, while firm B charges a lower fee to its new ones.

Let us now compare the first-period fees just derived to the fees firms charge when they are forward looking but do not price discriminate. We subtract (50) from (25) to get $-s^3\delta^2(r_A + r_B)(6r_A + 5r_B)/4(r_A - r_B)^2(s^2\delta + 2(r_A - r_B)^2) < 0$. The first-period equilibrium fees consist of two terms with the first term common for both fees, so we only need to compare the second terms. For $r_A > 3r_B$, both second terms are negative, thus, we conclude that the first-period fee when firms do not price discriminate is lower compared to when firms do discriminate between new and old customers. When $r_A < 3r_B$ but $s^2\delta > -(r_A - r_B)^2(3r_A^2 - 7r_Ar_B + 2r_B^2)/2(2r_A^2 + r_Ar_B + 2r_B^2)$, the second term of the fee when firms do not discriminate is negative while the second term of the fee when firms discriminate is positive, therefore we cannot tell for sure which fee is higher. Finally, when $r_A < 3r_B$ and $s^2\delta < -(r_A - r_B)^2(3r_A^2 - 7r_Ar_B + 2r_B^2)/2(2r_A^2 + r_Ar_B + 2r_B^2)$ both second terms are positive; since their difference is negative we conclude that the second term when firms discriminate is larger than the second term when firms do not discriminate. Therefore, in this case, the first-period fee when firms do not price discriminate is smaller than when firms do discriminate between new and old customers. In general, the first-period fee of firm B when firms price discriminate is lower than the corresponding fee when firms are myopic, while the first-period fee of firm A when firms price discriminate is lower than the corresponding fee when firms are myopic only if $r_A > 3r_B$. □

A discussion on the properties of the second-period fees may be useful. We have seen that firm A, charges a lower fee to its loyal customers relative to the fee it would charge if it could not price discriminate, while firm B charges a lower fee to its new customers.[7] Firm A, the high rate firm, would like to continue serving the customers it served in the first period: in the second period, some of these customers will have a high usage level and will be "stuck" to firm A only because of the switching cost. These "heavy" users are being charged a high rate and thus increase firm A's profit. Customers that wish to switch from firm B to firm A are customers with low usage level so firm A is better off with its old customers than with some new ones. On the other hand, firm B, the low rate firm, finds relatively more attractive its new customers, who have high usage level, than keeping its old customers, some of which will have a low usage level in the second period. As a result, both firms vigorously compete for the trapped customers of firm A, and these are the customers that in equilibrium pay the lowest price, regardless of whether they switch from A to B or if they continue purchasing from A.

Finally, we establish the following result.

Proposition 7. When firms are forward looking and can price discriminate between old and new customers in the second period, the market share of firm B is larger than the market share of firm A in both periods. Moreover, firm B serves more customers in the second period when it price discriminates than when it does not. In the first period, firm B serves more customers when it price discriminates, than when it does not, if $2(r_A - r_B)^2 > s^2\delta$.

Proof: In order to determine the first-period's indifference usage level we substitute (50) and (51) into (1) and get

$$\hat{\theta}_1^* = \frac{1}{2} - \frac{s\delta(r_A + r_B)}{4(r_A - r_B)^2}. \tag{52}$$

To have $\hat{\theta}_1^* \in (0, 1)$ condition $s < 2(r_A - r_B)^2/\delta(r_A + r_B)$ must hold given that $s > 0$. As we can see, $\hat{\theta}_1^* < 1/2$ and, therefore, firm B has a larger market share than firm A in the first period. To determine the equilibrium values of $\hat{\theta}_A$ and $\hat{\theta}_B$ we substitute (44)–(47) into (32) and (35) and get

$$\hat{\theta}_A^* = \frac{1}{2} + \frac{s}{2(r_A - r_B)}$$

and

$$\hat{\theta}_B^* = \frac{1}{2} - \frac{s}{2(r_A - r_B)}.$$

For $0 < \hat{\theta}_B^* < \hat{\theta}_A^* < 1$ to hold, condition $s < (r_A - r_B)$ must be satisfied.

The market share of firm A in the second period is $\hat{\theta}_B^* + \hat{\theta}_1^*(\hat{\theta}_A^* - \hat{\theta}_B^*)$ which is equal to

$$\text{A's market share} = \frac{1}{2}\left(1 - \frac{s^2\delta(r_A + r_B)}{2(r_A - r_B)^3}\right). \tag{53}$$

The market share of firm B in the second period is $(1 - \hat{\theta}_A^*) + (1 - \hat{\theta}_1^*)(\hat{\theta}_A^* - \hat{\theta}_B^*)$ which is equal to

$$\text{B's market share} = \frac{1}{2}\left(1 + \frac{s^2\delta(r_A + r_B)}{2(r_A - r_B)^3}\right). \tag{54}$$

Firm A's market share in period 2 is smaller than firm B's market share. We conclude that firm B has more customers than firm A in both periods. To compare firm A's market share when firms price discriminate and when they do not, we subtract (53) from (30) to get $s^4\delta^2(r_A + r_B)/4(s^2\delta + 2(r_A - r_B)^2)(r_A - r_B)^3 > 0$. Thus, the market share of firm A in the second period is larger when firms do not price discriminate. To see how firm's B market share changes when firms price discriminate we subtract (54) from (31) to get $-s^4\delta^2(r_A + r_B)/4(s^2\delta + 2(r_A - r_B)^2)(r_A - r_B)^3 < 0$. Thus, the market share of firm B in the second period is larger when firms price discriminate. To compare firm B's demand in the first period when it price discriminates and when it does not, we subtract (29) from (52) and find that firm B serves more customers when it price discriminates than when it does not if $2(r_A - r_B)^2 > s^2\delta$. □

7. CONCLUSION

In this chapter, we have studied a simple two-period duopoly model with the following features. Pricing by each firm has two parts: a per-unit usage rate (taken as given in the analysis) and a fixed fee charged to each customer – the fees are the strategic variables in the game. Although all consumers view the products as perfect substitutes, heterogeneity with respect to their usage levels implies that endogenous segmentation of the market is possible with both firms making positive profit. In equilibrium, "light" users choose the product that is priced with the lower fee and "heavy" users the rival product, priced with the lower rate. Our main focus is on the dynamics: consumers' usage levels may change across

Table 1. Equilibrium Profits for $r_A = 6$, $r_B = 2$, $s = 1$ and $\delta = 0.8$.

	π^*_{1A}	π^*_{1B}	π^*_{2A}	π^*_{2B}	$\pi^*_{1A} + \delta\pi^*_{2A}$	$\pi^*_{1B} + \delta\pi^*_{2B}$
Myopic firms	0.25	1.25	0.43	1.187	0.599	2.199
Forward looking firms	0.038	1.135	0.406	1.314	0.362	2.189
Firms charge one fee	0.057	1.172	0.173	2.831	0.195	3.436
Price discrimination	0.08	1.2	0.24	1.453	0.272	2.362

periods and, as a result, they may wish to switch from one product to the other; for instance, a consumer that finds he needs to borrow a larger amount using his credit card or wishes to stay connected to the internet longer, would then tend to find more attractive a supplier with a low rate per unit of usage, even if that supplier charges a relatively high fixed fee. However, switching involves a cost. We examine equilibria in this general setting, and under a number of different assumptions as to whether firms can change fees across periods or not, whether the change in usage levels is anticipated to the firms or not and whether price discrimination among old and new users is possible or not. A general result is that, in the presence of switching costs, changes in usage rates do not affect firms symmetrically. For instance, while when price discrimination is possible, the high rate firm lowers its fee for its old customers, the low rate firm lowers its fee for its new customers.

Since we have derived results in closed form, it is straightforward to present numerical examples. In Table 1, we calculate firms' profit levels for the different scenarios we have studied. For parameter values $r_A = 6, r_B = 2, s = 1$ and $\delta = 0.8$ we see that when firms are myopic, firm A has a higher profit in the second period, compared to its first-period profit, while firm B's profit decreases, as we have seen in Section 3. In all cases, firm A's profit increases in the second period compared to the first-period profit, since in the second period firm A captures some customers that have a usage level higher than the first period indifference usage level, because of the presence of switching cost. Firm's A total profit is lower in all scenarios compared to the scenario of myopic firms. For the specific parameter values, firm B maximizes its total profit when firms are constrained to charge one fee in both periods.

In this chapter, we have examined only one aspect of firms' competition and necessarily have abstracted away from a number of other important issues; at the same time, we have made a number of simplifying assumptions. Some remarks are in order. First, in our setting, firms do not compete with fees and rates both being endogenous; we start the analysis at a point where the rates are taken by the firms as given. This assumption allows us to make a first step towards examining dynamic pricing and the role of switching costs in a market where consumers self-select between two suppliers according to their usage levels – but it is restrictive. There are two main directions in which one could go starting from this point. Either to introduce product differentiation and derive the implied equilibrium prices, or to modify the game and study a two-stage game where rates are chosen first. Second, demand is modeled so that each customer's usage level is not dependent on the prices. While this assumption is in line with related models of price competition under product differentiation and fixed (unit) demands, relaxing it would lead to modified results and may be required for certain applications. Third, consumers are assumed myopic, or, put differently, the change in their usage levels takes them by surprise. Whether this assumption is reasonable or not depends on the particular application of the model. We imagine in some cases such changes would be anticipated and in other not. The assumption is made primarily for simplicity, but is also internally consistent in the model since usage levels are anyway exogenously specified. Making (some) consumers forward looking would enrich the set of results.

Future research should shed additional light to the general issue of duopoly competition via two-part tariffs and the implications for dynamics under switching costs. This appears an important aspect of competition in many industries, including several that have a significant "new economy" character, such as telecommunication, banking and financial services. Thus, additional work is required both in the direction of theoretical modelling, as well as that of empirical evaluation.

NOTES

1. For a study of related pricing issues see e.g. Ausubel (1991), Calem and Mester (1995), Evans and Schmalensee (1999) and Stango (2002) for credit cards; for telecommunications see e.g. Levy and Spiller (1996), Laffont and Tirole (2000) and Laffont et al. (2003). Pricing practices vary across firms and across markets. For instance in some countries (currently in Australia, Canada and in many cases in the USA) internet access and local telephone is typically "unmetered," whereas in many European countries charges are typically metered. Likewise, accessing information at World Wide Web sites, some are free to the user (sometimes supported by advertising), other charge a monthly or annual access/subscription fee and some other charge per each item that is accessed or downloaded.
2. In addition, it has been examined how two part tariffs can be used by upstream competitors when attempting to endow with commitment power their downstream counterparts. See e.g. Fershtman and Judd (1987), Bonnano and Vickers (1988), and Saggi and Vettas (2000) – also Irmen (1998) for a survey.
3. The usage level is, e.g. the amount the user borrows in the case of a credit card, or the amount of time he is connected to a network in the case of telecommunications. Here, we assume for simplicity that the usage level, θ, for a given consumer is fixed and in particular, completely inelastic with respect to the rates charged.
4. It is straightforward to introduce a constant unit cost for each firm; such a modification does not qualitatively alter the results.

5. This formulation is consistent with the related literature in the "discrete choice" tradition and involves two implicit assumptions. First, that the utility of having a product is high enough that no consumer would choose not to have any of the two. Second, that no consumer purchases both products. As long as prices are positive, this assumption follows from the fact that the products are perfect substitutes. If some prices are negative, then in principle consumers may wish to obtain both products in case their total payment is negative. In some markets such behavior may be possible (e.g. in some segments of the credit/payment cards market) while in other it is not (e.g. a traveler may drive only one rental car at a time, or an office may have space only for one photocopy machine). In Griva and Vettas (2003), we extend the model to allow consumers to purchase more than one products. This implies, in equilibrium, that total payment for all consumers should be positive.

6. A word of warning here, that in the model as it presently stands, a pure strategy equilibrium in fees only exists for a certain range of the rates.

7. Arbatskaya (2000), using a Hotelling-type model with linear prices, finds that if one firm has sufficiently higher marginal cost than its rival, it discriminates in favor of its own customers.

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