

THE DVD vs. DIVX STANDARD WAR: NETWORK EFFECTS AND EMPIRICAL EVIDENCE OF VAPORWARE

David Dranove, Northwestern University (e-mail: d-dranove@nwu.edu)
and

Neil Gandal, Tel Aviv University and CEPR (e-mail: gandal@post.tau.ac.il)

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Abstract

Two important welfare implications of network effects are that (1) market forces often result in suboptimal standardization, that is, left alone the market may fail to achieve standardization when it is socially desirable and (2) even if the market settles on a standard, the chosen standard may be inferior.

Some policy makers have interpreted these results to mean that when there are strong network effects, regulators should play an active role in setting standards. Others have urged regulators not to intervene despite the presence of network effects, unless owners of proprietary standards take strategic actions to influence the adoption decisions of consumers. One action that has raised regulatory (antitrust) concerns is strategic product preannouncements or “vaporware.” In this paper, we empirically test for network effects and vaporware effects in the DVD market and examine the role played by the Internet.

Keywords: Network Effects, Product Preannouncements, Standardization, Vaporware, Internet

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1 Introduction

The theoretical literature on network effects has extensively examined the tradeoff between “standardization” (all consumers adopt compatible products) and “variety” (several incompatible products have positive market shares). Two important welfare implications of this tradeoff are

- Market forces often result in suboptimal standardization, that is, left alone the market may fail to achieve standardization when standardization is socially desirable.¹
- Even if the market settles on a standard, the standard may be inferior, that is, social welfare would have been higher had an alternative standard been chosen.

Some policy makers have interpreted these results to mean that when there are strong network effects, regulators should play an active role in setting standards. This is especially true when a new technology emerges and backwards compatibility is an issue.² Others have urged regulators not to intervene despite the presence of network effects,³ unless owners of proprietary standards take strategic actions to influence the adoption decisions of consumers. One such action that has raised regulatory (antitrust) concerns is strategic product preannouncements or “vaporware.”⁴

¹This result is robust to both physical networks and virtual networks. For the physical networks case, see Farrell and Saloner (1986). For the virtual network case, see Chou and Shy (1990) and Church and Gandal (1992). The latter shows that suboptimal standardization is most likely to occur when consumers place a relatively high value on software variety.

²Recently, the FCC set down the guidelines for the new digital television (HDTV) standard. NTSC televisions will be able to view new broadcasts with a “down-converter” box, which will provide a somewhat improved image. New HDTVs will be able to watch old NTSC programs if they have a second (analog) tuner built-in. The speed of adoption of HDTV has some ramifications; the FCC has scheduled an end to NTSC broadcasts by the year 2006. (See “HDTV: How the Picture Looks Now,” *Business Week*, May 26, 1997, and “Should you Roll Out the Welcome Mat for HDTV?” *The New York Times*, April 27, 1997.)

³Leibowitz and Margolis (1994) criticize the literature on network effects in part because it cannot tell us whether effects identified by the theoretical literature (such as the failure to achieve compatibility) are privately or socially important. They argue that until the literature is able to estimate such effects in a meaningful fashion, the public policy debates are premature.

⁴According to the 1991 Microsoft Press Computer Dictionary, vaporware is defined as “promised software that misses its announced release date, usually by a considerable length of time.” Thus vaporware includes products that simply arrive significantly late due to unexpected technical difficul-

In this paper, we empirically test for network effects and vaporware effects in the DVD market and examine the role played by the Internet. 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 and that the preannouncement of DIVX slowed down the adoption of DVD technology. This suggests that strategic preannouncements can indeed affect the outcome of a standards competition.

The paper proceeds as follows. In section 2, we provide an introduction to network effects, while section 3 briefly discusses vaporware. In section 4, we describe the DVD market. Section 5 describes our data and section 6 contains our empirical results. Section 7 provides brief conclusions.

2 A Brief Introduction to Network Effects

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, the network effect arises from **positive feedback from complementary goods**.⁵ Examples of virtual networks in which the value of the “base” product increases as the variety of complementary products increases include computer operating systems, videocassette recorders (VCRs), compact disc players (CD-players), and Digital Versatile Disc players (DVD-players). In the case of computer operating systems, the complementary goods are the applications software programs, while in the case of VCRs, the complementary goods are the VCR cassettes or tapes; similarly in the case of CD-players, the complementary goods are the compact discs, while in the case of DVD-players, the complementary products are the DVD-discs. The positive feedback mechanism

ties and products that arrive late because of strategic preannouncements. Anticompetitive vaporware allegations refer to the latter.

⁵In the case of computer application software, virtual network effects also arise because consumers want to move files among application programs. Here the horizontal technical compatibility between different application programs leads to a virtual network effect.

works as follows: the value of the base product is enhanced as the variety of (compatible) complementary products increases; hence consumers will be more likely to purchase a base product with many compatible complementary products. The variety of complementary products, in turn, will depend on the total number of consumers that purchase the base product. As the number of consumers that purchase the base product increases, there is a greater demand for compatible complementary products. This increases the profitability of supplying complementary products. Since there are typically fixed or sunk entry costs, production of the complementary products is characterized by increasing returns to scale. Hence more complementary products will be produced or developed for a base product with a large share of the market. This further enhances the value of the base product. Thus there is positive feedback in such a system: an increase in the sales of the base product leads to more compatible complementary products, which further increases (the value of and) sales of the base product.⁶

As Katz and Shapiro (1994) note, the positive feedback means that there is a “natural tendency towards de facto standardization” (p.105). They note that these system markets are often characterized by tipping: once a system has gained an initial lead, there is a snowball effect. One system ends up being the market standard with large amounts of compatible complementary products; the other system has a very small market share, if any at all. The value of the base product with little or no complementary software is essentially zero, since the base product itself provides little or no standalone benefits.

3 Product Preannouncements and Vaporware

In most cases, the premature announcement of a future product cannot be anticompetitive. As Fisher, McGowan, and Greenwood, (1983,p. 289) note “In general, there is no reason to inhibit the time when a firm announces or brings its products to the marketplace. Consumers will be the final arbiter of the product’s quality and the firm’s reputation...Advance announcements of truthful information cannot be anticompetitive.” Farrell and Saloner (1986, p.942) note, however, that when there are strong

⁶See Chou and Shy (1990) and Church and Gandal (1992).

network effects, “the timing of the announcement of a new incompatible product can critically determine whether a new product supersedes the existing technology.” Lemley and McGowan (1998, p.505) remark that “by preannouncing a product, a large company may therefore influence the outcome of a standards competition in an industry characterized by network effects.” Other things being equal, a firm’s incentive to strategically preannounce products is greater in the presence of network effects.⁷

The legality of product preannouncements is unclear. According to McGowan (2000), “Judge Sporkin the Department of Justice Antitrust Division argued that ‘product preannouncements do not violate the antitrust laws unless those preannouncements are knowingly false and contribute to the acquisition, maintenance, or exercise of market power’ ” (p.8). But others believe that truthful preannouncements might violate antitrust laws. See McGowan (2000) for further discussion.

Despite the ambiguity, anticompetitive vaporware allegations have been leveled at IBM and Microsoft. Claims of anticompetitive vaporware were leveled against Microsoft in the 1994 Antitrust case. One of the main claims in the IBM case was that IBM increased its market share by preannouncing products that were in very early stages of development (see Fisher, McGowan, and Greenwood (1983)). In April 1990, DR-DOS 5.0 was introduced and received positive reviews. Baseman, Warren Boulton, and Woroch (1995) noted that “within a month of DR-DOS 5.0’s inauguration, Microsoft reported development of MS-DOS 5.0. Curiously, it boasted nearly all of the innovative features of the DRI product (p.7).” MS-DOS 5.0 was eventually released in June 1991.

Concerns about vaporware led the Software Publishers Association (the computer software industry’s largest trade association) to include prohibitions (in February 1998) against vaporware in the associations’ eight principles of competition.⁸ Despite the antitrust concern about vaporware, there is no empirical work on the issue.⁹

⁷Of course, false preannouncements can benefit firms in non-network industries. But the potential gain to firms is much greater in net industries. Other things being equal, a firm would be less inclined to risk its reputation with a false announcement in a non-network industry than in a network industry. We thank Dennis Carlton for this point.

⁸See McWilliams, B., “Industry Group Issues Software Competition Guidelines,” PC World Communications, February 2, 1998 (<http://pcworld.com/news/daily/data/0298/980202164433.html>).

⁹See Levy 1996 for a recent theoretical manuscript on vaporware.

3.1 Empirical Evidence for Virtual Network Effects

A small but growing literature has empirically (statistically) found evidence of virtual network effects. See Greenstein (1993), Gandal (1994, 1995), Brynjolfsson and Kemerer (1996), and Gandal, Greenstein, and Salant (1999) for empirical evidence of network effects in the computer software industry.

Other papers that provide empirical evidence of virtual network effects include Saloner and Shepard (1995), the ATM industry, Park (1997), the VCR market, Shankar and Bayus (1997), the Home Video Game Industry, Berndt, Pindyck, and Azoulaly (1999) and Gandal, Kende, Rob (2000), the CD industry.¹⁰

4 The Development of the DVD Market

Throughout the 1990s, video hardware and software manufacturers sought a digital format to replace videocassettes. 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). DVD discs are identical in appearance to compact discs, but store ten times as much information - more than enough for a feature film with twice the visual clarity of a videocassette - as well as providing a five channel surround soundtrack.

In September 1996, the “DVD forum” of hardware and software firms published the DVD specifications. 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

¹⁰See Berndt, Pindyck, and Azoulaly (1999) for a nice survey of the literature.

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. Smaller firms that held distribution rights to movies, documentaries, and IMAX films, also committed to the format.¹¹ When the first DVD players were released in the U.S. in early 1997, there were forty 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.¹² 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 laserdisc 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 laserdisc, and speculated about the future of the new format. All agreed that DVD had two advantages over laserdisc. First, it was much cheaper to master and produce DVD software. DVD software retail prices range from \$10-\$30 per movie, compared with \$30-\$70 for films on laserdiscs. Second, the laserdisc market had peaked without becoming mainstream, leaving laserdisc enthusiasts searching for

¹¹IMAX are ultra-high resolution films usually shown in specially-designed theaters with enormous screens and state-of-the-art sound systems. Most IMAX films are short (about 40 minutes) and have subject matter that best shows off the technology, such as automobile racing, volcanoes, and whales. Many home theater buffs use IMAX films on DVD to show off their systems.

¹²Paramount only committed to DVD provision in April 1998, while 20th Century Fox did so in August 1998. Because DVD is digital, it offers opportunities for pirates to make perfect digital copies. The DVD consortium had included some protection against piracy in the DVD format, including Macrovision, which prevents direct copying onto videotape or a recordable DVD player. They 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.

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 in the first few months were well within industry expectations, and much higher than sales of CD players during its first few months on the market (see figure 1). 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.¹³

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. The most popular DVD chat sites received over 1000 posts weekly, many from individuals who did not own a DVD player. (By late 1998, there were at least four on-line chat sites receiving as many as 10,000 postings weekly.) At the same time, new Internet vendors emerged, offering discounted prices on DVD hardware and software sales.¹⁴

4.1 The Introduction of DIVX

Tempering this early enthusiasm were occasional rumors about a competing technology known only as “zoom,” which was supposed 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 plans to introduce

¹³In early 1999, manufacturers introduced third and fourth generation machines, the latter using progressive scan technology to provide the incredible resolution available on high definition television.

¹⁴These companies include DVD Express and Netflix.

DIVX (Digital Video Express).¹⁵ DIVX players would play all DVD discs. But they would also play special DIVX discs (that could not be played on DVD players). DIVX discs are “locked” by an encryption technology. They are unlocked when the user starts playing them, and remain unlocked for 48 hours. Once time expires, the user can replay the disc by contacting a computer operated by a firm working for Circuit City. (This is 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. In this way, DIVX offered an alternative to rental.¹⁶

Despite the fact that Circuit City had no prototype to demonstrate or firm date for introduction of DIVX, the 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.¹⁷ (Table 2 lists the major studios and the dates on which they committed to “open” DVD and DIVX.) The new format seemed like it might prove to be a viable threat to DVD.

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.”¹⁸ To add to the confusion, there seemed to be no technological reason for studios to support only one format. Once a digital master is created for either format (at a cost ranging from \$50,000 to a few hundred thousand dollars per movie), the incremental cost of creating a disc in the other format was negligible. The studio merely had to add or delete the encryption code. Apparently, the only reason that certain studios, notably Disney, released any titles exclusively to DIVX was that Circuit City had paid them handsomely to do so.

Many suspected that Circuit City prematurely announced DIVX in order to slow

¹⁵DIVX is a joint venture between Circuit City and the law firm of Ziffren, Brittenham, Branca & Fischer.

¹⁶Shortly after the DIVX announcement, Netflix began offering DVD rentals through the mail.

¹⁷At the time of the DIVX announcement, Paramount had not yet committed to DVD.

¹⁸DVD Centre Webpage <http://web.ukonline.co.uk/Members/s.roberts/index.htm>.

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.”¹⁹ The editorial also noted that while DIVX attempted to “submarine DVD in September of 1997,” DIVX actually embraced DVD a few months later (in January 1998) as a basic component in the DIVX system.

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 established 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.

Although DVD supporters were disappointed by the DIVX announcement, investors were reasonably pleased. In the three trading days surrounding the announcement, Circuit City’s share values increased by 17.6 percent. In contrast, Best Buy’s shares increased by 13.6 percent. Investors might have even reacted more favorably to the announcement had Circuit City offered more concrete plans for DIVX. Indeed, 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.

Finally, on January 17, 1998 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 and was on the verge of bankruptcy; he also announced that only one retailer (The Good Guys) had agreed to join Circuit City in offering DIVX products. Finally, he indicated that DIVX would be marketed as an advanced feature of DVD, rather than as an alternative standard.²⁰

¹⁹See the DVD Resource Page at <http://www.dvdresource.com>.

²⁰Indeed, some internet reports suggest that most DIVX owners use their players solely to play

With this second announcement, fears of format wars seemed to die down. 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 climbed 3.2 percent. Indeed, Circuit City had actually been lagging Best Buy ever since its September announcement. Circuit City shares fell by 5.5 percent between the two announcements, while Best Buy's shares increased by 153 percent! Numerous press reports attributed a substantial portion of Circuit City's woes to the unsuccessful launch of DIVX.²¹

4.2 The Demise of DIVX

Divx was launched nationally on September 25, 1998. Within less than a year Circuit City decided (on June 16, 1999) to abandon DIVX.²² The facts on the ground justified the decision. By the end of 1998, the installed base of DVD players (players shipped to retailers) was approximately 1.32 Million; during the first twenty weeks of 1999, at least 572,000 additional DVD players were sold to retailers, yielding a DVD installed base of at least 1.9 million through that period. The DIVX installed base through the first twenty weeks of 1999 was at most 165,000.²³ As of May 31, 1999, there were 3,317 titles available on the DVD format and 471 titles available on DIVX.²⁴

"open" DVD disks.

²¹According to "Still, business booms for Circuit and others," by David J. Elrich, June 4, 1999 (from e-town.com), Circuit City had invested more than \$207 million on DIVX (as of February 28th, 1999), nearly seven percent of the firm's total assets. The article also notes that quarterly earnings per share were off by 16 cents due to charges for DIVX. 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.

²²For details, see "DIVX DVD Backers Call it Quits," by Brooke Crothers, CNET News.com, June 16, 1999 at <http://www.news.com/News/Item/0,4,37894,00.html?st.ne.ni.rel>. She notes that DIVX is "being phased out by its creator and national retailer Circuit City, bringing an end to a technology which thousands of customers have already bought into."

²³87,000 Divx players were sold to retailers in 1998. Although an exact breakdown of the 650,000 DVD and DIVX players sold to retailers in the first twenty weeks of 1999 is not possible, 12 percent of RCA's player sales were DIVX players. (RCA is a firm that produces both DVD and DIVX players) See <http://etown.com/news/articles/rcadvd050799swa.html> for details. Since all major manufacturers produce DVD players and only several of these manufacturers produce DIVX players, it would seem that 78,000 (12 percent of 650,000) is an upper bound on DIVX sales for the first 20 weeks of 1999.

²⁴The source for these data is <http://www.hom.net/wayneb/nodivx.htm>.

In the remainder of this paper, we determine whether Circuit City’s vaporware announcement did, indeed, have a chilling effect on DVD sales.

5 Data

The dataset was compiled from several sources, as described below. We collected data from the first week in the second quarter of 1997 (the first period for which weekly sales data of DVD players were available) through the middle of April 2000. We essentially have three years of data. We now describe the variables used in the study.

- We have weekly data on the sales of DVD players from manufacturers to dealers. These 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 three week moving averages. The variable we employ in the analysis, denoted LSALES, is the natural log of the three week moving average of DVD-player sales to retailers.^{25,26} Three week moving averages of DVD player sales, denoted SALES are shown in figure 1. The natural log of this variable is denoted by LSALES.
- The variable LPRICE is the natural log of the average monthly price of DVD players to retailers. The average (sales weighted) monthly prices of DVD players are shown in figure 2.
- 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.²⁷ These data are

²⁵We are grateful to the Consumer Electronics Manufacturing Association for supplying these data and for supplying the data on prices.

²⁶The 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, we estimate that the DIVX installed base through the first twenty weeks of 1999 was at most 165,000, while the installed base of DVD was at least 1.9 million through the same period.

²⁷The box office data have been adjusted for inflation. Since DVD sales began in 1997, we use data on box office releases through 1996.

displayed at the Mr. Showbiz website under the Movie Guide Box Office Leaders category.²⁸ We sorted the movies by studio and added up the box office revenues in order to obtain an impact measure for each studio. (See table 1.) We then constructed the studio impact measure by using the dates at which each studio *committed* to DVD. (See table 2 and figure 3.) The variable *LSOFT* is the natural log of the studio impact measure.

- 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*.²⁹ See figure 4.
- 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 the preannouncement date of the DIVX technology (September 8, 1997) until the date in which a DIVX player was demonstrated (January 17, 1998); at the time of the demonstration, Circuit City’s CEO Richard Sharp embraced DVD technology as the basic technology of the “DIVX enhanced” player.

Table 3 summarizes descriptive statistics for these variables.³⁰

6 Empirical Results

6.1 The Model

We estimated the following consumer adoption equation:

$$LSALES_t = \beta_0 + \beta_1 LPRICE_t + \beta_2 LSOFT_t + \beta_3 BOA_t + \beta_4 DIVX_t + \beta_5 q_t^2 + \beta_6 q_t^3 + \beta_7 q_t^4 + \epsilon_t. \quad (1)$$

²⁸See (<http://mrshowbiz.go.com/reviews/moviereviews/numbers/top100adjusted.html>).

²⁹Since *BOA* is a percentage, there is no reason to employ a logarithm in this case.

³⁰Given that a quarterly lag is necessary for the construction of *LSALES*, there are 156 observations, that is, three full years of data.

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.

6.2 Estimation Issues

Since studios likely made their decision to release films in DVD format in part on the number of DVD player sales, the variables LSOFT and BOA are endogenous. It is also likely that prices are endogenous.³¹ Hence, Ordinary Least Squares (OLS) estimates are biased.

Given the endogeneity of LSOFT, BOA, and LPRICE, it is rather straightforward to show theoretically that the OLS estimate of β_1 (the price elasticity) is biased towards zero, while 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, BOA, the endogenous variables on the right-hand side of (1). We now discuss the instruments that we employed:

- We built a predicted (hedonic) price series for DVD players using semiparametric methods. Parametric predictors included player characteristics (e.g. on-board Dolby Digital decoder), brand, and generation. After controlling for these effects (following the methods described in Robinson (1988)), we performed a kernel regression of price on time, and recovered the predicted prices for each month. We obtained the data for this analysis by conducting an on-line survey of DVD owners on the hometheaterforum.com website. While visitors to this site obviously do not represent a random sampling of DVD owners, we believe that

³¹Like many consumer electronic products, DVD players are fairly standardized products produced by many firms. Nevertheless, given that the nascent stage of the industry, it is likely that firms had market power.

their responses do reasonably estimate the time trend of DVD player prices. We asked respondents to identify the make and model of their DVD player, the date of purchase, and the purchase price. We obtained product features from manufacturer web sites. Over 80 forum members responded to our request for data. Observations were available for most, but not all months. For those months without observations, linear interpolation from predicted prices of adjacent months was used. Clearly this series is correlated with price and, because of its construction, uncorrelated with the error term.³² The log of this variable, denoted LHEDPRICE is one of the instruments that we employ.

- We used the stock price of “Best Buy” (denoted BBPRICE) as another instrument. Since Best Buy is a major retailer of consumer electronic products, Best Buy’s stock price depends, in part, on the success of the DVD industry. Hence, it should be positively correlated with both LSOFT and BOA. It is reasonable to assume that Best Buy’s stock price is uncorrelated with the error term in (1).
- We used the stock price of Circuit City (denoted CCPRICE) as a third instrument. Circuit City was the promoter of DIVX and its announcement in September 1997 should have affected its stock price as well as the endogenous variables LSOFT and BOA. Indeed Circuit City’s announcement can be viewed as an “external shock” to the DVD system. Hence, it is likely uncorrelated with the error term.

6.3 Estimation

Table 4 reports ordinary least squares (OLS) results with an AR(1) term. The AR(1) term was included because we smoothed the sales data using three-week moving averages. Table 4 shows that all of the coefficients have the expected sign, and that all of the estimates with the exception of the price elasticity of demand are statistically significant. In all cases, we use Newey-West standard errors which are robust to unknown serial correlation.

³²Since this series is incomplete and unweighted, we would not want to use it as an independent variable in place of price in (1). This qualification does not affect its quality as an instrument.

The results of the instrumental variable regression are contained in table 5. It is no surprise that the estimated price elasticity is much larger (in a negative sense) in this table, relative to table 4.

Additionally, the estimated coefficients of LSOFT and BOA are smaller, although still positive and statistically significant. This suggests that there are positive virtual network effects. As the important studios began to release their films in DVD format, the number of consumers adopting DVD players also increased.

The appropriateness of the instruments can be examined by comparing the estimates in tables 4 and 5. As the two tables show, 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. This suggests that the instruments are working well.³³

Table 5 also shows that the DIVX preannouncement somewhat 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.³⁴ The coefficient estimate on the DIVX dummy variable suggests that the preannouncement reduced DVD sales by approximately 25 percent.³⁵ 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.

Note that 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 that the second and third quarter sales are higher than first quarter sales (typically the lowpoint of the year). Note that the Durbin Watson statistic in all three regressions suggests that the autocorrelation has been accounted for by the

³³First stage regressions of the endogenous variables on the instruments yield relatively high values of R^2 .

³⁴It is not possible to theoretically determine the direction of the OLS bias for the DIVX coefficient.

³⁵This follows from that fact that $\exp(-.28) = .75$.

AR(1) term, which is statistically significant.³⁶

To test for robustness, we added a linear time trend (denoted TIME) as an independent variable. The results of the instrumental variable regression with the time trend are shown in table 6. Table 6 shows that the time trend is borderline significant ($t=-1.52$). With the exception of the coefficients on the quarterly dummies (two of which are slightly smaller), the other coefficients are more significant statistically, but the story is essentially the same. The coefficient estimate on the DIVX dummy variable in this case suggests that the preannouncement reduced DVD sales by approximately 32 percent.

7 Conclusion

We established that there are network effects in the DVD market and that the preannouncement by DIVX somewhat slowed down the adoption of DVD technology. While we cannot say whether the preannouncement was strategic or whether the release of DIVX was delayed due to technical difficulties, we have quantified the effect of the preannouncement. While the future of the technology is bright (The U.S. installed base of DVD players now exceeds six million units), there was certainly some concern at the time that the potential format war would kill it.

In the case of DVD vs. DIVX, the product preannouncement was made by an entrant rather than an incumbent firm and hence was probably not a concern to regulators.³⁷ Additionally, there were clearly consumer benefits from the preannouncement. First, the announcement provided information to consumers about the future entry of a competing standard. Additionally, it's likely that the DVD rental market emerged more quickly due to the DIVX preannouncement; consumers certainly benefited from the rental market.

Nevertheless, the result that the product preannouncement by an entrant had such a large effect suggests that a product preannouncement by an incumbent would likely have a much larger effect; hence the general antitrust concern about vaporware seems justified.

³⁶In any case, as noted above, we employ Newey-West standard errors which are robust to unknown serial correlation.

³⁷We thank David McGowan for this point.

Finally, the internet played a key role in helping 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 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.

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Major Studio	Studio Impact Measure
Warner (HBO, New line)	2022
Columbia	1865
MGM/UA	2544
Universal	3702
Disney (Buena Vista)	4422
Paramount	5218
20 th Century Fox	5204

Table 1: Studio Impact Measure

Major Studio	DVD Date	DIVX Date
Warner (HBO, New line)	Before DVD players were available	Did Not Release in format
Columbia	Before DVD players were available	Did Not Release in format
MGM/UA	Before DVD players were available	March 1998
Universal	July 1997	September 1997
Disney (Buena Vista)	August 1997	September 1997
Paramount	April 1998	September 1997
20 th Century Fox	August 1998	February 1998

Table 2: Dates On Which Major Studios Committed to DVD and DIVX

Variable	Mean.	Std. Dev.	min	max
LSALES	11.22	1.09	9.00	13.30
LPRICE	5.88	0.26	5.47	6.32
LSOFT	9.83	0.41	8.77	10.13
q^1 (q^2 , q^3 , & q^4)	0.25	0.43	0	1
DIVX	0.12	0.32	0	1
LHEDPRICE	5.76	0.31	5.20	6.19
BBPRICE	31.87	23.21	3.00	86.00
CCPRICE	28.27	11.59	15.35	60.88

Table 3: Descriptive Statistics ($N = 156$)

Indpt. Variables	Coeff.	t-Stat
Constant	6.62	1.17
LPRICE	-0.17	-0.24
LSOFT	.41	2.07
BOA	6.31	4.52
q^2	0.32	2.62
q^3	0.32	2.85
q^4	0.56	6.13
DIVX	-0.29	-2.11
AR(1)	0.32	5.45
Adjusted R^2	0.90	
Number of Obs.	155	
DW Statistic	1.176	

Table 4: Ordinary Least Squares Results with AR(1) term: Dependent Variable LSALES (Three week moving average of DVD sales)

Indpt. Variables	Coeff.	t-Stat
Constant	16.66	2.14
LPRICE	-1.69	-1.68
LSOFT	0.36	1.81
BOA	3.42	1.91
q^2	0.20	1.30
q^3	0.27	2.46
q^4	0.50	6.57
DIVX	-0.28	-2.00
AR(1)	.29	4.60
Number of Obs.	155	
DW Statistic	1.77	

Table 5: Instrumental Variable Results: Dependent Variable LSALES: Instruments: CCPRICE, BBPRICE LHEDPRICE.

Indpt. Variables	Coeff.	t-Stat
Constant	18.28	1.83
LPRICE	-2.65	-1.60
LSOFT	0.89	2.18
BOA	9.33	2.65
q^2	0.17	0.85
q^3	0.37	2.64
q^4	0.48	4.16
DIVX	-0.38	-2.05
TIME	-0.027	-1.52
AR(1)	.32	5.59
Number of Obs.	155	
DW Statistic	1.74	

Table 6: Instrumental Variable Results: Dependent Variable LSALES: Instruments: CCPRICE, BBPRICE LHEDPRICE. Time Trend Included.