Temporal Price Dispersion: Evidence from an Online Consumer Electronics Market

by

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Abstract

Economic theory indicates that E-retailers competing at price comparison sites, such as Shopper.com, must charge prices that cannot be systematically predicted by their rivals. Consistent with theory, we find significant variation in the identity of the low-price firm as well as the level of the lowest price for 36 of the best-selling consumer electronics products sold at Shopper.com between November 1999 and May 2001. The observed pricing patterns can be explained by firms engaging in short-term price promotions in an attempt to avoid the deleterious outcome associated with price competition. Based on our arguments and the evidence presented, the managerial implications are clear: Strategic unpredictability in prices—through the use of hit and run sales—is a widely used and effective weapon for avoiding all-out price competition in online markets.

Keywords: Temporal price dispersion, price comparison sites, e-retail, sales promotion.

JEL Nos.: D4, D8, M3, L13

1. Introduction

The main stylized fact to emerge from the growing empirical literature on E-retailing is that price dispersion is both ubiquitous and persistent—even in markets for apparently homogeneous products (see, for example, Brynjolfsson and Smith, 2000 or Baye, Morgan, and Scholten, forthcoming a and b and the references contained therein). The present paper shows that the price dispersion observed in online markets is consistent with what we term "hit and run" pricing strategies by firms. The key testable implication of hit and run pricing strategies examined in this paper is that there should be considerable turnover in the identity of the firm offering the lowest price in the market over time.

Specifically, we show that hit and run pricing—short-term price promotions undertaken at unpredictable intervals—is an effective and widely used "weapon" for E-retail managers. This not only precludes rivals from being able to exploit predictable pricing strategies, but also enables firms to price discriminate over time, even when market forces preclude price discrimination at each point in time.

The theory suggesting the effectiveness of hit and run pricing strategies stems from an equilibrium analysis of "clearinghouse models" of price competition. In clearinghouse models, some or all consumers can gain access to a list of prices offered by competing firms for a similar product by consulting an "information clearinghouse," typically controlled by a "gatekeeper." Examples of such information clearinghouses are Internet price comparison sites, such as Shopper.com and Nextag.com. This class of models, which will be discussed in more detail in Section 2

of the paper, has led to important contributions and insights in both marketing and economics. The earliest clearinghouse formulation is due to Varian (1980). While that model and its successors (see, for instance, Rosenthal (1980), Narasimhan (1988), and Raju, *et al.* (1990)) were designed to explain price dispersion in offline markets, Baye and Morgan (2001) adapts the clearinghouse framework to capture some of the unique institutional features of online markets. Specifically, the Baye-Morgan model endogenizes a number of decisions including those of firms to list prices on the site, those of consumers to subscribe to the site, and those of information gatekeepers regarding fees charged to firms and consumers for use of the site. Among other things, the Baye-Morgan model explains it is typically free for a consumer to use a price comparison site while it is costly for a firm to list its price there.

In clearinghouse models, the motivation for engaging in unpredictable price promotions stems from the heterogeneity between informed and uninformed consumers. Both the timing and intensity of sales is designed to prevent rivals from systematically undercutting a firm's price and thereby netting the mass of informed customers.

An empirical literature has also arisen to study the implications of this important class of models. In the context of offline markets, Villas-Boas (1995) and Lach (2002) examine some implications of Varian's model and find limited support for it. Also in the context of offline markets, Rao, Arjunji, and Muthi (1995) provide empirical evidence consistent with unpredictable price promotion strategies in

environments where the decision is a binomial choice to offer a regular price or an advertised special.[1]

In terms of empirically testing clearinghouse models in online markets, the extant literature is less well developed. Baye, Morgan, and Scholten (forthcoming a) test comparative static properties of various clearinghouse models using online price data, while Baye, Morgan, and Scholten (forthcoming b) show that, even after controlling for observed and unobserved firm heterogeneities, 28% of price dispersion exhibited at a particular clearinghouse (Shopper.com) is left unexplained. The present paper advances this literature by explicitly examining whether a firm's position in the price distribution is persistent over time or, as predicted by the clearinghouse models, varies unpredictably over time.

Our study is based on data for 36 consumer electronics products tracked over a 19-month period at Shopper.com – a leading price comparison site. In the Shopper.com environment, consumers with Internet access can freely access lists of prices for physically identical products, but firms are required to pay to transmit price information. These data exhibit considerable price dispersion, with the highest price for a consumer product nearly 60 percent higher than the best available price quoted by firms at the site.

[1] Several studies discuss situations where promotions are not mixed strategies in equilibrium. Rao (1991) provides another rationale for price promotion: a firm with national brand recognition will promote – to enable private label firms to charge "regular" prices – as a defensive strategy for maintaining market share of non-price conscious consumers. Lal (1990) also shows that in a three-firm model, two firms that are "national" brands can collude to keep the "local" brand out of the market.

An open question is whether the central prediction of clearinghouse models—price unpredictability at the firm level—is borne out in pricing online. That is, do some firms persistently charge lower prices than others? We test this hypothesis and show—consistent with theory—that there is considerable turnover in firms' relative position in the distribution of prices. In particular, there is significant variation in the identity of the low-price firm and, to a lesser extent, the high-price firm for the same product over time. Thus, this paper offers some new evidence in favor of clearinghouse models as a potential explanation for the pricing behavior observed in some online markets. More importantly, it suggests that the strategy of unpredictable short-term price promotions is an important tool for managers in highly competitive E-retail markets.

The remainder of the paper proceeds as follows: In Section 2, we outline the theory and intuition underlying clearinghouse models and summarize the outstanding testable implications. Section 3 describes the dataset used in our analysis of this class of models. Section 4 presents our results, highlighting the evidence for unpredictability in online pricing strategies. Finally, Section 5 offers managerial implications stemming from the analysis in the paper.

2. Theory

As we have argued elsewhere (cf. Baye and Morgan, 2001; Baye, Morgan and Scholten, forthcoming a and b), price comparison sites such as Shopper.com are essentially "information clearinghouses" where firms transmit price information and consumers access this information in making choices among firms selling similar

products. A key feature of this environment is that firm prices must simultaneously try to appeal to two types of consumers: "shoppers," who search intensively using the price listing service, and "loyals," who do not—perhaps because they lack access to the clearinghouse (as in Varian, 1980 and Baye and Morgan, 2001) or perhaps because they have strong "brand" preferences for a particular firm (as in Rosenthal, 1980 and Narasimhan, 1988). The key point in all of these models is that some consumers observe the complete list of prices offered by firms and buy from the firm offering the lowest price.

Equilibrium pricing in all of these models entails temporal price dispersion. At each point in time, a (stationary) distribution of prices will be observed at the information clearinghouse; however the identity of the firm offering the lowest price will vary *unpredictably* over time. This is true under differing assumptions about the decision to list prices at the clearinghouse, the fee structure of the clearinghouse, the number of competing firms, perceived quality of service provided by competing firms, and so on. Intuitively, firms need to employ "hit and run" pricing strategies to preclude rivals from being able to systematically undercut a fixed price.

In arriving at these implications about equilibrium pricing, clearinghouse models share the following modeling environment: Suppose that there are n firms offering a product to consumers. Each firm must determine a price to charge for its product and whether to list this price only at its website or to also list its price at a price comparison site (clearinghouse). Suppose there are L "loyal" consumers per firm and S "shoppers" interested in buying this product. Loyals buy from their preferred firm

while shoppers buy from the firm offering the lowest listed price at the comparison site. Baye, Morgan and Scholten (forthcoming a) show that this general framework subsumes the models of Baye and Morgan (2001), Varian (1980), Rosenthal (1980), and Narasimhan (1988) as special cases and formally shows (in Proposition 1) that the symmetric equilibrium in the general model also entails temporal price dispersion.

One might speculate that—faced with a choice between the ruinous competition arising from attempting to price low enough to attract shoppers, or pricing "high" and earning sizeable profits from loyals—the optimal pricing strategy would be for firms to abandon shoppers altogether and simply charge a high price. Such a pricing strategy, or indeed any other "predictable" pricing strategy, is not optimal, as the following argument shows.

Suppose all firms charge a high price, say H. With all firms posting the same price, each firm profitably sells to all of its loyal consumers, and, in addition, gets a share of the shoppers. However, since rivals' prices are "predictable," a firm could dramatically increase its profits by changing its pricing strategy. In particular, by reducing its price by an arbitrarily small amount, the firm's profits from sales to existing customers fall by a trivial amount. This loss is more than offset by the surge in demand from shoppers who switch from higher-priced rivals to the new low-price firm. More generally, for any predictable constellation of prices in which rivals enjoy positive margins, a firm can exploit the predictability by either lowering its price slightly below the rivals' best price, or abandoning shoppers all together and raising price to a high level.

In short, in the highly competitive E-retail marketplace, the pricing strategy that prevents systematic exploitation by rivals entails "hit and run" sales promotions, whereby the level of price at any instant in time is unpredictable. An added advantage of this strategy is that it permits firms to price discriminate (over time) among shoppers and loyals; on average, loyals end up paying higher prices than shoppers, even though at any instant in time, the firm charges a single price in the market.

Several testable implications follow directly from clearinghouse models. First, the continued need to avoid price predictability implies that prices will remain dispersed over time rather than converging to some fixed level. Second, unpredictability in pricing also implies the absence of a persistent "low-price" firm in these markets. Finally, the gains to hit and run sales obviously depend on their probability of succeeding in attracting shoppers. This success probability declines as the number of competing firms increases.

To summarize, three key implications of clearinghouse models are:

1. **Persistent price dispersion:** Firms' prices do not converge to the "law of one price" as E-retail markets mature.
2. **Temporal price dispersion:** The identity of the firm offering the *lowest* price on the comparison site varies unpredictably over time.
3. **Levels of price dispersion depend on market structure:** Levels of price dispersion systematically vary with the number of competing firms.

Baye, Morgan, and Scholten (forthcoming a) test implications 1 and 3 using a different dataset of online prices at Shopper.com and find no evidence of price

convergence over time and considerable evidence of a systematic relationship between levels of price dispersion and market structure.[2] That dataset covered the period from 1 August 2000 until 31 March 2001. Since that time, price dispersion has increased slightly. Indeed, the site Nash-equilibrium.com, which contains current statistics on price dispersion in online markets, shows that for every measure of dispersion reported there, price dispersion at price comparison sites is at least as large at the end of 2003 as it was at the end of 2000.

Our focus in this paper is to examine implication 2—that there is no consistent low-priced firm in E-retail markets. In the sequel, we describe the data we used to examine this implication of the general clearinghouse model, our findings, and what this means for managerial decision making in the area on online pricing.

3. Data

To examine the turnover in the identity of low-price firms and, more generally, the temporal component of price dispersion predicted by the models discussed above, we assembled a dataset of 36 popular products at Shopper.com over the period November 1999 to May 2001. Shopper.com is a price comparison site that closely approximates the institutional structure assumed in clearinghouse models. Consumers using this site can obtain a list of prices for physically identical products and purchase the product from either their preferred or the low-price E-retailer. The products sampled include a variety of printers, PDAs, digital cameras, software titles, CD-writers, networking hardware, and other relatively expensive products.

[2] Unfortunately, the dataset used in Baye, Morgan, and Scholten (forthcoming a) lacks identifiers for the identities of firms offering each price and hence cannot be used to test implication 2 directly.

A typical page viewed by a consumer wishing to purchase a specific product (identified by a unique part number) contains, among other things, a list of sellers along with the price charged by each seller for the item. With a single mouse-click, a consumer can sort prices from lowest to highest and easily buy from the firm offering the lowest price.

Our analysis focuses on the distribution of list prices for the products in our sample; for a detailed description of all of the information provided—and for an analysis of the impact of the role of shipping costs, branding, trust, and cost heterogeneity in explaining price dispersion—see our companion paper (Baye, Morgan, and Scholten, forthcoming b).[3]

In this environment, one may conjecture that the relevant unit of observation is a bundle of products. Lal and Villas-Boas (1998) examine the theoretical implications of firms selling in a multi-product environment. They find that the degree to which promotions are positively or negatively correlated across products critically depends on market structure. While a bundle of products is the likely unit of observation for relatively inexpensive items, such as books and CDs in online markets, our sample tends to include products with no obvious complementarities. Indeed, many products in the sample are likely to be consumption substitutes. Furthermore, given the prices of the items in our sample, bundling with an eye toward saving on shipping costs also seems implausible.

[3] Interestingly, Pan, Shankar, and Ratchford (2002) examine data from a competing price comparison site (Bizrate.com) and find that firms' improved reliability of service doesn't impact pricing decisions, although improving trust may. See also Shankar, Rangaswamy, and Pusateri (2001) and Ancarani and Shankar. (2002).

Data collection began on 5 November 1999, when we began physically downloading screenshots for the 36 most popular products at Shopper.com.[4] Our sample was limited in scale owing to the labor intensive nature of downloading the screenshots and coding the resulting data. We chose the most popular products because these products were likely to remain in the sample for the duration of our study as well as being products where competition was keenest. This process continued on the 5th of each month until May 2000.

4. Data Analysis

4.1 Summary Statistics

Table 1 offers summary statistics of our dataset including various measures of price dispersion for the entire period of the study. The average product in our sample sells for $200.35—significantly higher than the books and CDs that have largely been the focus of other recent studies of price dispersion in online markets. The average minimum price is $174.33. Consumers purchasing at the lowest price save about $31 compared to consumers purchasing at the average price. The average range is $76.52, or about 57 percent of the average lowest price. The coefficient of variation—the ratio of the standard deviation to the mean price of each product—averages 12.5 percent over the period. On balance, the summary statistics in Table 1 reveal considerable price dispersion.

[4] At the time, Shopper.com ranked its most popularly viewed and purchased 1000 products. Since then, Shopper.com now ranks the 50 most popular products in a variety of broad categories such as handhelds, software, monitors, and so on.

4.2 Cross-Sectional Variation in Price Rankings

Next we turn to the question of systematic price differences at the firm level. Tables 2a-2d provide a snapshot of the number of products offered by the E-retailers listing the largest number of products as well as the quartile ranking of each firm's prices at various points in the sample. In each table, E-retailers are ordered by the number of listed products. Several features of these tables are immediately apparent. First, on any given date, most firms in the sample neither consistently offer the lowest or highest price and that the relative price rankings change over time. Second, the number of products firms offer in the sample substantially declines over time. This is presumably, attributable to the relatively short product life cycles. Third, the set of firms listing price information over the sample period dramatically changes. Indeed, many of the firms that list prices for products in November 1999 no longer list prices by May 2001. Of the 30 firms listing prices for at least 20 products in November 1999 only six list prices in May 2001. Many new firms list prices in May 2001.

In the absence of temporal price dispersion and "hit and run" pricing, one would expect to see firms consistently offering prices within a given quartile, both cross-sectionally and over time. As the cross-sectional snapshot provided by Table 2a illustrates, however, the product offerings of most E-retailers do not fall into a single quartile group. Instead, there are only a few E-retailers, such as pcWonders, buy.com and eCost.com, who mostly offer lower prices than their rivals at the beginning of the sample. Similarly, there are some E-retailers, like Acentia and Micro X-press, who

seem to specialize in offering high prices for products. Several retailers resemble Computer411, offering some products in all four quartiles.

Table 2b presents the same information six months later. Overall, one still sees little evidence of clustering of prices offered by a firm in a single quartile. There are exceptions, however: Buy.com was among the consistent low-price sellers in November 1999 and remained so just six months later; although, the effect was not nearly as dramatic. In percentage terms, compared to rivals' prices, 89 percent of Buy.com's prices were listed in the first quartile in November 1999. While the total number of products Buy.com offered fell, the percentage of prices in the first quartile dropped to 69 percent by May 2000. Similarly, in November 1999 eCost.com listed 22 prices, all of which were in the first quartile. Six months later eCost.com listed five prices in the first quartile and eight in the second quartile. The E-retailer pcWonders was also among the low-price sellers in November 1999, but did not offer products in May 2000.[5] Similarly, Acentia – which was among the high-price E-retailers in November 1999 – no longer offered products in May 2000. Micro X-press' tendency for high prices, however, continued in May 2000. Despite considerable product turnover, the tendency for firms to list prices in each quartile remained.

Table 2c presents the same information for November 2000. Notice that firms' distributions of prices in the quartiles became more homogeneous. That is, firms specializing in offering low or high prices were increasingly rare. For instance,

[5] Pcwonders merged with Buyitnow.com on June 8, 2000.

Table 1: Summary Statistics
(Nov_99 - May_01)

Sample Characteristics	
Total Number of Months	19
Total Number of Products	36
Total Numer of Obervations	9435
Average Price	$200.35
Average Mininum Price	$174.33
Average Number of Sellers	17.50
Dollar Measures of Price Dispersion	
Range in Prices	$76.52
Difference Between Average and Lowest Price	$30.83
Unit-Free Measures of Price Dispersion	
Range in Prices (as a percentage of lowest price)	57.4%
Coefficient of Variation	12.5%

Table 2a: Number of Price Observations in each Quartile by Firm, November 5, 1999

		Number of Price Observations in each Quartile				Products
	Firm	1st	2nd	3rd	4th	**Listed**
1	AccessMicro.com	11	16	1	3	31
2	Computer411	9	14	7	1	31
3	McGlen Micro	0	8	14	9	31
4	COMPUTERS4SURE.COM	17	11	0	2	30
5	Soft4U.com	0	20	7	3	30
6	Solutions4SURE.com	17	11	0	2	30
7	pcWonders.com	24	2	3	1	30
8	Acentia	0	0	0	28	28
9	Buy More Products	0	4	13	11	28
10	Hardwarestreet.com	0	0	16	12	28
11	Software Buy Line	12	15	1	0	28
12	BUY.COM	24	0	2	1	27
13	Shopping.com	8	17	2	0	27
14	Gateway.com	0	7	16	3	26
15	NECX	0	7	16	3	26
16	CDW	0	1	5	19	25
17	CDworld	0	1	12	11	24
18	Club Computer	12	9	3	0	24
19	EGGHEAD.COM	7	8	6	3	24
20	GoGoCity.com	3	15	3	3	24
21	Micro X-press	0	1	4	19	24
22	ComputAbility	0	0	8	14	22
23	Micro Warehouse	0	2	5	15	22
24	PCMall	0	0	8	14	22
25	ShopNow	11	7	1	3	22
26	eCOST.com	22	0	0	0	22
27	Neutron	9	4	5	2	20
28	Outpost.com	1	2	5	12	20
29	Programmer's Paradise	0	0	10	10	20
30	firstsource.com	15	1	4	0	20

Table 2b: Number of Price Observations in each Quartile by Firm, May 5, 2000

		Number of Price Observations in each Quartile				Products
	Firm	1st	2nd	3rd	4th	**Listed**
1	firstsource.com	7	4	5	2	18
2	PCZone.com	3	2	7	4	16
3	Soft4U.com	1	10	4	1	16
4	TrioComputers.com	0	1	4	11	16
5	shoppingplanet.com	0	1	9	6	16
6	COMPUTERS4SURE.COM	9	3	3	0	15
7	Solutions4SURE.com	9	3	3	0	15
8	goVoom.com	1	2	8	4	15
9	BuyMoreProducts	4	4	5	1	14
10	Onvia.com	8	6	0	0	14
11	BUY.COM	9	1	2	1	13
12	ComputAbility	2	2	5	4	13
13	PCMall	2	2	5	4	13
14	eCOST.com	5	8	0	0	13
15	McGlenMicro	1	3	7	1	12
16	Micro X-press	0	0	2	10	12
17	AccessMicro.com	5	4	2	0	11
18	CompSource	0	0	7	4	11
19	NECX	1	4	4	2	11
20	PCNation.com	0	2	3	6	11
21	SoftwareBuyLine	1	5	4	1	11
22	#1 TechStore	6	4	0	0	10
23	EGGHEAD.COM	6	2	0	2	10
24	IC-Direct.com	7	2	1	0	10
25	NationStores.com	2	3	2	3	10
26	Outpost.com	0	0	3	7	10
27	PageComputer	4	6	0	0	10
28	Sunluck Distributors	0	1	5	4	10

Table 2c: Number of Price Observations in each Quartile by Firm, November 5, 2000

		Number of Price Observations in each Quartile				Products
	Firm	1st	2nd	3rd	4th	**Listed**
1	AllBusiness.com	2	2	4	6	14
2	eleaseorbuy.com	6	4	3	1	14
3	COMPUTERS4SURE.COM	5	5	3	0	13
4	Solutions4SURE.com	5	5	3	0	13
5	EGGHEAD.COM	3	5	2	0	10
6	Micro X-press	1	1	3	5	10
7	PCZone.com	3	1	4	1	9
8	firstsource.com	2	2	3	2	9
9	BUY.COM	5	2	1	0	8
10	Onvia.com	4	3	1	0	8
11	PCMall	0	4	1	3	8
12	PCNation.com	0	0	4	4	8
13	PageComputer	5	3	0	0	8
14	Soft4U.com	1	3	3	1	8
15	Softwaremedia.com	0	0	1	7	8
16	eCOST.com	3	4	0	1	8
17	RCSeShop	0	0	1	6	7
18	Gateway.com	0	2	3	1	6
19	MSL Computers Inc.	0	1	3	2	6
20	NECX	0	2	3	1	6
21	Sunluck Distributors	0	0	3	3	6
22	Vision Computers	0	1	3	2	6
23	pcWonders.com/buyitnow	5	1	0	0	6
24	#1 TechStore	2	3	0	0	5
25	California Computer Center	1	2	0	2	5
26	Hardware BuyLine	0	0	2	3	5
27	OfficeExpress.com	3	2	0	0	5

Table 2d: Number of Price Observations in each Quartile by Firm, May 5, 2001

		Number of Price Observations in each Quartile				Products
	Firm	1st	2nd	3rd	4th	**Listed**
1	MicroWarehouse	1	0	2	2	5
2	Outpost.com	0	1	2	2	5
3	Dell Computer Corp.	1	2	1	1	5
4	CDW	0	1	1	2	4
5	Gateway.com	1	3	0	0	4
6	BUY.COM	3	0	0	0	3
7	Sunluck Distributors	1	0	1	1	3
8	AtomicPark.com	1	0	1	0	2
9	COMPUTERS4SURE.COM	1	1	0	0	2
10	LibiIndustries	1	0	1	0	2
11	MPSuperstore.com	1	0	0	1	2
12	MultiwaveDirect	1	1	0	0	2
13	APlusDigital	0	1	0	0	1
14	Digital E-Tailer	0	1	0	0	1
15	EBWorld.com	0	0	0	1	1
16	FamilyPhoto&Video	1	0	0	0	1
17	U-Save Gelt	0	0	1	0	1
18	CCI Camera City	1	0	0	0	1
19	Datavision Computer Video	0	0	1	0	1
20	Port.com	0	0	1	0	1
21	Turboprice	1	0	0	0	1
22	TravelinJack.com	0	0	1	0	1
	Totals	15	11	13	10	49

Table 3a: 3Com HomeConnect: Low-Price Firm's Identity and Price ($)

Firm	5-Nov-99	5-Dec-99	5-Jan-00	5-Feb-00	5-Mar-00	5-Apr-00	5-May-00	5-Jun-00	5-Jul-00	5-Aug-00	5-Sep-00	5-Oct-00	5-Nov-00	5-Dec-00	5-Jan-01	5-Feb-01	5-Mar-01	5-Apr-01	5-May-01
1								109.93											
2	104.95																		
3											118.34					104.95		107.95	105.95
4		104.99	104.99			113.79													
5														108.99					
6				103.88					114.25			117.94							
7													105.00		101.50				
8					114.95														
9																	109.85		
10										117.95									
11							109.99												

Firm Identities

1	AllBusiness.com
2	BUY.COM
3	ChaseShop.com

4	eCOST.com
5	EGGHEAD.COM
6	firstsource.com
7	MultiwaveDirect

8	NationStores.com
9	Page Computer
10	pcWonders/BuyItNow
11	Ssmart.com

Table 3b: 3Com HomeConnect: High-Price Firm's Identity and Price ($)

Firm	5-Nov-99	5-Dec-99	5-Jan-00	5-Feb-00	5-Mar-00	5-Apr-00	5-May-00	5-Jun-00	5-Jul-00	5-Aug-00	5-Sep-00	5-Oct-00	5-Nov-00	5-Dec-00	5-Jan-01	5-Feb-01	5-Mar-01	5-Apr-01	5-May-01
1	157.00		152.00																
2						150.99													
3		250.30																	
4									149.95	149.95			147.95						
5																		149.95	149.95
6				149.95	149.95		149.95	149.95											
7						150.99					149.94	149.94							
8														149.99	149.99	149.99	149.99		
9								149.95											

Firm Identities

1	Acentia
2	ComputAbility
3	Computer411

4	Hardware BuyLine
5	MicroWarehouse
6	Outpost.com

7	PCMall
8	RCSeShop
9	SoftwareBuyLine

Table 4: Runs Test of the Identity of the Minimum-Price Firms with No Ties

Product	Minimum-Price Observations	Number of Runs	Z-statistic	p-value	
3Com Homeconnect	19	11	0.25	0.80	
ADOBE ACROBAT V4.0	21	9	-0.32	0.75	
ADOBE PHOTOSHOP V5.0.2	12	6	-0.52	0.60	
ATX MBD	5	5	-2.43	0.02	**
CASSIOPEIA E-105	10	9	2.01	0.04	**
Creative Labs 3D Blaster RIVA TNT2 Ultra	10	6	0	1.00	
Creative Labs Blaster CDRW 4224	8	4	-0.76	0.45	
Creative Labs CDRW 6424	10	2	-2.68	0.01	**
Creative Labs PC-DVD Encore 6X	16	7	-1.04	0.30	
Creative Labs PC-DVD RAM 5.2GB SCSI-2	17	11	0.77	0.44	
Creative Labs Sound Blaster Live Value	21	8	-0.39	0.70	
Creative Labs Video Blaster WebCam 3	20	6	-2.3	0.02	**
Diamond Viper V770 Ultra	11	5	-0.93	0.35	
EpsonStylus Color 740	17	9	-0.24	0.81	
FRONTPAGE 2000	18	9	-0.49	0.63	
HALF LIFE	15	4	-2.23	0.03	**
HP CD-Writer Plus 8200i	13	7	-0.09	0.92	
INTELLIMOUSE EXPLORER	19	9	-0.7	0.49	
Intel Create & Share Camera Pack USB	4	2	-1	0.32	
MONEY DELUXE 2000	14	7	-0.49	0.63	
Matrox Millennium G400 MAX	17	10	0.27	0.79	
Nikon Coolpix 950	20	12	0.46	0.65	
OFFICIAL RED HAT LINUX V6.0	19	11	0.25	0.80	
Olympus C-2000Z	19	10	-0.22	0.82	
Olympus D-340R	17	4	-2.23	0.03	**
PAINT SHOP PRO V5.0	15	5	0.68	0.49	
PENTIUM III 450	20	13	0.92	0.36	
PENTIUM III 500	16	8	-0.46	0.65	
Palm III	9	4	-1.04	0.30	
Palm IIIx	20	8	-1.38	0.17	
Palm V	21	13	0.68	0.49	
QUICKEN DELUXE 2000	17	8	-0.74	0.46	
STAR WARS EPISODE I: RACER	19	10	0.08	0.94	
STAR WARS X-WING ALLIANCE	20	8	-1.35	0.18	
UPGRADE WINDOWS 98	3	1	.	.	
VIRUSSCAN CLASSIC V4.0	16	6	-1.55	0.12	

** Significant at the 5-percent level

Table 5: Runs Test of the Identity of the Maximum-Price Firm with No Ties

Product	Maximum-Price Observations	Number of Runs	Z-statistic	p-value	
3Com Homeconnect	17	5	-2.08	0.04	**
ADOBE ACROBAT V4.0	17	8	-0.64	0.52	
ADOBE PHOTOSHOP V5.0.2	12	3	-2.39	0.02	**
ATX MBD	7	4	-0.36	0.72	
CASSIOPEIA E-105	9	3	-1.77	0.08	*
Creative Labs 3D Blaster RIVA TNT2 Ultra	9	2	-2.33	0.02	**
Creative Labs Blaster CDRW 4224	7	2	-2.06	0.04	**
Creative Labs CDRW 6424	10	2	-2.62	0.01	**
Creative Labs PC-DVD Encore 6X	13	5	-1.06	0.29	
Creative Labs PC-DVD RAM 5.2GB SCSI-2	15	6	-1.23	0.22	
Creative Labs Sound Blaster Live Value	18	6	-1.94	0.05	**
Creative Labs Video Blaster WebCam 3	19	6	-1.47	0.14	
Diamond Viper V770 Ultra	11	7	0.35	0.73	
EpsonStylus Color 740	16	5	-1.94	0.05	**
FRONTPAGE 2000	17	2	-2.74	0.01	**
HALF LIFE	15	5	-1.79	0.07	*
HP CD-Writer Plus 8200i	13	5	-1.06	0.29	
INTELLIMOUSE EXPLORER	19	4	-3.07	0.00	**
Intel Create & Share Camera Pack USB	4	2	-1	0.32	
MONEY DELUXE 2000	13	4	-1.94	0.05	**
Matrox Millennium G400 MAX	15	7	-0.79	0.43	
Nikon Coolpix 950	19	11	0.25	0.80	
OFFICIAL RED HAT LINUX V6.0	16	2	-3.27	0.00	**
Olympus C-2000Z	18	8	-0.97	0.33	
Olympus D-340R	17	6	-1.75	0.08	*
PAINT SHOP PRO V5.0	15	5	-1.62	0.10	*
PENTIUM III 450	10	5	-0.67	0.50	
PENTIUM III 500	16	6	-1.55	0.12	
Palm III	12	4	-1.77	0.08	*
Palm IIIx	14	7	-0.56	0.58	
Palm V	15	4	-2.35	0.02	**
QUICKEN DELUXE 2000	16	3	0.38	0.71	
STAR WARS EPISODE I: RACER	15	9	0.45	0.65	
STAR WARS X-WING ALLIANCE	18	3	-3.21	0.00	**
UPGRADE WINDOWS 98	3	1	.	.	
VIRUSSCAN CLASSIC V4.0	16	5	-1.41	0.16	

* Significant at the 10-percent level
** Significant at the 5-percent level