

DISCUSSION PAPER SERIES

No. 3634

**THE DVD VERSUS DIVX STANDARD
WAR: EMPIRICAL EVIDENCE
OF NETWORK EFFECTS AND
PREANNOUNCEMENT EFFECTS**

David Dranove and Neil Gandal

INDUSTRIAL ORGANIZATION



Centre for Economic Policy Research

www.cepr.org

Available online at:

www.cepr.org/pubs/dps/DP3634.asp

THE DVD VERSUS DIVX STANDARD WAR: EMPIRICAL EVIDENCE OF NETWORK EFFECTS AND PREANNOUNCEMENT EFFECTS

David Dranove, Northwestern University
Neil Gandal, Tel Aviv University and CEPR

Discussion Paper No. 3634
November 2002

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

This Discussion Paper is issued under the auspices of the Centre's research programme in **INDUSTRIAL ORGANIZATION**. Any opinions expressed here are those of the author(s) and not those of the Centre for Economic Policy Research. Research disseminated by CEPR may include views on policy, but the Centre itself takes no institutional policy positions.

The Centre for Economic Policy Research was established in 1983 as a private educational charity, to promote independent analysis and public discussion of open economies and the relations among them. It is pluralist and non-partisan, bringing economic research to bear on the analysis of medium- and long-run policy questions. Institutional (core) finance for the Centre has been provided through major grants from the Economic and Social Research Council, under which an ESRC Resource Centre operates within CEPR; the Esmée Fairbairn Charitable Trust; and the Bank of England. These organizations do not give prior review to the Centre's publications, nor do they necessarily endorse the views expressed therein.

These Discussion Papers often represent preliminary or incomplete work, circulated to encourage discussion and comment. Citation and use of such a paper should take account of its provisional character.

Copyright: David Dranove and Neil Gandal

November 2002

ABSTRACT

The DVD Versus DIVX Standard War: Empirical Evidence of Network Effects and Preannouncement Effects*

In this Paper, we empirically test for network effects and preannouncement effects in the DVD market. We do this by measuring the effect of potential (incompatible) competition on a network undergoing growth. We find that there are network effects. The data is generally consistent with the hypothesis that the preannouncement of DIVX temporarily slowed down the adoption of DVD technology.

JEL Classification: K21 and L82

Keywords: network effects, product preannouncements and standards

David Dranove
Kellogg Graduate School of
Management
Northwestern University
2001 Sheridan Road
Evanston IL 60208
USA
Tel: (1 847) 491 8682
Fax: (1 847) 467 1777
Email: d-dranove@nwu.edu

Neil Gandal
Department of Public Policy
Tel Aviv University
Tel Aviv 69978
ISRAEL
Tel: (972 3) 640 6742
Fax: (972 3) 640 7382
Email: gandal@post.tau.ac.il

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=148482

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=144974

*This Paper is produced as part of a CEPR Research Network on The Evolution of Market Structure in Network Industries, funded by the European Commission under the Training and Mobility of Researchers Programme (Contract No ERBFMRX-CT98-0203). We are grateful to Severin Borenstein, Dennis Carlton, Luis Cabral, Paul Gertler, Richard Gilbert, Shane Greenstein, David McGowan, Michael Riordan, Carl Shapiro, Catherine Wolfram and seminar participants at New York University, UC-Berkeley, the second CEPR Conference on Applied Industrial Organization, the IDEI (Toulouse) Conference on Competition in Internet and Software Industries, the Tel Aviv University Conference on Antitrust and Regulation, the Haifa University Law School Conference on the Commodification of Information, and the Telecommunications Policy Research Conference for helpful comments.

Submitted 29 September 2002

1. Introduction

Product preannouncements are quite common in the computer software and consumer electronics industries. Bayus, Jain, and Rao (2000) document that only approximately 50 percent of 123 software products announced during the 1985-1995 period were shipped within three months of the announcement date. Moreover, more than 20 percent of the products were first shipped more than nine months after the announcement date.

Farrell and Saloner (1986, p.942) note that when there are strong network effects,¹ “the timing of the announcement of a new incompatible product can critically determine whether a new product supersedes the existing technology.”² Lemley and McGowan (1998, p.505) remark, “by preannouncing a product, a large company may therefore influence the outcome of a standards competition in an industry characterized by network effects.” The concern about preannouncement effects led the Software Publishers Association (the computer software industry's largest trade association) to include prohibitions (in February 1998) against strategic preannouncements in the associations' eight principles of competition.³

Despite the belief that product preannouncements can affect the outcome of a standards competition, there is no analytical empirical work on the issue. In this paper, we measure the effect of the DIVX preannouncement in the DVD market. We also

¹ A network effect exists when the value that consumers place on a particular product increases as the total number of consumers who purchase identical or compatible goods increases. In the case of an **actual (or physical) network**, such as the telephone network, the value of the network depends on the total number of subscribers who have access to the network. In the case of **virtual networks** that are not linked physically, such as compact disc players, the network effect arises from positive feedback from complementary goods.

² Product preannouncements far in advance of the product's release date are often referred to as “vaporware,” particularly when the product never reaches the market. Vaporware includes products that arrive significantly late due to unexpected technical difficulties and products that arrive late because of strategic preannouncements. For an interesting discussion of the origin of the term “vaporware,” see Bayus, Jain, and Rao (2000). See Levy (1997) for a recent theoretical manuscript on vaporware.

³ See McWilliams, B., “Industry Group Issues Software Competition Guidelines,” PC World Communications, February 2, 1998 (<http://pcworld.com/news/daily/data/0298/980202164433.html>).

empirically measure the strength of network effects in this market. We do this by measuring the effect of potential (incompatible) competition on a network undergoing growth.

We find that there are network effects in the DVD market. The data are also generally consistent with the hypothesis that the preannouncement of DIVX slowed down the adoption of DVD technology. The effect was short-lived, however, and subsequent announcements of the demise of DIVX did not lead to an increase in DVD adoption. Overall, DVD survived the DIVX preannouncement and went on to be one of the most successful new consumer electronics products in history.

The paper proceeds as follows. Section 2 describes the DVD market. Section 3 describes our data and section 4 contains our empirical results. Section 5 provides brief conclusions.

2. The Development of the DVD Market

Throughout the 1990s, video hardware and software manufacturers sought a digital format to replace videocassettes. The industry was aware of the market potential for a new format; past successes like VHS-format videocassette recorders and CD players had achieved penetration rates in excess of 70 percent (see Figure 1). Keen to avoid another Beta/VHS format war, hardware manufacturers led by Sony, Toshiba, and Panasonic, in conjunction with movie studios led by Warner and Columbia (a division of Sony), worked together to establish a single standard. The result was the DVD (digital video disc or digital versatile disc). Although DVD is mainly a video product and compact disc is an audio-only product, the two are similar in some ways. At first glance, they are physically identical. Both DVD and CD represented digital replacements for well-established analog technologies. And both DVD and CD were counted on to revive

stagnant hardware and software markets. A key difference is that DVDs store ten times more information -- more than enough for a feature film with twice the visual clarity of a videocassette, along with a five-channel surround soundtrack.

In September 1996, the “DVD forum” of hardware and software firms published the DVD specifications.⁴ DVD would be an “open format”, meaning that all machines carrying the DVD logo could play all DVD discs. All DVD discs would be encoded with the Dolby Digital sound process, and could also be encoded with other sound processes, such as Dreamworks' DTS surround process, as they became available. All DVD players would be capable of outputting the Dolby Digital bitstream to external decoders; some manufacturers included internal decoders as an added feature of their DVD players. DVD-ROM drives for computers would also be able to play DVD movies (though DVD video players need not be able to play DVD software designed specifically for the personal computer.) All DVD discs would be forward compatible with the soon to be launched high definition television, through a technology known as progressive scan.

Warner Home Video (and its sister companies such as HBO and New Line), Columbia Tri-Star, MGM/UA, and Polygram committed to providing DVD videos even before there were any DVD players available. (See Table 1.) Smaller firms that held distribution rights to movies, documentaries, and IMAX films also committed to the format. When the first DVD players were released in the U.S. in early 1997, there were 40 software titles to choose from, including Batman, Blade Runner, Singing in the Rain, and the IMAX film Africa: The Serengeti. In July and August 1997 respectively, Universal and Disney's live-action Buena Vista division entered the market.

Some studios held back support for DVD because of concerns about whether the technology would succeed and because of concerns about piracy. Because DVD is

⁴ We list this and other important dates in Table 1.

digital, it offers opportunities for pirates to make perfect copies. The DVD consortium included some protection against piracy in the DVD format, including Macrovision, which prevents direct copying onto videotape or a recordable DVD player. It also adopted regional coding, so that players designed for sale in the U.S. region could only play discs designed to play in the U.S. (There are seven regions altogether.) But many studios were concerned that these precautions were inadequate, and were reluctant to release films on DVD unless demand from the installed base of DVD players was large enough to offset the risks of piracy. Paramount did not commit to DVD until April 1998, while 20th Century Fox waited until August 1998.

Despite the lukewarm support of several studios, DVD was cautiously welcomed by “early adopters” -- electronics enthusiasts who derive utility from being the “first on their block” to own a new technology. Most of the early adopters were among the two million Americans who owned laser disc players, which came close to matching DVD's visual clarity and sound. Early adopters established several Internet “chat sites,” in which they debated the relative merits of DVD and laser disc, and speculated about the future of the new format. All agreed that DVD had two advantages over laser disc. First, it was much cheaper to master and produce DVD software. DVD software retail prices ranged from \$10-\$30 per movie, compared with \$30-\$70 for films on laser discs. Second, the laser disc market had peaked without becoming mainstream, leaving laser disc enthusiasts searching for stores that rented or sold discs. With lower prices and renewed interest from hardware and software makers, DVD held out the promise of finally replacing the inferior videocassette format. When Best Buy (the nation's second largest electronics retailer) indicated that it would fully support DVD with special in-store displays, wide selections of hardware and software at discounted prices, and heavy advertising, many believed that the format would quickly become mainstream.

Sales of DVD hardware (Figure 2) in the first few months were well within industry expectations, and much higher than sales of VCRs and CD players during their first few months on the market.⁵ As the market grew, more brands of hardware became available, and most major electronics retailers, including Circuit City, the nation's leading electronics retailer, jumped into the market. By the end of 1997, manufacturers introduced second generation DVD players with enhanced features such as a higher video bitstream rate for superior video imaging, 96/24 audio resolution for playing DVD audio (expected to eventually replace CDs), and component outputs for direct connection to projection televisions

During this time, a DVD culture was emerging over the Internet. Early adopters tended to be frequent Internet users, and it was no surprise when several on-line hardware and software vendors established DVD-related sites. By early summer 1997, just a few months after the DVD launch, the most popular DVD chat sites were receiving more than 1,000 posts weekly, many from individuals who did not own a DVD player. Posters discussed the quality of competing hardware makers and speculated about which studios would join the DVD bandwagon. At the same time, new Internet vendors were emerging, offering discounted prices on DVD hardware and software.

2.1 The DIVX Threat

Tempering this early enthusiasm were occasional rumors about a competing technology known only as “zoom,” which was purported to be a pay-per-view alternative to open DVD. Rumors on the Internet about zoom died down during the summer of 1997, only to come true on September 8, 1997, when Circuit City announced the

⁵ For example, the *Washington Post* reported that sales in the first four months met or exceeded industry expectations. Liu, C. “DVD Strives to be a Player” *Washington Post* 7/8/1997 p. C1

introduction of DIVX (Digital Video Express).⁶ DIVX players would play all DVD discs. But they would also play special DIVX discs that could not be played on DVD players. (Thus there was one-way compatibility.) DIVX discs are “locked” by an encryption technology. They are unlocked when the user starts playing them, and remain unlocked for 48 hours. When time expired, the user could replay the disc by contacting a computer operated by a firm working for Circuit City. (This was done via a modem connection that comes with the DIVX player.) Circuit City planned to charge \$4 - \$5 for the first time use of each disc, with a similar fee for each reuse. This, indeed, was the widely rumored pay-per-view alternative to rental.

Circuit City gave no firm date for the introduction of DIVX, and DIVX would not reach the market for nearly a full year. Even so, the DIVX announcement shocked DVD enthusiasts. Circuit City was the leading seller of home electronics in the U.S. and could be expected to heavily promote DIVX. It also had commitments from Disney, Paramount, Universal, and Dreamworks to release DIVX discs “day and date” with VHS tapes. These studios had not been enthusiastic supporters of DVD, so it appeared that the market was becoming divided among the studios.

One Internet site summed up the problem this way: “The confusing situation where two formats exist, supported by different companies, was what DVD was supposed to avoid. The DVD forum was set up to stop a format war but it now looks like the introduction of DIVX could result in just that...The fact some studios are supporting only open DVD and some are supporting only DIVX will lead to confusion and ultimately be harmful to DVD.”⁷

⁶ DIVX was a joint venture between Circuit City and the law firm of Ziffren, Brittenham, Branca & Fischer.

⁷ DVD Centre Webpage at <http://web.ukonline.co.uk/Members/s.roberts/index.htm>.

DVD supporters did not view DIVX to be an acceptable alternative technology. Early adopters of DVD technology worried that Circuit City would not support many of the special features that they enjoyed, such as widescreen presentations and director's commentaries. This may reflect the fact that Circuit City was likely intending to target consumers who preferred to pay just a few dollars for one-time use, and might not be willing to pay extra for special features. Early adopters were also concerned about the quality of DIVX players. All of the well-known consumer electronics manufacturers supported DVD. It seemed that DIVX players would have to be made by a "second-rate" manufacturer. For these reasons, many early adopters believed DIVX would be an inferior product, and continued to support DVD.

Some suspected that Circuit City prematurely announced DIVX in order to slow the growth of DVD. A December 13, 1998 editorial in the popular Internet site DVD Resource Page noted that the DIVX preannouncement created "confusion in a marketplace a year ago (fall of 1997) when DVD sales SHOULD have taken off, but did not because people wanted to know how they were going to watch movies on a format not supported by all the studios."⁸ Despite these suspicions, it is not readily apparent whether Circuit City was acting strategically or really believed that the introduction of DIVX was imminent.

Circuit City had two reasons to prematurely announce DIVX. First, if DVD established itself too quickly, it would all but eliminate the market for DIVX. Second, Circuit City rival Best Buy had embraced DVD from the beginning, and was firmly establishing itself as the nation's leading seller of DVD hardware and software. If DVD continued to grow, electronics shoppers would be drawn to Best Buy, costing Circuit City sales in other categories.

⁸ DVD Resource Page at <http://www.dvdresource.com>.

Claims of vaporware appeared almost immediately after the DIVX announcement. For months after the announcement, Circuit City had neither DIVX hardware nor software to demonstrate. To make matters worse for Circuit City, only one regional electronics retailer (The Good Guys) had agreed to carry DIVX players and no studios had made commitments to release movies exclusively in DIVX format. Despite Circuit City's setbacks, the months following the DIVX announcement saw countless debates on Internet chat sites about whether early adopters should buy DVD players. Those who had already made purchases exhorted others to support the open DVD format. But many fence sitters responded that they preferred to see which format emerged as the dominant one, with some posters referring specifically to the demise of the Betamax. Thus, there was strong anecdotal evidence that the preannouncement was slowing DVD sales. This is supported by data on DVD hardware sales, presented in Table 2. There is a dip in sales in the fall of 1997, corresponding to the period just after the Circuit City announcement.

In section 3, we will test whether this dip in sales was statistically meaningful. Regardless of whether the preannouncement resulted from strategic thinking or excessive optimism, the implications of a statistically significant dip would be the same: preannouncements can have an effect on standards adoption.

2.2 The Rise and Fall of DIVX

Throughout the Christmas 1997 season, DIVX players were nowhere to be seen. The market gradually realized that the launch of DIVX was a long way off. Share values of Circuit City declined 24 percent through mid-January 1998. During the same period, Best Buy's shares climbed 89 percent. Investors apparently had their doubts about DIVX.. This did not guarantee that DVD would succeed, though the rise in Best Buy's

stock price may have indicated investor optimism about DVD. On January 17, 1998 Circuit City CEO Dick Sharp made an announcement that seemed to settle the DVD market. He demonstrated a DIVX prototype to the media, but announced that test marketing of DIVX (in San Francisco and Richmond, Virginia) would not begin until the summer, with a nationwide release expected in the fall. He also indicated that initially all DIVX players would be manufactured by Zenith, which was not a significant force in the audio/video hardware market, had a poor reputation for quality, and was on the verge of bankruptcy. He confirmed that The Good Guys was the only major retailer willing to join Circuit City in offering DIVX products. (A Denver-area retailer also came on board.) Finally, he indicated that DIVX would be marketed as an advanced feature of DVD, rather than as an alternative standard.

With this second announcement, fears of format wars seemed to die down. Chat groups on the Internet voiced confidence that the DVD format would survive. Investors seemed resigned to the fact that Circuit City would not become the dominant force in the digital video market. In the three-day window surrounding the January 17th announcement, Circuit City shares lost 0.35 percent of their value while Best Buy shares climbed 3.2 percent. Numerous press reports attributed a substantial portion of Circuit City's woes to the unsuccessful launch of DIVX. According to a June 1999 online article appearing in e-town.com (another popular DVD site), Circuit City had invested more than \$207 million on DIVX (as of February 28th, 1999), nearly seven percent of the firm's total assets.⁹ The article also notes that quarterly earnings per share were off by 16 cents due to charges for DIVX.

⁹ See "Still, business booms for Circuit and others," by David J. Elrich, June 4, 1999 (from e-town.com). During the time that Circuit City was launching DIVX, it had a difficult time digesting its acquisition of the CARMAX Group. This further suppressed the share value.

DIVX did reach the market in the fall of 1998, but it faced an uphill battle. Studio support for DIVX had weakened (no new studios had come on board and some of the fence-sitting studios had begun releasing in open DVD). Circuit City still could not convince competitors to carry the product. While Circuit City reported that it sold as many as 80,000 DIVX players in the crucial Christmas 1998 shopping season, this represented less than 25 percent of the sales of open DVD players during the same period. Moreover, some Internet reports suggested that DIVX owners used their players solely to play “open” DVD disks. If true, it meant that the complementary DIVX software market was even smaller than the hardware market. The handwriting was on the wall -- at best, DIVX would be a niche format.

In early June 1999, rumors swept the Internet that Circuit City would soon pull the plug on the DIVX format; those rumors came true on June 16, 1999. The facts on the ground justified the decision. By the end of 1998, the installed base of DVD players (shipped to retailers) was approximately 1.32 million. During the first 20 weeks of 1999, at least 572,000 additional players were sold to retailers, yielding a DVD installed base of at least 1.9 million through mid-1999. The DIVX installed base through that time was at most 165,000. As of May 31, 1999, there were 3,317 software titles available on the DVD format and only 471 titles available on DIVX, with substantial overlap. There were fewer than 100 DIVX-only titles.

In the remainder of this paper, we determine whether Circuit City's September 1997 preannouncement did, indeed, reduce DVD hardware sales. We also explore whether the entry of DIVX into the market in the fall of 1998 and the June 1999 official announcement of the demise of DIVX affected DVD hardware sales.

3. Data

We compiled the dataset from several sources, as described below. We collected monthly data from April 1997 (the first month in which DVD players were available) through June 2000. We have more than three years of data. We now describe the variables used in the study. (Descriptive statistics are in Table 2.)

- We have weekly and monthly data on the sales of DVD players (denoted SALES) from manufacturers to dealers. We are grateful to the Consumer Electronics Manufacturing Association for supplying these data, as well as the data on prices.¹⁰ Monthly DVD player sales are shown in figure 2. The natural log of this variable is denoted by LSALES.
- The variable LPRICE is the natural log of the average monthly price (denoted PRICE) of DVD players to retailers. Monthly prices of DVD players are shown in figure 3.
- One measure of software availability is when a particular studio committed to releasing films in DVD technology and the importance of that studio as measured by the 100 most successful box office releases of all time. (The box office data have been adjusted for inflation. Since DVD sales began in 1997, we use data on box office releases through 1996 for the construction of this variable.) These data are displayed at the Mr.

¹⁰ The sales data also include DIVX sales. DIVX sales began on a trial basis in June in the San Francisco and Richmond Va. markets. According to "How Circuit City Can Fix What Ails DIVX," Computer Retail Week, September 14, 1998, there were very few sales of DIVX players during the trial period. DIVX was launched nationally on September 25, 1998. As noted above, the DIVX installed base through the first 20 weeks of 1999 was at most 165,000, while the installed base of DVD was at least 1.9 million through the same period.

Showbiz website under the Movie Guide Box Office Leaders category.¹¹

We sorted the movies by studio and added up the box office revenues in order to obtain an impact factor for each studio. We then constructed the studio impact measure (denoted SOFT) by using the dates at which each studio committed to DVD. (See Table 1 and Figure 4.) The variable LSOFTE is the natural log of the studio impact factor.

- Another measure of software availability is the percent of U.S. Box Office top 100 films (adjusted for inflation) that had been **released** in DVD format by each point in time. This measure of software availability is denoted BOA. See Figure 5.
- q^i is a dummy variable that takes on the value 1 if the data is from quarter i . The quarterly dummies adjust for seasonal effects.
- The dummy variable DIVX takes on the value 1 from September 1997 (the preannouncement date of the DIVX technology was September 8, 1997) through December 1997, just before the DIVX demonstration.¹² At the time of the demonstration, Circuit City's CEO Richard Sharp embraced DVD technology as the basic technology of the "DIVX enhanced" player.

¹¹ See <http://mrshowbiz.go.com/reviews/moviereviews/numbers/top100adjusted.html>.

¹² The DIVX player was demonstrated January 17, 1998. If we also include the first half of January in this period, by setting DIVX=.5 for January 1998, the DIVX effect is slightly stronger. If we change the definition of the DIVX variable to include just half of September (DIVX=.5 for September 1997), the DIVX effect is stronger. If we add a half-month to the DEMISE and ENTRY variables, the results are qualitatively unchanged.

- The dummy variable ENTRY takes on the value one for the three-month period (October - December 1998) following the entry of DIVX into the market.
- The dummy variable DEMISE takes on the value 1 from June through August 1999. The Demise of DIVX occurred on June 16, 1999, but the announcement had been expected for several weeks.

4. Estimation and Empirical Results

4.1 Informal Examination of the Data

In addition to monthly sales data from April 1997-June 2000, we also obtained weekly sales data for April 1997-March 1999 period. We begin by informally examining weekly sales of DVD hardware during the first two years of the life of DVD. The weekly data typically have very large spikes once every four weeks, suggesting that dealers place major orders once a month. We hence smoothed these data by using five week moving averages. Figure 6 shows five-week moving averages of DVD sales for the April 1997- March 1999 period. We have highlighted the 4th quarter of 1997 (which roughly corresponds to the DIVX announcement period) and the 4th quarter of 1998. These two 4th quarters appear to be quite different.

Following the DIVX announcement on September 8, 1997, DVD sales (deliveries) from manufacturers to retailers continued to rise for the following four weeks. This is not surprising, since these orders were likely placed in advance of the DIVX announcement. However, from that point on (the beginning of the 4th quarter), DVD sales declined continuously until the end of the 4th quarter.

The 4th quarter of 1998 is very different. DVD sales for the most part increase dramatically throughout the quarter, peaking a couple of weeks before the end of the calendar year. This is the typical “Christmas” effect -- sales of other consumer electronic goods, such as compact disc players, also exhibit this effect.¹³ The difference between the 4th quarter in 1997 and the 4th quarter in 1998 provides strong qualitative evidence that the DIVX preannouncement both materially affected DVD hardware sales. It also provides evidence that the preannouncement precedes the decline in DVD sales.

We also compute quarter on quarter growth rates (QGR) and report these in figure 6 as well. We find that the growth rate between the third and fourth quarter of 1997 was 56% (labeled 1.56 in figure 6), while the growth rate between the third and fourth quarter of 1998 was 87% (labeled 1.87 in figure 6). The percent difference in these quarterly growth rates is approximately 20%; this is essentially the estimated magnitude of the DIVX preannouncement effect that we report below.

One curiosity in Figure 6 is the relatively lackluster growth of DVD in the third quarter of 1997, prior to the DIVX announcement. In contrast, DVD sales increased rapidly in the third quarter of 1998. This may reflect unmeasured anticipation of DIVX in 1997 (early adopters has spread rumors of “zoom” technology prior to September 1997) and DVD success in 1998 (the demise of DIVX had already been brewing). It may also result from high sales of DVD hardware in April 1997 as retailers built up initial inventories (weekly sales were higher in April than in the subsequent four months).

To the extent that the “initial retail build up” theory is correct, our estimate of the DIVX effect may be understated. If, however, the lackluster growth in the third quarter

¹³ In our earlier working paper, we provided evidence that there was a “Christmas” effect in CD player sales during the first year that CD players were marketed to the nonprofessional consumer. While no two products are identical, both CDs and DVDs in their early phases may have appealed to the same type of early adopters, and so may be likely to display similar adoption patterns. Hence this evidence supports the view that there would have been a Christmas effect in DVD player sales in 1997 had DIVX not made its preannouncement.

of 1997 reflects some other, unmeasured hindrance to DVD sales in 1997, our estimate of the DIVX effect may be overstated.

In the remainder of this paper, we develop and estimate a model of DVD sales to determine if the decline in sales observed for the period subsequent to the DIVX introduction is statistically meaningful. This analysis is done at the monthly level; price is not available by week.

4.2 The Model

Like other electronics products, consumer demand is likely a function of price and the availability of software as well as seasonal effects and shocks (such as the DIVX announcement). We estimate the following consumer adoption equation:

$$(1) \quad \text{LSALES} = \beta_0 + \beta_1 \text{LPRICE} + \beta_2 \text{LSOFT} + \beta_3 \text{BOA} + \beta_4 \text{DIVX} + \\ \beta_5 \text{ENTRY} + \beta_6 \text{DEMISE} + \beta_7 Q^2 + \beta_8 Q^3 + \beta_9 Q^4 + \varepsilon$$

The coefficient β_1 is the price elasticity of demand. The coefficient β_2 is the elasticity of DVD player sales with respect to studio support for the DVD standard, while β_3 measures how increases in the availability of box office hits in DVD format affect DVD player sales. The coefficient β_4 , the DIVX parameter, measures how the DIVX preannouncement affected DVD adoption. β_1 should be less than zero while β_2 and β_3 should be greater than zero. β_4 , the DIVX parameter, should be less than zero if the DIVX preannouncement slowed down DVD adoption.

We also estimate a linear specification, that is, we use SALES, SOFT, and PRICE rather than the logarithm of these variables as shown in the following equation:

$$(2) \quad \text{SALES} = \beta_0 + \beta_1 \text{PRICE} + \beta_2 \text{SOFT} + \beta_3 \text{BOA} + \beta_4 \text{DIVX} + \\ \beta_5 \text{ENTRY} + \beta_6 \text{DEMISE} + \beta_7 Q^2 + \beta_8 Q^3 + \beta_9 Q^4 + \varepsilon$$

We prefer the logarithmic specification because it captures the economically sensible interpretation that the predictive variables have a multiplicative, rather than additive effect on sales. (For example, sales in the fourth quarter rise by a given percentage, rather than a given nominal amount.) Using a Box-Cox maximum likelihood test, we are unable to choose between a logarithmic or linear specification of sales.¹⁴ In any case, the results regarding the effect of the DIVX preannouncement are qualitatively similar; we report the results for both specifications.

4.3 Estimation Issues and Estimation

4.3.1 Estimation Issues

Although we do not estimate the software entry equation (with LSOFT as the dependent variable) or the software supply equation (with BOA as the dependent variable), LSALES is a right-hand side variable in both of these equations.¹⁵ This is because studios likely made their decision to release films in DVD format based in part on DVD player sales. Hence the variables LSOFT and BOA are endogenous. Given that increased DVD sales likely lead to increases in both LSOFT and BOA, the sign on the LSALES coefficient is positive in both the software entry and software supply equations.

We can get a general idea of the nature of the endogeneity bias in equation (1) by supposing that the right-hand side of the equation consisted of only two variables:

LPRICE and a single endogenous “software” variable. In such a case, the Ordinary Least

¹⁴ The logarithmic model is preferred using adjusted R^2 as a goodness-of-fit criterion. See table 3 below.

¹⁵ We cannot estimate the software entry equation, since no data are available on fixed costs of DVD production. See Gandall, Kende, and Rob (2000) for a case in which data on fixed costs are available.

Squares (OLS) estimate of the price coefficient is biased towards zero, while the OLS estimate of the software coefficient is biased away from zero. Hence, although it is not theoretically possible to “sign” the direction of the OLS bias in a regression with two endogenous software variables, intuition suggests that the direction will be as in the two variable case.¹⁶ This discussion suggests that the OLS estimate of β_1 (the price elasticity) is biased towards zero, while the OLS estimates of β_2 and β_3 (the software availability coefficients) are biased away from zero.

OLS bias is addressed by using instruments. To obtain consistent (i.e., asymptotically unbiased) estimates of the coefficients, we employed instruments for LPRICE, LSOFT, and BOA, the endogenous variables on the right-hand side of (1). Since DVD technology shares features with CD, VCR, and camcorder technologies, we used the installed base of these technologies (denoted VCRINSTALLED, CDINSTALLED, CAMINSTALLED) and the logarithm of installed base (denoted LVCRINSTALLED, LCDINSTALLED, LCAMINSTALLED) as instruments.¹⁷ In particular, DVD, VCR, and CD technologies share sound decoding and interconnection technologies. Sound decoding technologies were rapidly evolving during the late 1990s. Additionally, “S-video” connections became standard on DVD players, VCRs and camcorders.

It is reasonable to argue that there are some scope economies among the technologies and that the installed bases of VCRs, CD players, and camcorders are likely correlated with the endogenous variables (LPRICE, LSOFT, and BOA.) However, these instruments may be correlated with the error term as well. Ideally, we would like to

¹⁶ LPRICE itself may be endogenous, since the firms likely have some market power. Like many consumer electronic products, DVD players are fairly standardized products produced by many firms. Nevertheless, given the nascent stage of the industry, it is likely that firms had some market power. If price were the only endogenous variable, the OLS estimate of the price coefficient would be biased towards zero.

¹⁷ We use the installed base beginning with the January 1997 period.

employ true cost shifters that would be uncorrelated with the error term. Unfortunately, as in many other settings, such instruments are not available. Hence, these instruments are the best available and we employ them despite their limitations.

4.3.2 OLS Estimation

Table 3 reports ordinary least squares (OLS) results. Table 3 shows that all of the coefficients have the expected sign in the logarithmic model; in the case of the linear model, all coefficients except for the coefficient on SOFT have the expected sign. The DIVX coefficient is negative and marginally significant in the logarithmic model ($t=-1.61$) and statistically significant in the linear model ($t=-1.87$). This suggests that the DIVX preannouncement may have slowed down the adoption of DVD technology.

The coefficient on BOA is positive and statistically significant in both regressions, suggesting that there are network effects. The coefficient on LSOFT is positive, although not statistically significant in the logarithmic specification. The coefficient on SOFT has a negative sign in the linear specification.

The estimated coefficient on price is not statistically significant in either specification. Note that the Durbin Watson statistics in table 3 suggests that there is no serial correlation. Nevertheless, we employ Newey-West standard errors that are robust to unknown serial correlation.

4.3.3 Instrumental Variable Estimation

The results of the instrumental variable regression for the logarithmic specification are shown in Table 4.¹⁸ As expected, the estimated price elasticity is larger (in a negative sense) in this table, relative to Table 4. Additionally, the estimated

¹⁸ As noted above, the logarithmic specification is preferred to the linear specification. For ease of presentation, we do not present or discuss the results of the instrumental variable regression for the linear specification. Nevertheless, it is worth pointing out that the effect of the DIVX preannouncement is essentially identical; in the case of the logarithmic specification, $t=-1.51$, while in the case of the linear specification, $t=-1.57$.

coefficients of LSOFTE and BOA are smaller, although still positive. BOA remains statistically significant, while the coefficient on LSOFTE is much smaller and not significant. This suggests that as the important studios began to release their films in DVD format, the number of consumers adopting DVD players also increased. Specifically, each one-percentage point increase in BOA caused DVD sales to increase by approximately 5 percent.

Table 4 also shows that the DIVX preannouncement slowed down the adoption of DVD technology. Indeed, there is little difference in the estimated coefficient on DIVX between the OLS and Instrumental Variable estimates. In the case of the instrumental variable regression, the coefficient on DIVX is slightly less significant ($t=-1.51$). The coefficient estimate on the DIVX dummy variable suggests that the preannouncement reduced DVD sales by approximately 20 percent. This follows from that fact that $\exp(-.22)=.80$.¹⁹

As expected, there is a large positive fourth quarter effect (sales of consumer electronic durables usually increase significantly in the fourth quarter of the year) and the second and third quarter sales are higher than first quarter sales (typically the low point of the year). The Durbin-Watson statistic in table 4 again suggests that there is no serial correlation. In any case, as noted above, we employ Newey-West standard errors.

Table 4 shows that the demise of DIVX had essentially no effect on DVD sales. In contrast to the preannouncement in September 1997, this announcement had been expected for some time and its effect on sales of DVD players was minimal. The tables

¹⁹ This is a lower bound on the preannouncement effect. Since movie availability (as measured by studios supporting DVD and the number of box office hits released in DVD format) is endogenous, studio support for DVD might also have been affected by the preannouncement. In order to precisely measure how much faster DVD technology would have been adopted without the DIVX preannouncement, we would have had to estimate the “studio supply” equation. The DIVX effect is likely underestimated for an additional reason. If the DIVX preannouncement was strategic and was based on the early success of DVD, the DIVX variable itself is endogenous. In such a case, it can be shown that without correcting for the endogeneity, the estimated DIVX coefficient is biased towards zero.

show that the entry of DIVX into the market had a positive but insignificant effect on DVD sales. Although it is insignificant, the sign of this coefficient makes sense because DIVX sales are included in DVD sales and this period is where DIVX had its only real success.

Comparing tables 3 and 4, the direction of the OLS bias for PRICE, LSOFT, and BOA is as predicted by theory. That is, the empirical results in these tables are consistent with the theoretical direction of the bias. First stage regressions of the endogenous variables on the instruments yield relatively high values of R-squared as well.

We also estimated the model in equation using the variable DVDINSTALLED, which is the installed base of DVD players, and LDVDINSTALLED (which is the natural logarithm of DVDINSTALLED) as instruments instead of (i) camcorder sales and the logarithm of camcorder sales and (ii) CD player sales and its logarithm. The “moving down the learning curve” effect suggests that the inverse of the installed base can be thought of as a proxy for marginal cost. As the installed base increases, marginal cost declines. Clearly, DVDINSTALLED should be negatively correlated with LPRICE, and positively correlated with BOA and LSOFT. The estimate of the DIVX effect is virtually unchanged when using DVDINSTALLED and LDVDINSTALLED as instruments. We don't include DVDINSTALLED and LDVDINSTALLED as instrumental variables in table 4 because there is some concern that these variables may be endogenous, i.e., people learn about DVD players from neighbors or friends who have already purchased DVD players. We include this discussion simply to emphasize the fact that the DIVX effect is robust to changes in the instrumental variables that are employed.

4.4 Robustness of Results

In this section, we examine the robustness of preannouncement effect results.

4.4.1 Reduced Form Regressions

If we were only interested in measuring the preannouncement effect and not interested in testing for and measuring network effects, we could have run a reduced form regression with LSALES as the dependent variable and the exogenous variables (including the various “event variables”) on the right hand side of the equation.²⁰ Here we perform such an exercise and run a reduced form regression for LSALES.²¹ Table 5 shows that the effect of the DIVX preannouncement in this reduced form regression is marginal: $t=-1.35$. (Note that, as before, the effect of the DIVX announcement is stronger than the effect of the other subsequent events --DIVX entry into the market and the demise of DIVX.)

We also ran a reduced form “software supply” regression with BOA as the dependent variable. The results appear in table 5 as well. The sign of the DIVX coefficient is negative although not statistically significant ($t=-0.75$). This suggests that the DIVX preannouncement had little to no effect on software provision. The small effect here may help explain why the DIVX preannouncement effect on DVD sales was short-lived.

4.4.2 Causality

In order to further examine the issue of causality, we examined whether the DIVX preannouncement caused the drop in DVD Sales (and vice versa) in the narrow, technical sense formalized by Granger (1969) and Sims (1980). In this interpretation, a variable X causes Y if lagged values of X are significant in explaining Y in a regression in which lagged values of Y are also explanatory variables. It is, of course, possible that causality

²⁰ This assumes that the events were indeed exogenous. See footnote 19.

²¹ In order to conduct the exercise, we assume price equals marginal cost or alternatively that price is proportional to marginal cost. In this way, the right hand side of the equation has only exogenous variables.

can exist in both directions. This test can be performed using vector autoregressions (VARs).

The results appear in Table 6. The first and second columns of the table show that (controlling for two lags of DVD sales) the second lag of DIVX predicts later DVD Sales (LSALES) since the sign on the coefficient of the second lag is negative and significant as expected. Hence DIVX causes LSALES in the Granger/Sims sense.

Since DIVX is a binary variable, we then run a probit regression. We control for just a single lagged value of DIVX. (This is because of the near singular matrix with two lags of DIVX; hence it is not possible to run a probit regression with two lags of DIVX.) Table 6 shows that the first lag of DVD Sales (LSALES) is not statistically significant in the probit regression. The second lag of DVD sales is not quite statistically significant ($t=-1.52$). But since DIVX is highly correlated with its second lag (correlation coefficient of 0.44) as well as its first lag (correlation coefficient of 0.72), if it were possible to run the probit regression with two lags of DIVX, the effect of the second lag of LSALES would likely be even less significant.²² Hence LSALES likely does not cause DIVX in the Granger/Sims sense.

4.5 Further Discussion: Was Partial Compatibility a Mistake?

Despite the fact that DIVX machines could play DVD discs (because of one-way compatibility), the technology failed. In light of the DIVX demise, it is interesting to ask whether Circuit City's strategy of making DIVX players compatible, so that they could play DVD discs, was a mistake.

In general, the issue is whether a new entrant should choose one-way compatibility with the established standard so that software written for the incumbent

²² Indeed, in an OLS regression rather than a probit regression, it is possible to include two lags of DIVX. In this case, the second lag of DVD sales is insignificant ($t=-1.11$).

technology can be used on the entrant's technology. At first, this might seem like a no-brainer. Compatibility insures that purchasers of the entrant technology will not be orphaned. But there is a subtler point. In such a case, vendors of complementary products will likely choose to release their software in a form that is compatible with the incumbent technology since it reaches BOTH audiences. This will mean that very little software will be written specifically for the entrant's technology. In such a case, few consumers will buy the entrant's product.²³

Yet it is not clear if Circuit City would have enjoyed greater success had it opted for full incompatibility. Not only did the DVD format have a head start. Potential early adopters who were still on the sideline seemed unlikely to embrace DIVX. Early adopters were concerned that Circuit City's entry would confuse the market and cause both formats to fail. With the benefit of hindsight, it seems that Circuit City's tardiness in entering the market, and its failure to appeal to early adopters, were at least as critical to the failure of DIVX as was the decision about partial compatibility.

5. Conclusion

With the limited data available, the presence of only a single "event window", and the endogeneity of key predictors, establishing an effect of the DIVX preannouncement on DVD sales is a challenging task. We have presented a variety of evidence that seems to be consistent with the hypothesis that the preannouncement of DIVX temporarily slowed down the adoption of DVD technology.

Any confusion caused by the DIVX announcement was short-lived and that consumers quickly determined that the DVD market would thrive with or without DIVX. DVD has indeed thrived; as of 2002, the installed base in the United States exceeded 12

²³ Chou and Shy (1993) formalize this intuition. They show in a theoretical model that a base product that is more compatible with a second base product's software will have less software written in its format and this will in turn decrease its hardware (base product) market share.

million units, and DVD remained the hottest selling item in the consumer electronics industry.

It is also worth noting the key role played by the Internet. Chat groups helped consumers communicate information and coordinate actions. Since many of the early adopters were also Internet users, the large number of active DVD and DIVX web sites conveyed very useful information to potential adopters in real time. The information spread across the Internet turned out to be remarkably accurate. Internet chat sites correctly anticipated the nature of the “Zoom” technology, the difficulties that Circuit City would have in enlisting partners, and the dip in sales that would result from market confusion. The ability of the Internet to convey information quickly and inexpensively may reduce market failures (such as suboptimal standardization and the adoption of an inferior standard) associated with competition between incompatible technologies.

References

- Baseman, K., Warren-Boulton, F., and G. Woroch, 1995, “Microsoft Plays Hardball: The Use of Exclusionary Pricing and Technological Incompatibility to Maintain Monopoly Power in Markets for Operating Systems,” *Antitrust Bulletin*, 40: 265-315.
- Brynjolfsson, E., and C. Kemerer, 1996, “Network Externalities in Microcomputer Software: An Econometric Analysis of the Spreadsheet Market,” *Management Science*, 42: 1627-1647.
- Chou, C. and O. Shy, 1990, “Network Effects without Network Externalities,” *International Journal of Industrial Organization*, 8: 259-270.
- Church, J., and N. Gandal, 1992, “Network Effects, Software Provision and Standardization,” *Journal of Industrial Economics*, XL: 85-104.
- Dranove, D., and N. Gandal, 2000, “The DVD vs. DIVX Standard War: Empirical Evidence of Preannouncement Effects,” UC Berkeley IBER Working Paper # E00-293.
- Farrell, J. and G. Saloner, 1985, “Standardization and Variety,” *Economics Letters*, 20: 71-74.
- Farrell, J., and G. Saloner, 1986 “Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation,” *American Economic Review*, 76: 940-955.

Fisher, F., J. McGowan, and J. Greenwood, "Folded, Spindled, and Mutilated: Economic Analysis of U.S. v. IBM," Cambridge, MA: MIT Press, 1983.

Gandal, N., 1994, "Hedonic Price Indexes for Spreadsheets and an Empirical Test for Network Externalities," *RAND Journal of Economics*, 25: 160-170.

Gandal, N., 1995, "Compatibility Standards and Complementary Network Externalities in the PC Software Market," *Review of Economics and Statistics*, 77: 599-608.

Gandal, N., S. Greenstein, and D. Salant, 1999, "Adoptions and Orphans in the Early Microcomputer Market," *Journal of Industrial Economics*, XLVII: 97-106.

Gandal, N., M. Kende, and R. Rob, 2000, "The Dynamics of Technological Adoption in Hardware/Software Systems: The Case of Compact Disc Players," *RAND Journal of Economics*, 31: 43-61.

Greenstein, S., 1993, "Did Installed Base Give an Incumbent any (Measurable) Advantages in Federal Computer Procurement," *RAND Journal of Economics*, 24: 19-39.

Katz, M. and C. Shapiro, 1992, "Product Introduction with Network Externalities," *Journal of Industrial Economics*, XL: 55-84.

Katz, M. and C. Shapiro, 1994, "Systems Competition and Network Effects," *Journal of Economic Perspectives*, 8: 93-115.

Lemley, M., and D. McGowan, 1998, "Legal Implications of Network Economic Effects," *California Law Review*, 86: 481-611.

Levy, S., 1996 "Vaporware," mimeo.

Park, S., 1997, "Quantitative Analysis of Network Externalities in Competing Technologies: The VCR Case," SUNY- Stonybrook mimeo.

Rohlf's, J., 1974, "A Theory of Interdependent Demand for a Communications Service," *Bell Journal of Economics*, 5: 16-37.

Saloner, G. and A. Shepard, 1995 "Adoption of Technologies with Network Externalities: An Empirical Examination of the Adoption of Automated Teller Machines," *RAND Journal of Economics*, 26: 479-501.

Shankar, V., and B. Bayus, 1997, "Network Effects and Competition: An Empirical Analysis of the Home Video Games Industry," mimeo.

Figure 1. % of U.S. households with VCRs and CD players: 1974-1999
(Note - VCRs were introduced in 1974, CD players in 1983)

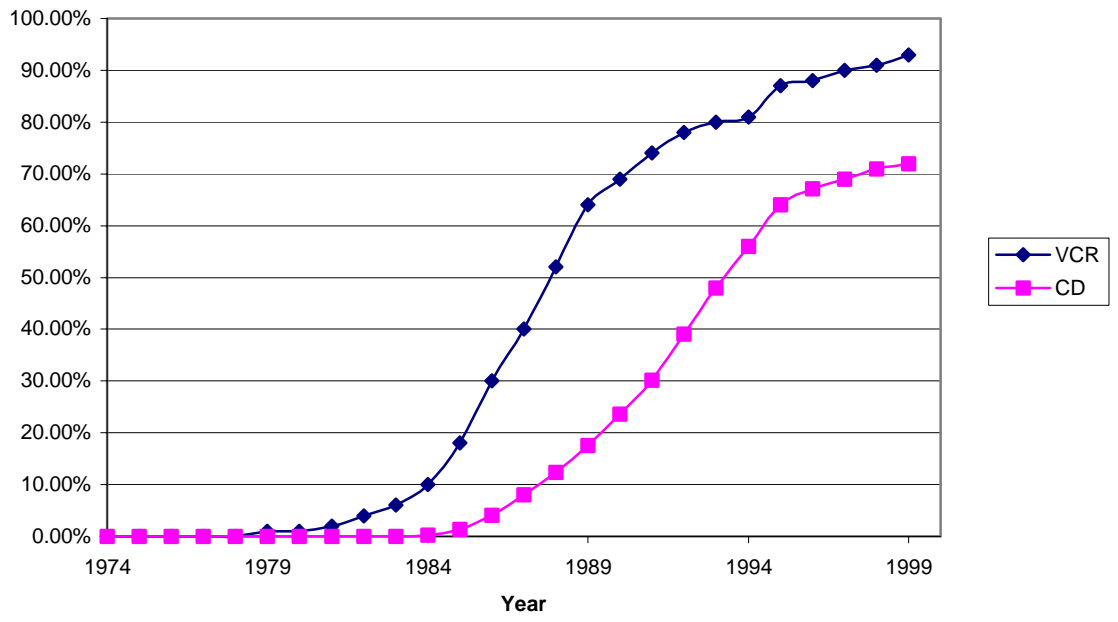


Figure 2. DVD Player Sales

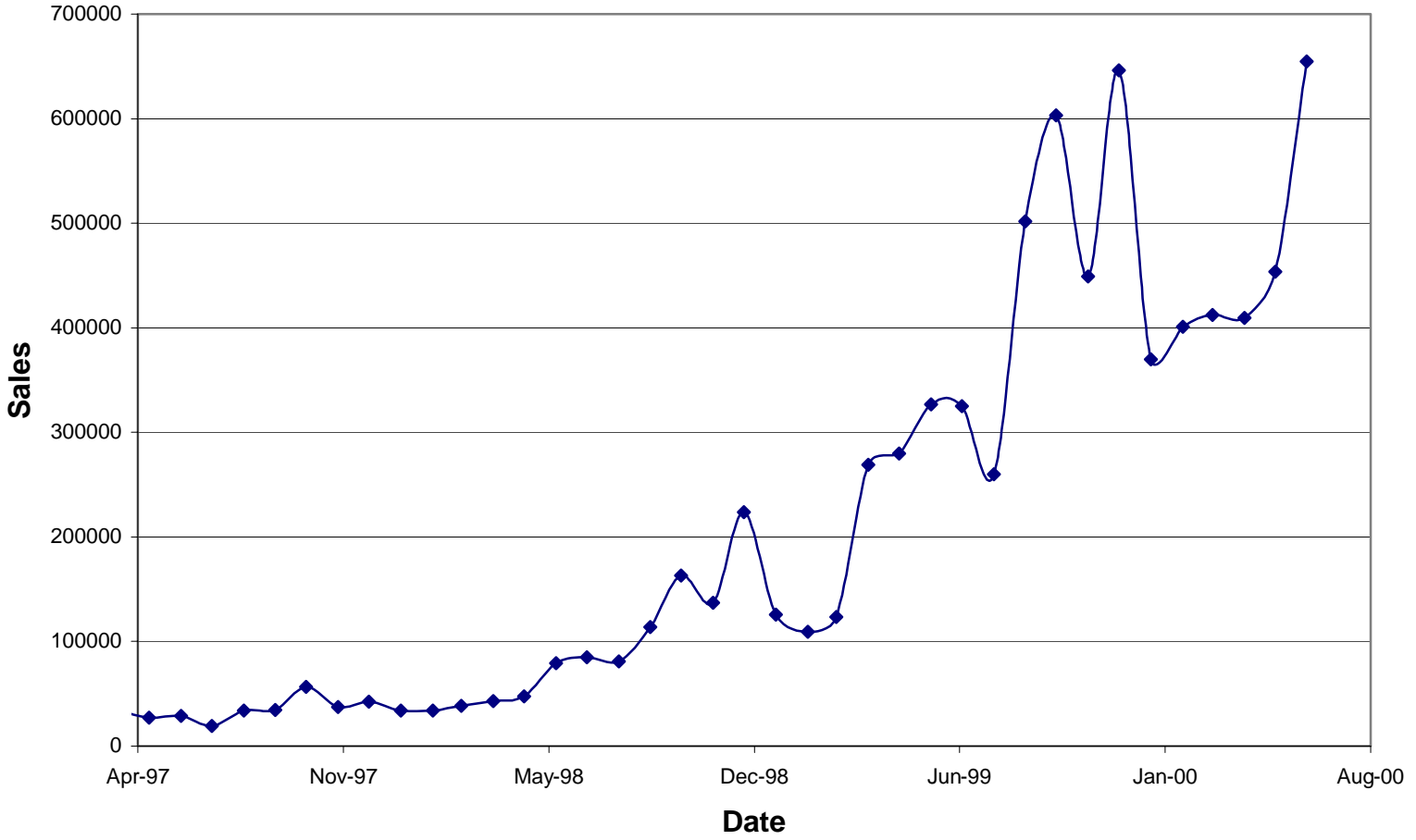


Figure 3. Average Sales Weighted Prices for DVD Players

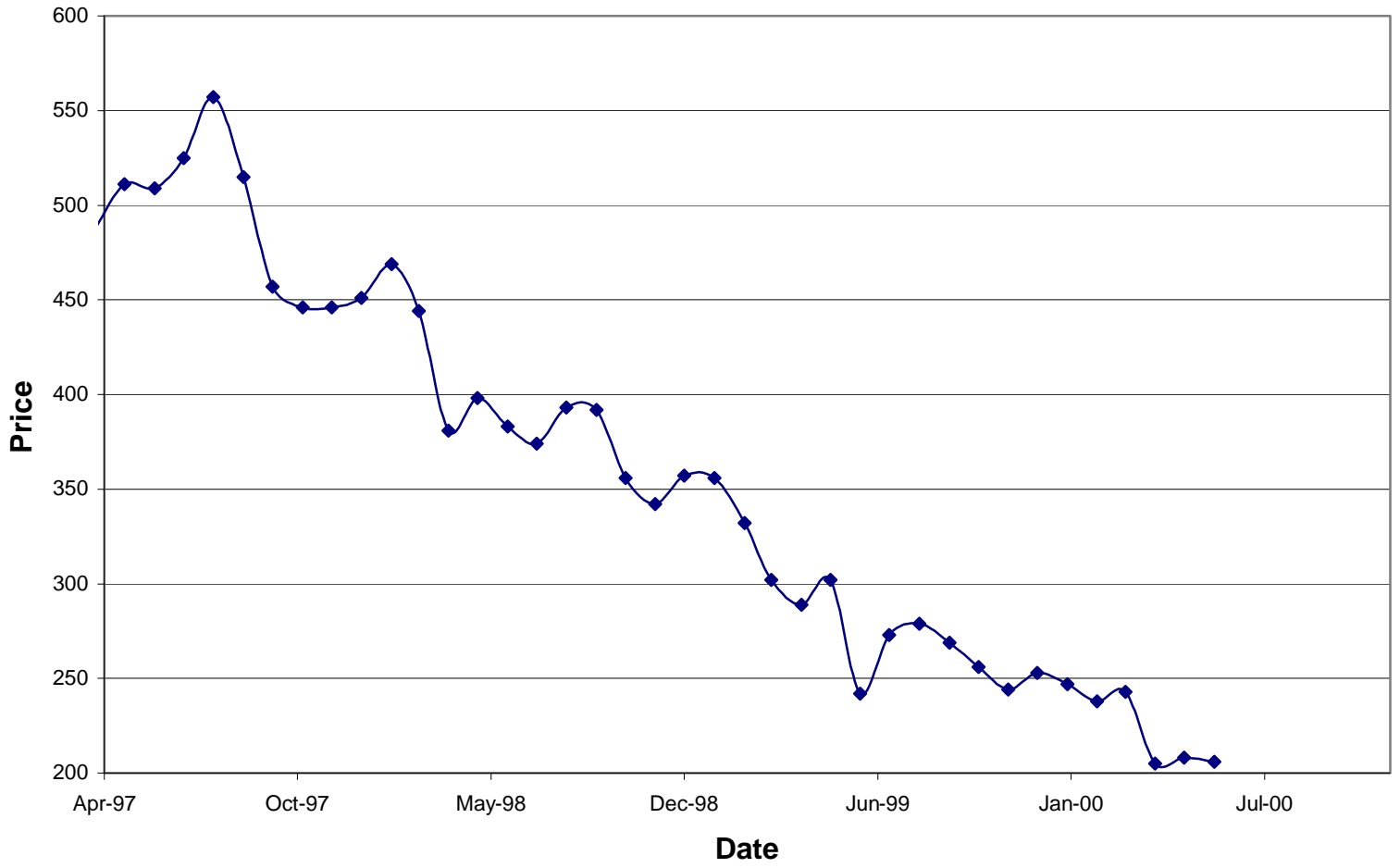


Figure 4. Studio Impact Factor for DVD (LSOFT)

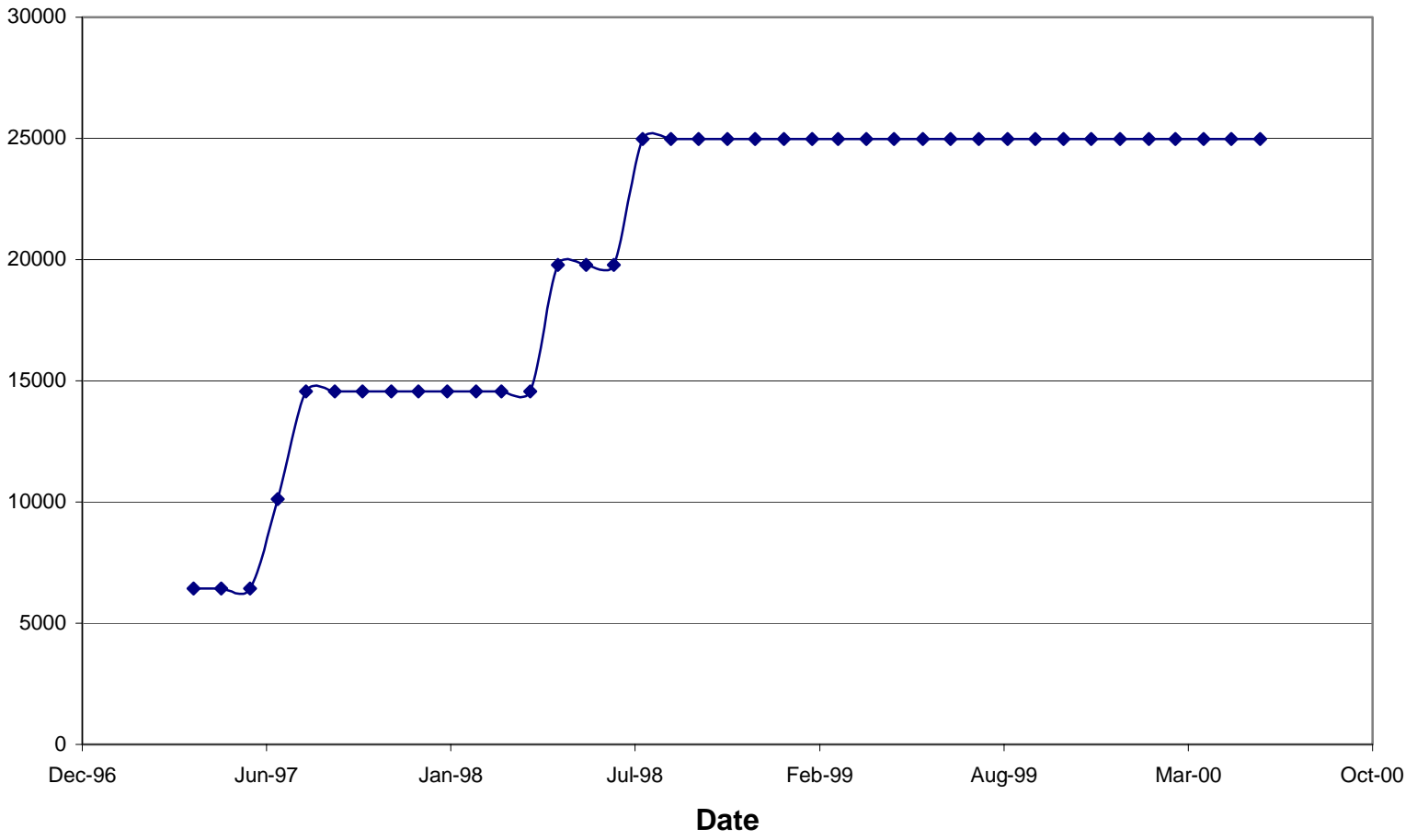


Figure 5. Percentage of top 100 Box Office Hits Released in DVD format (BOA)

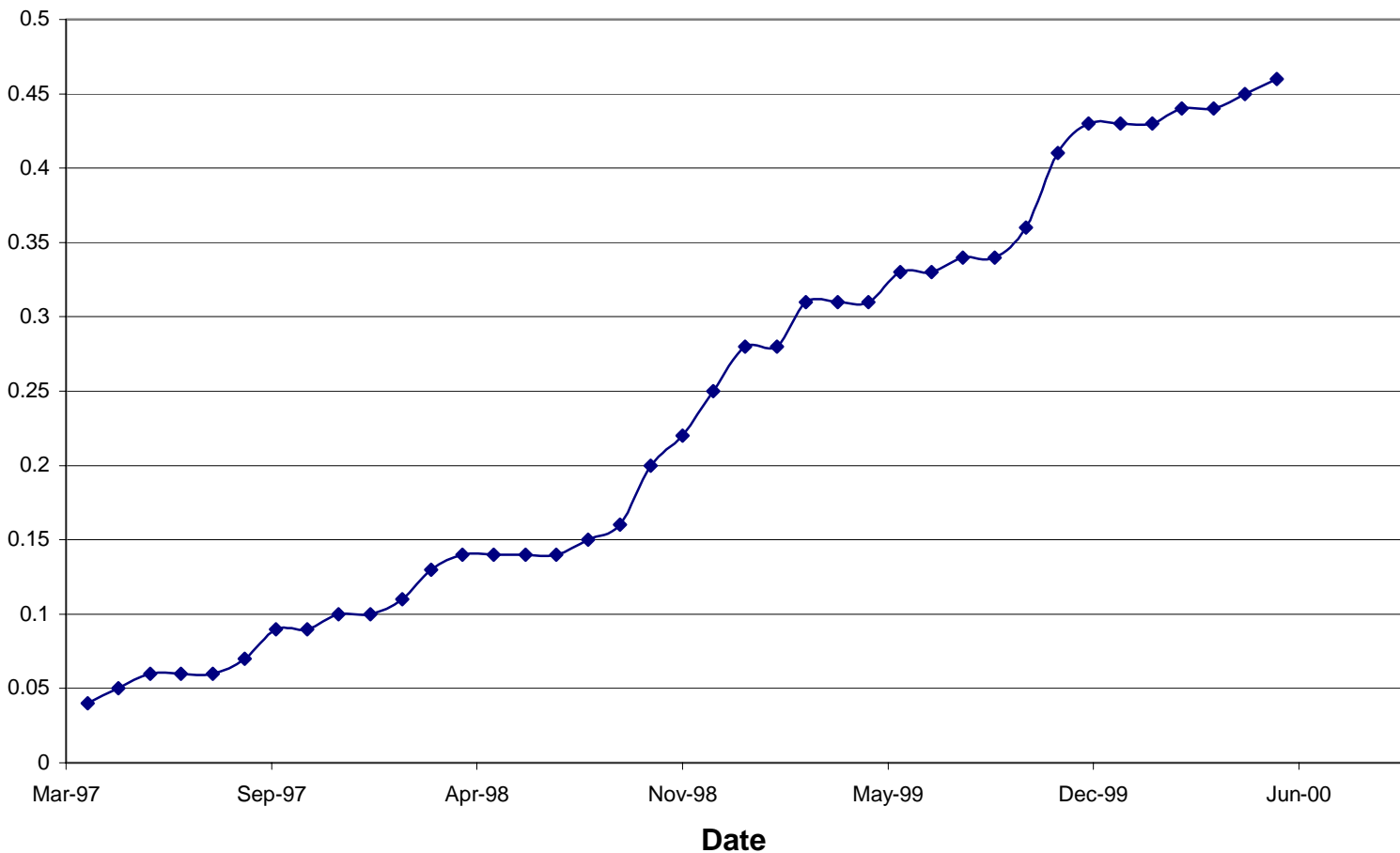


Figure 6: DVD Sales: Five Week Moving Averages and Quarterly Growth Rates (QGR)

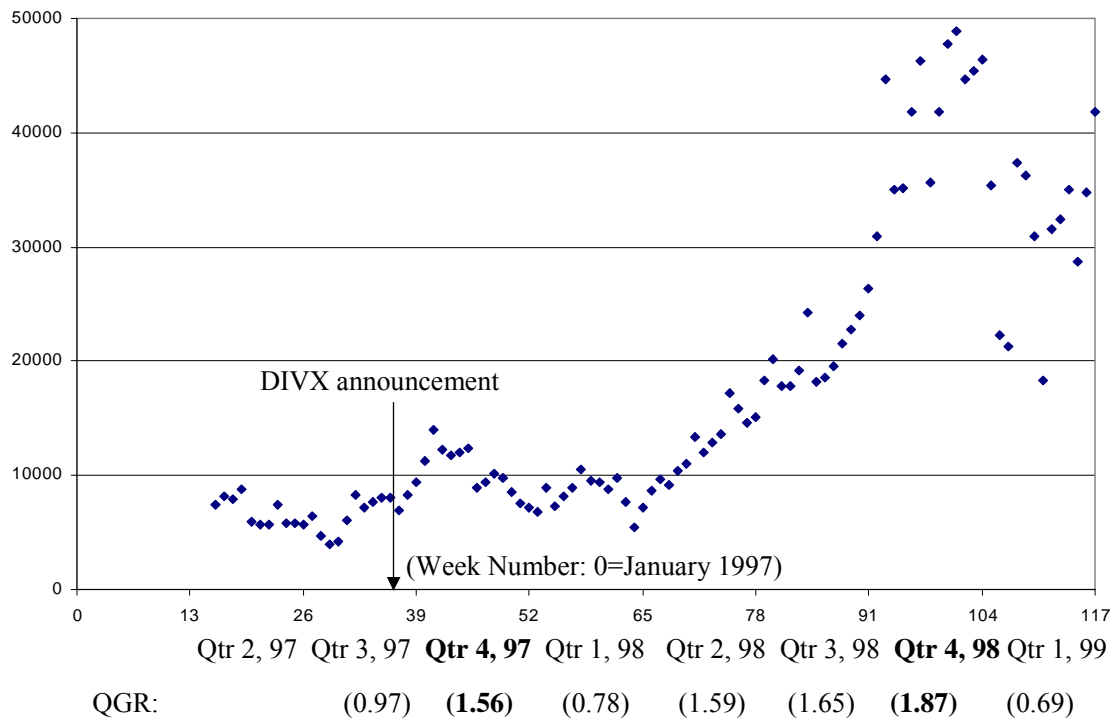


Table 1: Dates the Studios Committed to DVD & DIVX Formats (Columns 1 and 2) and Studio Impact Factor for DVD (column 3)

Major Studio	DVD Date	DIVX Date	LSOFT
Warner (HBO, New Line)	Before DVD players were available	Did not release in format	2022
Columbia	Before DVD players were available	Did not release in format	1865
MGM/UA	Before DVD players were available	March 1998	2544
Universal	July 1997	September 1997	3702
Disney (Buena Vista)	August 1997	September 1997	4422
Paramount	April 1998	September 1997	5218
20 th Century Fox	August 1998	February 1998	5204

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
SALES	208,070	194,510	19,146	654,687
PRICE	357.4	103.2	205.0	557.0
SOFT	20,364	3,524	6431	24977
BOA	0.24	0.14	0.04	0.46
DIVX	0.10	0.31	0	1
ENTRY	0.08	0.27	0	1
DEMISE	0.08	0.27	0	1

Table 3: OLS Results

Independent Variables	Logarithmic Specification (1)		Linear Specification (2)	
	Coefficient	T-statistic	Coefficient	T-statistic
CONSTANT	11.71	1.69	-47785.66	-0.17
LPRICE/PRICE	-1.70	-0.79	-39.09	-0.083
LSOFT/SOFT	0.25	1.18	-9.24	-3.11
BOA	5.55	3.74	1588314.00	6.08
q ²	0.31	1.82	79239.96	2.43
q ³	0.47	3.36	144622.50	3.61
q ⁴	0.61	5.75	198566.50	5.17
DIVX	-0.23	-1.61	-80866.55	-1.87
ENTRY	0.057	0.50	-86564.04	-2.56
DEMISE	0.015	0.17	-59422.71	-1.14
N of observations	39		39	
Durbin-Watson	1.77		2.04	
Adjusted R ²	0.95		0.89	

**Table 4: Instrumental Variable Results: Dependent Variable LSALES:
(Instruments: CAMINSTALLED LCAMINSTALLED, VCRINSTALLED,
LVCRINSTALLED, CDINSTALLED, LCDINSTALLED)**

Independent Variables	Coefficient	T-statistic
CONSTANT	15.55	1.92
LPRICE	-1.20	-1.24
LSOFT	0.18	0.65
BOA	4.71	3.05
q ²	0.25	1.44
q ³	0.46	3.41
q ⁴	0.58	5.22
DIVX	-0.22	-1.51
ENTRY	0.082	0.60
DEMISE	-0.016	-0.10
N of observations	39	
Durbin-Watson	1.82	

Table 5: Reduced Form Regressions for LSALES and BOA

Independent Variables	Dependent Variable LSALES		Dependent Variable BOA	
	Coefficient	T-statistic	Coefficient	T-statistic
CONSTANT	32.43	29.67	2.97	29.24
LPRICE	-3.58	-19.06	-0.46	-26.60
q ²	-0.018	-0.14	-0.047	-4.01
q ³	0.38	2.57	-0.023	-1.60
q ⁴	0.48	2.64	-0.018	-1.09
DIVX	-0.28	-1.35	-0.014	-0.75
ENTRY	0.10	0.44	-0.0093	-0.44
DEMISE	-0.12	-0.60	-0.020	-1.12
N of observations	39		39	
Adjusted R ²	0.93		0.96	

Table 6: VARs using two period lags

Independent Variables	Dependent Variable			
	LSALES		DIVX (Probit Regression)	
	Coefficient	T-statistic	Coefficient	T-statistic
Constant	0.79	1.30	28.94	0.87
LSALES(-1)	0.62	3.93	0.18	0.074
LSALES(-2)	0.32	2.00	-3.11	-1.52
DIVX(-1)	0.14	0.59	2.95	1.98
DIVX(-2)	-0.43	-1.83		
N of obs.	37		37	
Adjusted R ²	0.92			

