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RESEARCH ARTICLE

COMPETING WITH FREE: THE IMPACT OF MOVIE BROADCASTS ON DVD SALES AND INTERNET PIRACY[1]

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Abstract

The creative industries have frequently expressed concern that they can't compete with freely available copies of their content. Competing with free is particularly concerning for movie studios, whose content may be more prone to single-use consumption than other industries such as music. This issue has gained renewed importance recently with the advent of new digital video recording and distribution technologies, and the widespread availability of Internet piracy.

We examine competition between "free" and paid video content in two important contexts: the impact of legitimate free distribution in one channel on sales through paid channels, and the impact of illegitimate free distribution in pirated channels on sales through paid channels. We do this by studying the impact of movie broadcasts on DVD demand and the impact of piracy availability at the time of broadcast on DVD demand. Our data include all movies shown on over-the-air and cable television during an eight-month period in 2005–2006.

With respect to the impact of movie broadcasts on piracy and sales, we find that movie broadcasts on over-the-air networks result in a significant increase in both DVD sales at Amazon.com and illegal downloads for those movies that are available on BitTorrent at the time of broadcast. With respect to the impact of piracy on sales, we use the television broadcast as an exogenous demand shock and find that the availability of pirated content at the time of broadcast has no effect on post-broadcast DVD sales gains.

Together our results suggest that creative artists can use product differentiation and market segmentation strategies to compete with freely available copies of their content. Specifically, the post-broadcast increase in DVD sales suggests that giving away content in one channel can stimulate sales in a paid channel if the free content is sufficiently differentiated from its paid counterpart. Likewise, our finding that the presence of pirated content does not cannibalize sales for the movies in our sample suggests that if free and paid products appeal to separate customer segments, the presence of free products need not harm paid sales.

Keywords: Information goods, movie broadcasts, movie promotion, DVD sales, movie piracy, broadcast flag, consumer surplus

[1]Chris Kemerer was the accepting senior editor for this paper.

Introduction

> "We can't compete with free. That's an economic paradigm that doesn't work."
>
> *James Gianopulos, Co-chairman, Twentieth Century Fox Filmed Entertainment (quoted in Thompson 2003)*

As noted in the above quote, members of the creative industries have long expressed the belief that they are unable to compete with "free" copies of their content made available through new information technologies. Their argument is intuitive: Once a consumer is able to consume and potentially retain a copy of free content, why would they consider purchasing that content?

Sales cannibalization from free distribution may be particularly salient in the movie industry for two reasons. First, movie content may be more prone to single-use consumption than other intellectual property categories such as music or software. Second, movie studios are particularly reliant on revenue from media sales: Media sales (primarily DVD sales) made up 46 percent ($14.9 billion) of total movie revenue in 2002 (Epstein 2005, p. 20; PBS 2005), a little over twice that of theater revenue, and margins on these media sales are higher than margins in many of the studios' other lines of business.[2]

With these issues in mind, the goal of this research is to analyze the impact of free distribution of movies on paid consumption in two important contexts. First, the impact of free television broadcasts of movies on consumer demand for DVDs. Second, the impact of piracy availability at the time of broadcast on post-broadcast DVD demand. These two empirical questions highlight two important areas of competition between free and paid content: the impact of legitimate free distribution in one channel on demand in a paid channel, and the impact of illegitimate "free" pirated distribution on demand in a paid channel.

These questions have also become salient from a business and public policy perspective with the development of new technologies such as digital video recorders, high definition digital television (HDTV), high bandwidth Internet access, and a proliferation of tools facilitating Internet piracy. Specifically, with the development of new HDTV standards and the prevalence of piracy on the Internet, studios have expressed concern that consumers' ability to make copies of free, unencrypted high definition television broadcasts will harm the marketability of the studios' content. For example, in testimony before the Federal Communication Commission regarding the need for federally mandated broadcast flag content protection in high definition broadcasts, Viacom made the following statement:

> Viacom believes that [digital television] sales and broadband subscriptions have reached the "tipping point" at which it can no longer afford to expose its content to piracy. A broadcast flag regime is needed now to protect the value of our important assets or we must withhold our quality HD digital content [from over-the-air broadcasts].
>
> *Viacom comments before the Federal Communications Commission in the matter of Digital Broadcast Copy Protection, December 6, 2002 (in Lucey 2002, p. 8)*

These concerns are driven by two main factors. First, that the ability of consumers to easily record, edit, and retain digital television broadcasts will reduce demand for paid content. And second, that the ability of (disreputable) consumers to post high quality copies of movies shown on television will increase the supply of pirated content and reduce demand for legitimate media sales.

At the same time, in the face of these concerns it is possible to see "competing with free" as a special case of price competition. In this context, the academic literature has shown that, in spite of initial concerns of fierce price competition in Internet markets, some Internet retailers are able to maintain both high market share and high margins through product and service differentiation and customer segmentation (e.g., Brynjolfsson and Smith 2000; Smith and Brynjolfsson 2001).

Thus, as is outlined in more detail below, it is unclear from a theoretical perspective what impact these two types of free goods might have on subsequent demand through legitimate channels. Because of this, we address these questions empirically by gathering a new data set including all movies shown on over-the-air television networks and the four most popular advertising supported cable networks (hereafter ad-cable) from July 12, 2005, to March 3, 2006. For each movie in our sample, we collect data on its sales level at Amazon.com and piracy levels at two prominent BitTorrent tracker sites.

Our results show that, contrary to fears about competing with free content, neither type of free content analyzed in this study seems to reduce demand for paid content. In the case of free movie broadcasts on television, we find that the broadcast acts as a strong, short-term stimulus to demand for

[2]For example, according to a studio executive we spoke to, studios currently pay only 20% of DVD revenues to the various artist and production unions, keeping the remaining 80%.

DVDs. In our sample, over-the-air movie broadcasts result in an increase in DVD sales at Amazon.com by an average of 118 percent during the first week after broadcast.

With respect to the impact of free pirated content, studies of the impact of piracy face the endogeneity concern that (unobserved) popularity influences both sales (left-hand-side variable) and piracy levels (right-hand-side variable). In this study, we attempt to address this endogeneity concern by using the promotional stimulus from the movie broadcast as an exogenous shock, and comparing the post-broadcast promotional gain for movies that have pirated versions readily available on BitTorrent networks at the time of broadcast and those that do not. If piracy is harming sales for these movies, movies that have pirated copies readily available on BitTorrent will exhibit a smaller post-broadcast promotional stimulus than those that do not because some consumers who would otherwise have purchased a DVD will (illegally) download the free BitTorrent version instead. However, we observe in our data that movies that have pirated copies readily available on BitTorrent networks at the time of broadcast have statistically the same increase in DVD sales as those that do not.

For movie studios, our results suggest that competing with free is possible through product differentiation and customer segmentation. With regard to differentiation, our results suggest that the television broadcast of a movie is sufficiently differentiated from the DVD version (in terms of convenience, usability, and content) that, not only does it not appear to cannibalize sales, it has a net promotional effect on sales—even though nearly the entire copy of the movie is shown on television and even though movies are thought to be single-use consumption products. With respect to segmentation, our results suggest that, at the time of broadcast, pirates and purchasers represent two different market segments. The movie broadcast stimulates demand for DVDs and demand for piracy. However, the presence of pirated content does not cannibalize DVD sales at the point of time a movie is shown on television. This is conceptually similar to well-known examples of price discrimination where a lower priced product (in this case a free pirated product) need not cannibalize sales from higher priced products if the two products appeal to different customer segments. The difference, in this case, is that rights holders have only limited control over the availability and "price" of pirated content as compared to price setting and product differentiation strategies available to firms in more traditional settings.

For policy-makers, we find no evidence to indicate an immediate need for "broadcast flag" style copy protection of movie broadcasts. In contrast, our results suggest that at present the net effect of television broadcasts is to increase media sales, and that the presence of pirated content does not reduce post-broadcast sales of movies shown on television.

For academics, our research presents a new empirical strategy for tracking piracy levels on the BitTorrent network and a new strategy for analyzing the impact of piracy on media sales. Specifically, in settings where the decision to promote or distribute a product (through broadcast in our case) is uncorrelated with the availability of the product on pirate networks, the promotional stimulus can be used as a natural experiment to compare the response of products with and without pirated copies available.

The remainder of this paper proceeds as follows. In the next section, we review the relevant literature pertaining to the impact of broadcasts and piracy on product sales, and on the effectiveness of product differentiation and market segmentation strategies in Internet markets. In the third section, we present our main empirical tests and briefly discuss the theoretical basis for each test. We then discuss our data and present our empirical models and results. Finally, we discuss the implication of our findings, limitation of our analysis, and areas for future research.

Literature

Our work most closely pertains to the literature on the impact of piracy in markets for information goods. Most of the work in this area has focused on software or music piracy, and particularly on peer-to-peer file sharing networks and their impact on firm profitability. A prominent trend in the analytic literature has been to show that piracy need not be bad for firms. Prasad and Mahajan (2003) argue that piracy may be good for a new product if the firm needs to establish an initial user base to speed up diffusion. Gu and Mahajan (2005) show that because piracy removes the most price sensitive buyers from the market it can reduce price competition, thus benefiting sellers. Finally, Peitz and Waelbroeck (2003) show that piracy can act as a free "sample," increasing product awareness.

The empirical work on piracy has focused on estimating the impact of piracy on demand for legitimate content. The majority of this literature has focused on the music industry, addressing three related sets of empirical questions. The first question is the degree to which the emergence of peer-to-peer file sharing in 1999 can explain the steady decline in record sales from 1999 to 2003. In addressing this question, Liebowitz (2008) finds that increased Internet penetration can

explain the significant reduction in album sales from 1999 to 2003, while Hong (2004) and Peitz and Waelbroeck (2004) find that approximately 20 percent of the decline in record sales can be explained by piracy using data from 2000 and 1998 to 2002 respectively.

The second, and related, major question addressed in the literature is the degree to which the consumption of pirated content displaces sales of legitimate content. Here, estimates range from 42 percent displacement in an international sample from 1994 to 1998 (Hui and Png 2003), to 33 percent displacement among U.S. sales in 2003 (Blackburn 2007), to 30 percent displacement among 15,000 European consumers in 2001 (Zentner 2006), to 20 percent displacement among a sample of University of Pennsylvania students (Rob and Waldfogel 2006), to finally no displacement among U.S. downloaders in late 2002 (Oberholzer and Strumpf 2007).

The third major question addressed in the literature is the degree to which harm from piracy affects popular and less popular artists. Here Blackburn (2007) finds that piracy has a stronger impact on popular artists while Bhattacharjee et al. (2007) and Rob and Waldfogel (2006) seem to find the opposite effect: that less popular CDs face higher piracy risks. Thus, each of the papers in the literature—with one notable exception—has found some level of harm from music piracy in the late 1990s and early 2000s, but there is a fair amount of disagreement as to the degree of harm from piracy.

However, while there is now a great deal of literature in the context of music piracy, we are aware of only two papers to address movie piracy. First, Rob and Waldfogel (2007) use survey data from 500 University of Pennsylvania undergraduates and find that piracy displaces paid consumption by nearly 100 percent on the first viewing and 20 percent on the second viewing. Second, Smith and Telang (2007) find that increases in broadband Internet penetration from 2000 to 2003 led to a $1.3 billion *increase* in DVD sales. Moreover, it may be particularly important to analyze the impact of video piracy separately from music piracy because of differences in size, download speed, digital rights protection, and consumption patterns between the two types of content.

Another stream of the literature analyzes piracy from a policy perspective. In this context, Gopal and Sanders (1998) show that government enforcement of intellectual property rights depends on the robustness of the domestic software industry. With respect to copyright policy, Png and Wang (2006) show that copyright extensions enacted by OECD countries from 1991 to 2002 were associated with an increase in movie production—and that this increase was stronger in countries where piracy was lower. Finally, from the perspective of the supply of piracy, Byers et al. (2003) show that the majority of movies available on file sharing networks originate from studio leaks, as opposed to copies from DVDs or other post-market sources.

From the perspective of empirical methods, our analysis relates to the growing empirical literature using Amazon's sales rank data to estimate the company's product-level sales. While Amazon.com does not provide product-level sales information for its products, the company does provide information about the sales ranking of products within a particular product category. Researchers have used this sales rank data to estimate Amazon's sales through direct empirical estimation (Brynjolfsson et al. 2003) and experimental calibration (Chevalier and Goolsbee 2003). Subsequent papers in the literature have used Chevalier and Goolsbee's experimental calibration technique in a variety of contexts (e.g., Chevalier and Mayzlin 2004; Ghose et al. 2006; Ghose and Sundararajan 2005; Smith and Telang 2004).

Finally, we note that the impact of piracy on product markets is conceptually similar to the impact of used goods markets on new product sales (Ghose et al. 2006), the impact of increased TV and radio penetration on the movie and music industries (Liebowitz 2004), competition between traditional print copies of books and PDF copies of books (Kannan and Jain 2002), consumers' decisions to rent or purchase movies (Knox and Eliashberg 2005), and international movie release windows (Elberse and Eliashberg 2003).

Theoretical Framework

In this section, we outline the main empirical questions addressed in this paper and discuss the theoretical rationale underlying each question.

The Impact of Movie Broadcasts on DVD Sales

On one hand, it is possible that the dominant impact of "giving away" a movie through an unencrypted, freely available medium such as broadcast television would suppress DVD sales. In this view, consumers who would have otherwise purchased the movie on DVD would be less inclined to do so if they could instead watch and retain copies of movies shown on free television. The movie studios first raised this argument in 1982 as part of the development of the first analog videocassette recorders. At that time, the movie industry argued before the United States Congress and

Supreme Court that home recording of television programs infringed the studios' copyright and that manufacturers of home video equipment should be held liable of all resulting instances of copyright infringement. This argument was most famously advanced by Jack Valenti's statement before Congress that "the VCR is to the American film producer and the American public as the Boston strangler is to the woman home alone."[3] As noted above, studios have again raised this concern in the context of HDTV broadcasts and digital video recorders, noting that it is easier for consumers to retain, edit, and share digital broadcasts than analog broadcasts and that, unlike analog broadcasts, digital storage, editing, and sharing can occur without loss of signal quality.

On the other hand, it is possible that television broadcasts of movies could have no effect on DVD sales, or even stimulate sales. The "no effect" view is consistent with Liebowitz (1985), who concluded that there was no detrimental impact of the VCR on TV content providers. In the "stimulate sales" view, the television broadcast would serve as advertising for the movie, allowing consumers who otherwise would not have purchased the DVD to become aware of (or reacquainted with) its content. These consumers might decide to purchase the DVD even after seeing the movie on television because DVDs offer more information (e.g., deleted scenes, director's commentary), higher convenience (e.g., no commercials, easy portability), and higher video quality than television broadcasts do. A similar idea was espoused, though not empirically tested, by Liebowitz (1985).

We also note that these effects might exist side-by-side, with some consumers deciding not to purchase DVDs because they can view and retain the television broadcasts, and some consumers deciding to purchase the DVD on the basis of seeing the broadcast. While our data do not allow us to separately identify these two effects, we are able to identify the net effect of the television broadcast on DVD sales.

[3]"Hearings Before the Subcommittee on Courts, Civil Liberties, and the Administration of Justice of the Committee on the Judiciary House of Representatives, Ninety-Seventh Congress, Second Session, on Home Recording of Copyrighted Works," 1982, Serial No. 97, Part I, U.S. Government Printing Office, 15-168O, Washington, D.C.

The Impact of Pirated Content on After-Broadcast DVD Sales

If movie broadcasts serve to stimulate DVD sales, will this sales stimulus be lower for movies that have pirated content available at the time of broadcast? This is a critical empirical question for movie studios looking to protect their valuable content.

On one hand, the majority of the empirical literature has shown that, at least in the context of music and software, the availability of pirated content reduces, at least somewhat, legitimate demand. It would be natural to expect that the same rationale would carryover to movies as well.

However, it is also possible that the availability of pirated content for movies has a negligible effect on legitimate consumption. This view is consistent with the notion that pirated content for music and software is a much stronger substitute for paid content than pirated copies of movies. Pirated music and software have nearly the same quality and usability as the legitimate content. In the case of music, pirated content may have even higher usability as, unlike many legitimate digital downloads, pirated music does not contain restrictions associated with Digital Rights Management, and unlike CDs, pirated music does not require a separate step to be played on portable digital music players.

In contrast, pirated movies frequently have significantly lower quality than legitimate media due to the compression necessary to facilitate easy Internet downloads. Likewise, from a usability standpoint, it is harder to play pirated movies on most home theater systems than it would be to play a legitimate DVD.

The impact of piracy on legitimate demand also critically depends on how loosely (or tightly) coupled the user segments in these markets are. On one hand, it is possible that these segments are tightly coupled and that a significant number of users would forgo the purchase of a DVD if pirated content were available. On the other hand, these segments might be loosely coupled such that potential DVD buyers would not consider the availability of pirated content in their purchase decision, and potential pirates would not consider purchasing the DVD if pirated content were not available.

Thus while the economic theory underlying our empirical analysis is well established, the actual effects critically depend on the market structure and user choices associated with the provision of free media products. Therefore, we believe that these issues are inherently empirical and in the next two sections we outline the data gathered to address these questions and our empirical results based on this data.

Data

We address these empirical questions using data collected from July 12, 2005, through November 23, 2005,[4] and from January 1, 2006, through March 3, 2006. We have eliminated all observations during the Christmas 2005 holiday season to avoid any potential counter-explanations that might occur during this time period (e.g., increased sales of DVD, reduction in piracy, systematic changes in preferences for piracy versus legitimate purchases owing to holiday gift purchases).

Our data consist of information on all movies shown on over-the-air broadcast channels and major advertising supported cable channels. With respect to over-the-air channels, we gathered data on all movies shown in national broadcasts on the major broadcast networks during our sample: ABC, CBS, NBC, FOX, UPN, and WB. We used only national broadcasts as a partial control for audience size as local affiliates have the option of slotting movies that will only be shown in a local region. We determined that a broadcast was national if it was shown in both the New York City and Los Angeles affiliates during the same time slot.

We also collected data from the four most popular advertising-supported cable networks (hereafter ad-cable): TBS, TNT, USA, and Lifetime. We selected these four networks based on Nielsen Media Research viewership estimates (as reported by TelevisionWeek magazine) for the six-month period from March to August 2005. The four most popular channels were the same whether we considered total daily viewers or prime time viewers.

We collected data for each of these movie broadcasts from three primary sources. We collected broadcast information—broadcast date and time, broadcast duration, movie name and description, and whether the movie was shown in high definition format—from TitanTV.com. We used TitanTV because it is easily searchable and provided a 14-day advance notice before a movie's broadcast date. This advance notice allowed us to obtain a baseline level of sales and piracy before broadcast. We used the Internet Movie Database (imdb.com) to obtain information on the theatrical release date, rental revenue, gross revenue, gross budget, and IMDB user star rating for each of the movies in our study. Finally, as an additional control for "popularity" of the movie, we collected data from Nielsen media research on television viewership for each movie at the time of broadcast.

We also collected information about DVD characteristics and sales rank for each version of the movie available at Amazon.com. Many movies have separate wide screen and full screen editions, and in some cases separate special or unrated editions.[5] For each of the DVD versions, we collected product characteristics including list price, release date, MPAA rating, aspect ratio, number of discs, and sound quality (e.g., Stereo, Dolby Surround, Dolby THX). We also collected Amazon marketplace information including the Amazon price, the Amazon users' star rating of the movie, and the movie's sales rank. We collected this information hourly for two weeks before and after the movie was broadcast, and daily thereafter. We do not include observations that occur after the second showing of a movie in our data or for movies that had shown on television during the six-month period prior to July 2005. This allows us to focus our attention on the sales gain from the first showing.

Finally, we eliminated any movies in our sample that had sequels that appeared in movie theaters or were released on DVD during the period of March 2005 through September 2006 (i.e., six months before and after our data collection period). This is done to control for endogenous promotional effects associated with theatrical and DVD release dates. Our final sample contains 522 broadcast movies and 759 DVD titles. The summary statistics for our sales data are shown in Table 1.[6]

We use Amazon's DVD sales rank as a proxy for the number of products sold at Amazon. Amazon.com lists the rank of products sold in each product category, with 1 corresponding to the highest selling product, 2 to the second highest selling product, and so on. Following Brynjolfsson et al. (2003) and Chevalier and Goolsbee (2003), we assume that the relationship between sales and sales rank follows a Pareto distribution:[7]

$$Quantity = \alpha\, Rank^{\beta} \qquad (1)$$

[4]November 23, 2005, was the day before Thanksgiving, the traditional start of the Christmas shopping season. Our results are not sensitive to this choice of dates. For example, a more conservative approach of eliminating all observations from November 1, 2005, to January 1, 2006, would result in a slight (and statistically insignificant) increase in the post-broadcast sales gains reported here.

[5]We did not collect data on box sets that contain multiple different movies, even if one of the movies in the box set was present in our sample.

[6]This table includes all data from 14 days before broadcast date through 28 days after the broadcast date consistent with our regressions below.

[7]This technique has also been applied in a variety of other studies, including Chevalier and Mayzlin (2004), Ghose et al. (2006), and Ghose and Sundararajan (2005).

Table 1. Sales Data Summary Statistics

Variable	Obs.	Mean	St. Dev.	Min	Max
Amazon Rank	39,013	12,853	13,100	2	97,459
Amazon Price	39,013	12.95	4.06	4.98	39.99
IMDB Star Rating	39,013	5.95	1.24	1.80	8.80
Broadcast Duration (Hours)	39,013	2.21	0.41	1.35	5
Broadcast Network	39,013	0.18	0.38	0	1
Number of Discs in DVD	39,013	1.10	0.36	1	5
Ln(Gross Revenue ($ Million))	31,974	17.36	1.32	10.53	20.20
IMDB User Votes	39,013	12,103	19,987	1	191,707
No of Viewers (in millions)	522	2.04	1.97	0.28	9.50
Minutes Edited from Broadcast	39,013	9.90	10.50	0	90

This relationship can be parameterized using either direct observation of sales and ranks for select titles, typically obtained from product suppliers (see Brynjolfsson et al. 2003) or by means of an experiment (see Chevalier and Goolsbee 2003).

Lacking supplier data, we apply Chevalier and Goolsbee's experimental technique by finding two DVDs with high rank (low sales) and observing their rank over the course of several weeks to estimate the number of daily sales. We then ordered seven copies of the DVDs in an hour, observing the initial and final rank. This allows us to obtain two points on the curve, which we can then use to determine the slope (β) of equation (1) in log-log space. We performed this experiment on July 1 and July 8, 2004, for two separate DVDs and found the β parameter for equation (1) was equal to –1.61 in both cases. We performed this experiment again on February 8, 2006, for two additional DVDs, and found β parameters of –1.76 and –1.81 respectively. We use the average of the four β estimates (–1.70) in our subsequent calculations.[8]

Our piracy data come from piratebay.org and mininova.org, two public tracker sites for the BitTorrent protocol. We selected BitTorrent as a proxy for piracy levels for two reasons. First, BitTorrent is currently the most popular protocol for sharing large files, such as movie files (which typically range from one to six gigabytes in size for content sourced from DVDs). Second, the design of the BitTorrent protocol is such that all nodes participating in a file download report their status to the tracker every 20 seconds. Thus, tracker sites such as Piratebay and Mininova can report in near real-time the number of users providing the entire file (i.e., seeds), the number of users actively downloading the file (i.e., leechers), and the number of cumulative downloads. This characteristic makes BitTorrent tracker sites particularly useful for empirical analysis of piracy levels, and we believe that the use of BitTorrent tracker sites in this way represents an additional contribution of this paper to the literature.

Among BitTorrent trackers, we selected Piratebay and Mininova as data sources because they were among the most popular BitTorrent tracker sites during our study period,[9] and these sites also listed the current number of seeds, leechers, and downloads for each of their trackers at the time of our study (Figure 1 shows a sample screen from mininova.org).

For each of the movies in our data set, we use an automated script to search for movie torrents matching the movie title. We collect this data daily starting before the movie's broadcast date and continuing after the broadcast date. This allows us to track both (1) any activity on torrents that existed before the broadcast and (2) any new torrents that might be added after the broadcast date. For all trackers that match the movie title and general description, we collect the date the tracker was added to the respective tracker site, the file size, and daily observations of the number of seeds, leechers, and cumulative downloads.

Our final data set covers the period of October 28, 2005, through March 3, 2006. As above, we exclude the Christmas holiday period (November 23, 2005, through January 1, 2006) to avoid the possibility that piracy levels are systematically different during this time period. The summary statistics for our piracy data are shown in Table 2.[10]

[8]Our results would be qualitatively the same if we used either the July 2004 or February 2006 coefficients.

[9]For example, Gil (2006) lists both Piratebay and Mininova among the five most popular BitTorrent tracker sites.

[10]Our summary statistics only include observations from 14 days before broadcast to 7 days after broadcast, consistent with our regressions below.

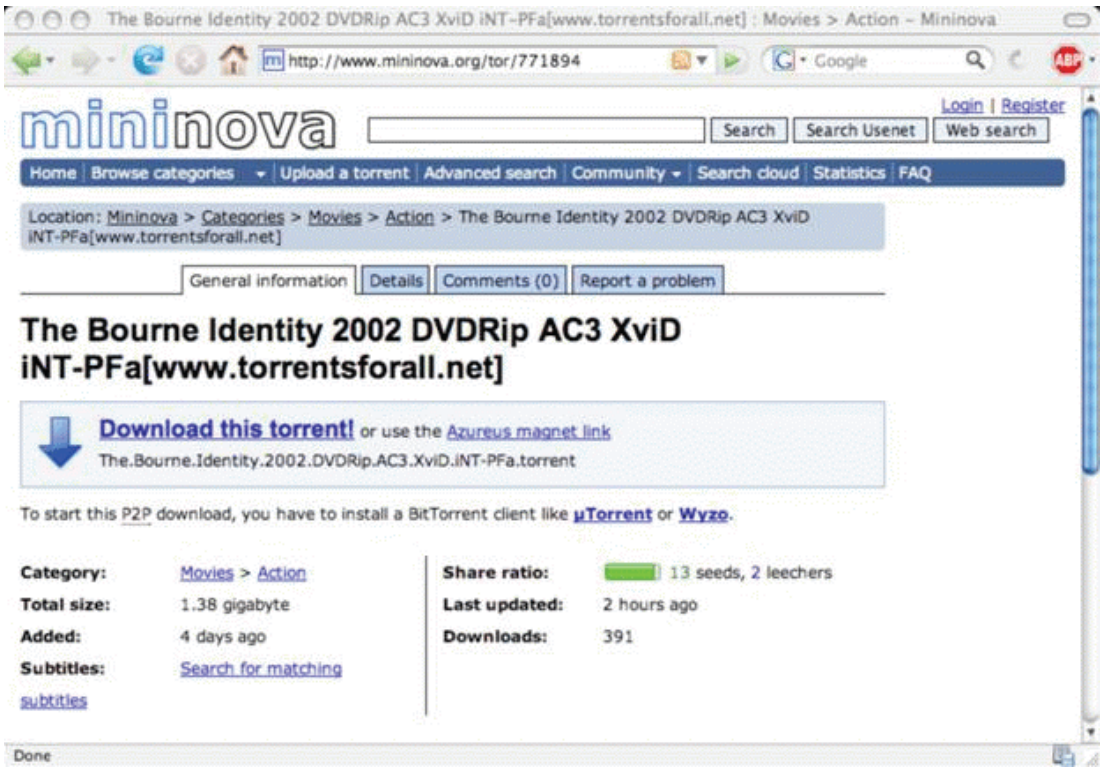

Figure 1. Mininova.org Screen

Table 2. Piracy Data Summary Statistics

Variable	Obs.	Mean	St. Dev.	Min	Max
Broadcast Network	22,798	0.44	0.49	0	1
Leechers	22,798	11.61	29.50	0	1,070
Seeds	22,798	4.33	13.98	0	485
Daily Downloads	21,826	4.27	13.81	0	467

Results

The Impact of Movie Broadcasts on DVD Sales

To estimate the effect of movie broadcasts on DVD sales, we create a set of weekly time dummy variables that control for the sales levels before and after the broadcast. For notational simplicity, the dummy variable *D(x)* will be equal to one for *x* weeks before or after the broadcast. Thus, D(–1) equals 1 for the time period from one week before broadcast until the time the broadcast started on the East Coast of the United States. Likewise, D(1) equals 1 for the first week after the start of the broadcast in Eastern time zone.

We then estimate a model with DVD-level fixed effects to examine how sales change after a movie is broadcast on over-the-air or cable television. A fixed effect model ensures that changes in sales are captured within DVDs. The fixed effect model we estimate is

$$Ln(Rank_{it}) = \xi\, Price_{it} + \delta\, D_t + \varepsilon_{it} \qquad (2)$$

Table 3. Impact of Movie Broadcasts on Sales Rank (Fixed Effects)

Independent Variables	Broadcast	Ad-Cable
D(–1)	0.000 (0.3)	0.000 (0.3)
D(1)	–0.008** (14.1)	–0.012** (20.2)
D(2)	–0.005** (7.8)	–0.002** (2.0)
D(3)	–0.002** (3.4)	0.000 (0.3)
D(4)	–0.000 (0.8)	0.003** (3.5)
Amazon Price	0.129** (11.3)	0.090** (20.4)
Constant	8.649** (0.282)	7.825** (38.5)
Number of Observations	3,063	14,551
Number of of Groups	93	678

The dependent variable is ln(sales rank). T-statistics are listed in parenthesis; ** and * denote significance at 0.01 and 0.05, respectively. All models use DVD-level fixed effects and AR(1) serial correlation correction. Results are normalized per 100,000 viewers.

where i indexes a movie and t indexes time. ξ and δ are the vectors of coefficients to be estimated, where δ captures the effect of the movie broadcast on DVD sales, our variable of interest. Due to time series effects, we control for AR(1) disturbances in the error term.

As noted above, we start observing the sales rank for a DVD two weeks before its television broadcast. Using this data, the left out variable in this regression is the average sales level two weeks before broadcast. Since the number of viewers differs significantly across movies and across channels, we interact our time dummy variable D_t with the number of viewers reported by Nielsen media research (in units of 100,000 viewers). This allows us to control for differences in viewership and for movie popularity effects. Thus, the impact of D_t should be interpreted as the change in rank in week t per 100,000 viewers. Our results for this regression are shown in Table 3.

The crucial variables in our model are the dummy variables on time. As noted above, the left out category is the time period two weeks prior to broadcast. First note that D(–1) is insignificant. Thus, in the week prior to the movie broadcast there is little change in the rank (sales) of DVDs relative to their sales two weeks before broadcast. This suggests that our results are not driven by consumers delaying their purchases until after the movie is broadcast or by responses to pre-broadcast promotion of the movie.[11]

Next note that after broadcast D(1) is negative and highly significant. In the week after the movie is shown on television, the DVD sales rank decreases (DVD sales increase) significantly for both movies shown on broadcast networks and movies shown on cable networks. Similarly, D(2) and D(3) are also negative and significant (except for D(3) in the case of ad-cable, which is insignificant), although the magnitudes are decreasing with respect to D(1). Thus the sales in weeks two and three are also higher than pre-broadcast levels, although they are not as high as in week one. Finally, the estimate on D(4) is small, positive, and insignificant (except in the case of ad-cable, where it is positive and significant). Thus by week four, DVD sales reach approximately the same level as they were two weeks prior to the broadcast. To focus on the event of interest, we do not include dummies beyond week four, although the estimates on D(5) are economically and statistically insignificant. Also note that, over time, DVD sales show a declining trend. If we were to control for it (by including age of the DVD or by including a control group of movies that were not broadcast) our estimates on the weekly dummies would be even stronger. In summary, broadcasting movies on television—essentially giving away the content for free—provides a strong short-term stimulus to DVD sales.

Based on these estimates, we can quantify the percentage increase in sales due to a movie broadcast. To do this, we interpret the values of the dummy variables in terms of overall changes in sales. Recall that $\text{Ln(Sales)} = \beta \times \text{Ln(Rank)}$ where $\beta = -1.70$. From this, it is straightforward to show that the percentage increase in sales resulting from a coefficient δ_i is

$$\Delta sales = e^{\beta\delta} - 1 \quad (3)$$

Recall that our estimates in Table 3 are normalized to be per 100,000 viewers. Since we know the viewership numbers for each movie, we can calculate the percentage increase in weekly sales due to movie broadcasts (Table 4).

[11]Note that advertising for movie broadcasts typically occurs in the week prior to broadcast.

Table 4. Percentage Increase in Weekly Sales Due to Movie Broadcast		
Weeks Since Broadcast	**Broadcast**	**Ad-Cable**
D(–1)	–1.4%	0.03%
D(1)	118.9%**	27.2%**
D(2)	55.8%**	3.2%**
D(3)	21.5%**	0.5%
D(4)	4.9%	–5.7%**
Average Number of Viewers	5.6 million	1.2 million

**denotes statistical significance at 0.01

From Table 4, we can see that movies shown on over-the-air broadcast networks experience a 119 percent increase in DVD sales in week one, a 56 percent increase in week two and a 22 percent increase in week three. As noted above, by week four, DVD sales return to levels that are statistically the same as the levels before the movie was broadcast.

We also note that the weekly percentage sales increase for movies shown on ad-cable networks is significantly lower than the percentage increase for broadcast networks. This is because fewer viewers watch movies on ad-cable (viewership on ad-cable is approximately one-fifth of over-the-air viewership for movies in our sample). Thus, while Table 3 shows that the *per viewer* increase in sales is comparable for ad-cable and broadcast networks, Table 4 shows that the aggregate increase in DVD sales is far higher for broadcast networks.

To test whether the sales gains differed systematically across different movies' characteristics, we interacted the weekly dummies with movie characteristics in a random effects specification. We did not find strong evidence of an interaction effect. However, interaction with box office revenues and the "star rating" given to movies by IMDB voters were statistically (but not economically) significant and in the expected direction.[12] We also tested whether sales changes are different between high definition and standard broadcasts, and did not find any difference between the two.

In summary, our results show that both ad-cable and over-the-air movies experience a large, statistically significant increase in sales immediately following their broadcast, and that this increase in sales typically persists for three to four weeks before returning to its baseline level. Thus, our findings show that the sales promotion benefits of digital television broadcasts far outweigh any short-term cannibalization effect. We next turn our attention to measuring the impact of broadcasts on the supply of and demand for pirated content.

The Impact of Pirated Content on After-Broadcast DVD Sales

In the second part of our analysis, we examine how the presence of free pirated content at the time of broadcast impacts DVD sales. To do this, we first analyze how television broadcasts impact the demand for pirated content on two prominent BitTorrent file-sharing networks at the time of broadcast. The models we estimate are of the form

$$\{downloads_{it}, leechers_{it}, seeds_{it}\} = \lambda D_t + \beta\, tracker\_age + \varepsilon_{it} \quad (4)$$

where our dependent variables include, separately, the daily download rate, the number of leechers, and the number of seeders for each movie tracker i on day t. Our independent variables include weekly time dummy variables for weeks after broadcast as in the sales models, and the age of the tracker measured in days since it was first posted on the BitTorrent network. This controls for changes in the popularity of individual tracker files over time. We include weekly dummy variables through week five as the movie downloads show a statistically significant increase through the fifth week after broadcast. In many cases, due to data collection limitations, the tracker data was not available for a full two weeks prior to the broadcast. Therefore, the omitted variable in this regression is the number of seeds, leechers, and downloads before broadcast. We also did not have viewership data for all trackers and to avoid dropping some

[12]To keep the paper within page limits, we do not show these results. In Table A1 of the Appendix, we show how change in sales differs across movies with different initial ranks, finding that percentage sales gains after broadcast are statistically the same across high and low ranked DVDs.

Table 5. Impact of Movie Broadcasts on Piracy (Fixed Effects) for Broadcast Channels

Independent Variables	Daily Downloads	Leechers	Seeds
D(1)	5.32** (1.3)	4.03* (2.174)	2.38** (1.01)
D(2)	6.24** (1.45)	5.79** (2.45)	2.95** (1.15)
D(3)	8.72** (1.57)	2.86 (2.67)	1.68 (1.26)
D(4)	7.35** (1.67)	3.31 (2.8)	217 (1.33)
D(5)	7.01** (1.8)	2.30 (3.1)	1.81 (1.44)
Tracker Age	–5.13* (2.72)	–2.29 (5.3)	–1.08 (2.56)
Constant	25.51** (4.53)	22.78** (7.4)	2.69** (1.25)
Number of Observations	3654	3866	3866
Number of of Groups	161	165	165

The dependent variable is daily downloads (column 1), number of leechers (column 2), and number of seeds (column 3). Standard errors are listed in parenthesis; ** and * denote significance at 0.01 and 0.05, respectively. All models use tracker-level fixed effects.

data we do not interact viewership numbers with time dummies as done in the previous section. We first estimate the impact of over-the-air broadcasts on piracy (Table 5).

Our results show a significant increase in piracy immediately after movies are broadcast on over-the-air channels. From our estimates, we quantify the magnitude of these changes in Table 6, where the baseline levels for daily downloads, leechers, and seeders were 8.8, 15.7, and 5.4 per week per tracker respectively.

The magnitude of these changes is nontrivial. For example, our results suggest that daily downloads increase by 60 to 100 percent in the four weeks after broadcast. Similarly, seeds and leechers increase by between 25 and 55 percent in the first two weeks after broadcast, with smaller (and statistically insignificant) increases in weeks three and four.

We ran the same piracy regressions as above on the movies shown on cable channels in our sample. Our results are shown in Table 7. The cable results reveal a slight increase in downloads, which is statistically significant only in week three. The regressions show no statistical change in the levels of leechers or seeders after broadcast. As in the previous section, a significant reason for the low estimates on piracy levels in these regressions is that viewership levels for ad-cable movies are significantly smaller than those for over-the-air broadcasts.

In summary, we find that over-the-air movie broadcasts tend to stimulate both DVD sales and piracy, and these increases are substantially higher for over-the-air broadcasts than they are for cable broadcasts.

It is important to note that these increases are driven by demand-side effects as opposed to supply-side effects. To test supply-side effects, we used our BitTorrent tracker data to analyze the names and sizes of all trackers added in the month after the movie's broadcast date and found no evidence that television broadcasts (whether digital or analog) serve as the source material for pirated content in our sample. That is, the increase in downloads, seeds, and leechers is driven by increased interest in the existing trackers for these movies (based on similar affects to those driving increased DVD sales), as opposed to an increased supply of copies of the movies taken from the (unencrypted) over-the-air or cable broadcasts.

Given these empirical findings, we are now able to analyze whether the availability of pirated content on prominent BitTorrent networks at the time of broadcast is associated with smaller increases in DVD sales after broadcast than for movies where no BitTorrent tracker is available at the time of broadcast. One might wonder if the availability of pirated content at the time a movie is broadcast on television reduces the number of DVD purchases that otherwise would have occurred. In short, does movie piracy adversely impact DVD sales for movies at the point in time where they are shown on television? To analyze this question, we use the television broadcast of movies as an exogenous demand shock and compare the DVD sales gain for movies that have BitTorrent trackers at the time of broadcast to the DVD sales gain among movies that do not have BitTorrent trackers at the time of broadcast. If the presence of pirated content harms sales, we should see a smaller increase in post-broadcast sales for movies with pirated copies available than for those with no pirated copies available.

Table 6. Percentage Gain in Piracy

Weeks Since Broadcast	% Increase in Daily Downloads	% Increase in Leechers	% Increase in Seeds
D(1)	60%**	25%	45%**
D(2)	71%**	37%*	55%**
D(3)	99%**	17%	31%
D(4)	83%**	21%	40%
D(5)	80%**	15%	33%

** and* denote statistical significance at 0.01 and 0.05 respectively.

Table 7. Impact of Movie Broadcasts on Piracy (Fixed Effects) for Cable Channels

Independent Variables	Daily Downloads	Leechers	Seeds
D(1)	0.31 (0.42)	0.34 (0.33)	0.25* (0.13)
D(2)	1.15** (0.57)	–0.45 (0.45)	0.02 (0.17)
D(3)	2.1** (0.63)	–0.55 (0.51)	–0.04 (0.19)
D(4)	0.69 (0.68)	–0.07 (0.54)	–0.07 (0.20)
D(5)	0.11 (0.73)	0.17 (0.58)	0.006 (0.21)
Tracker Age	0.22 (1.23)	–1.24** (0.55)	–0.91** (0.23)
Constant	3.91 (3.29)	16.71** (1.26)	7.82** (0.61)
Number of Observations	5628	6070	6070
Number of Groups	388	390	390

The dependent variable is daily downloads (column 1), number of leechers (column 2), and number of seeds (column 3). Standard errors are listed in parenthesis; ** and * denote significance at 0.01 and 0.05, respectively. All models use tracker-level fixed effects.

We have data for 160 movies that were available on BitTorrent at the time of broadcast and 107 movies that were not available on BitTorrent at the time of broadcast. One potential concern with the data is that more popular movies might be more likely to be available on BitTorrent than less popular movies.[13] However, note that we are interested in changes in sales rather than the absolute sales level (the fixed effect model measures changes in rank within movies). Thus, the actual starting rank is less of a concern. Rather, if popular movies show a larger increase in sales after broadcast than do less popular movies, we would have cause for concern due to a selection problem.

However, we see no evidence in the data that there is a difference between more popular and less popular movies in terms of the change in rank after broadcast (see Table A1 in the Appendix for these estimates). Moreover, in our regressions we control for movie popularity by including the number of viewers as a control variable. The fact that we see no differences between popular and less popular movies in terms of percentage change in rank after broadcast, combined with our use of movie-level fixed effects and controls for the number of viewers (popularity), should control for selection effects when analyzing the change in sales for movies available on BitTorrent versus the change in sales for movies that are not available on BitTorrent. However, below we also use a propensity score method (Rosenbaum and Dubin 1983) as an additional check on the possibility of selection bias, again finding no evidence of selection bias in our results.

To avoid the additional notation of four weekly dummies and four additional interaction terms, we simply use an after broadcast dummy variable instead of four weekly dummies.

[13]This is supported by the data: The average Amazon sales rank of movies available on BitTorrent is about 10,000, while the average rank of movies that are not available on BitTorrent is about 16,000.

Table 8. The Impact of BitTorrent Availability on After Broadcast DVD Sales

Log (Rank)	Estimate
Price	0.073** (7.5)
After_Broadcast	–0.005** (3.9)
After_Broadcast × BT	0.0005 (0.4)
Constant	8.14 (150.0)
Number of Observations	5247
Number of Groups	266

The dependent variable is Log(Rank). T-statistics are listed in parentheses; ** and * denote significance at 0.01 and 0.05, respectively. All models use tracker-level fixed effects. Results are normalized per 100,000 viewers.

Thus, the dummy variable estimates the average change in DVD sales per 100,000 viewers over the four-week period after the movie broadcast. To capture the effect of BitTorrent, we also interact the BitTorrent dummy variable with the "after broadcast" dummy variable. Note that we cannot include a separate BitTorrent dummy variable in our estimation because, in the fixed effect estimation, this dummy variable cannot be identified. We show the results for both over-the-air and ad-cable movies in Table 8.

We first note that the estimate on the after broadcast dummy is negative and significant, which is consistent with our finding above that sales rank decreases (sales increase) in the month after a movie is broadcast on television. However, we also note that the estimate on the interaction dummy variable is positive but statistically and economically insignificant. This suggests that the increase in sales after broadcast is statistically the same for movies that are available on BitTorrent at the time of broadcast (BT = 1) and those that are not (BT = 0).

One potential concern about this result is that over-the-air movies seem to show a much stronger increase in piracy than ad-cable movies do, and thus over-the-air movies may experience more harm from piracy. To address this issue, in Table 9 we run this regression again, but this time with only movies that were shown on over-the-air broadcast networks.

The results of this regression are similar to those in Table 8, with slightly lower significance on the after broadcast dummy variable. Likewise, the interaction term is still statistically and economically insignificant, although the sign is now negative.

Finally, despite the controls for movie popularity outlined above, it is still possible that a selection problem is driving our results. To address this possibility, we reestimate our piracy regressions using a propensity score matching method. Propensity score matching has been used extensively in economics and statistics to overcome the problem of selection bias (Dehejia and Waba 2002). The basic principle of the propensity score is to use some observable variables (e.g., box office revenues, imdb.com user ratings) to predict the probability of a movie being on the BitTorrent network. This allows the direct comparison of movies that have similar characteristics (propensity scores), where one movie is available on BitTorrent while the other is not. Matching movies in this way should substantially reduce any remaining selection bias issues.

Propensity scores are calculated using the standard Probit function with observed explanatory variables (see Table A2 in the Appendix for the Probit results). We plot the propensity scores for movies on BitTorrent (BT = 1) and not on BitTorrent (BT = 0) in Figure 2.

Propensity score analysis techniques rely on being able to find movies with similar propensity scores in both groups (BT = 0 and BT = 1). Based on this, it is important to note that the plots in Figure 2 have a similar shape and most importantly that for any given propensity score it is possible to find movies with similar propensity scores in both the BT = 1 and BT = 0 groups.

Once the propensity score is calculated, the analysis reduces to comparing the sales changes of movies in the treatment (BT = 1) and control groups (BT = 0) with appropriately matched propensity scores. For this test, the estimate on the difference in sales changes for movies on BitTorrent (as compared to movies not on BitTorrent) is –0.038 with a standard error of 0.061, making this coefficient statistically insignificant.

Table 9. The Impact of BitTorrent Availability on After Broadcast DVD Sales (Over-the-Air Only)

Log (Rank)	Estimate
Price	0.075** (3.6)
After_Broadcast	–0.003** (1.7)
After_Broadcast × BT	–0.0002 (0.0)
Constant	7.39 (71.9)
Number of Observations	823
Number of Groups	28

The dependent variable is Log(Rank). T-statistics are listed in parentheses; ** and * denote significance at 0.01 and 0.05, respectively. All models use tracker-level fixed effects. Results are normalized per 100,000 viewers.

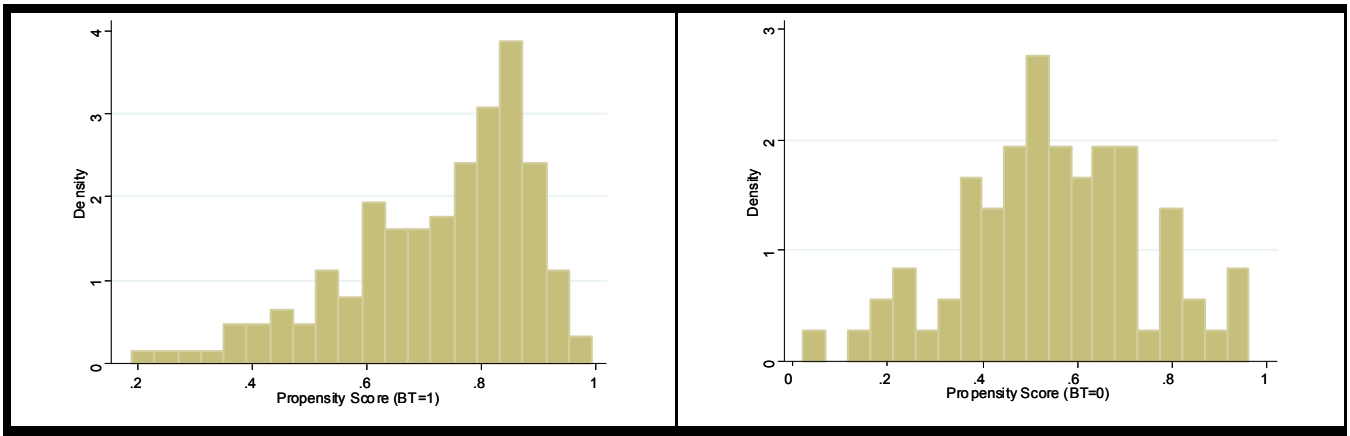

Figure 2. Propensity Scores for Movies That Are Available (1) and Not Available (0) on BitTorrent

Thus, using both the regression analysis and propensity score matching methods, we find no evidence that a movie's availability on BitTorrent at the time of broadcast reduces the post-broadcast increase in DVD sales. Put another way, while television broadcasts of movies increase both DVD sales and movie piracy, it seems that these two user segments (legitimate buyers and pirates) are separate. The television broadcast acts as a stimulus that affects both segments. Legitimate buyers order more DVDs from Amazon after broadcast and pirates download more copies of the movies from BitTorrent networks as well. But there is (statistically) no crossover between the two groups in terms of pirates purchasing DVDs that are unavailable on BitTorrent or potential DVD buyers choosing instead to consume a pirated copy of a movie that is available on BitTorrent. We discuss these findings in more detail below.

Discussion

In this study, we analyze the ability of movie studios to compete with free copies of their content made available through both television broadcasts and pirate networks. The creative industries have long argued that they can't compete with free, and these concerns may be particularly salient for movie studios, whose content may be more prone to single-use consumption than other industries such as music.

We address this question by collecting data from all movies shown on over-the-air and advertising supported cable broadcasts from October 28, 2005, through March 3, 2006. Our data include DVD sales information from Amazon.com and data tracking the supply of and demand for pirated content through two prominent BitTorrent networks.

We find that after a movie is shown on broadcast television, there is a strong and immediate increase in sales of the corresponding DVD through Amazon.com. Similarly, we find that after broadcast there is a strong increase in the demand for pirated content of these movies through two prominent BitTorrent tracker sites. However, there is no corresponding after-broadcast increase in the supply of pirated content. That is, movie broadcasts in our sample promote the consumption of pirated material but do not serve as the source material for pirated content.

We then use these empirical observations to analyze the impact of piracy on DVD demand by using the broadcast as an exogenous shock to movie sales. In this analysis, we find that movies that have pirated content available on BitTorrent at the time of broadcast have statistically the same post-broadcast increase in sales as those that do not have pirated content available at the time of broadcast.

Our results have several managerial and policy implications. First, for movie studios and broadcasters, our finding that movie broadcasts act as a strong complement to downstream content sales should be encouraging for broadcasters who have long feared that the dominant impact of consumer analog and digital recording devices would be reduced demand for subsequent media purchases. From the introduction of the VCR to the more recent introduction of digital broadcast television, movie studios have expressed concern that if a consumer can record and retain a copy of a movie, TV broadcasts of movies will serve as a substitute for subsequent purchases of the movie content. However, in a digital world, this argument may ignore the increased opportunities for studios to differentiate their digital media products from content shown over TV. For example, the increased capacity and random-access capabilities of the DVD format (and nascent Blu-ray format) allow studios to include extra content such as commentary tracks, deleted scenes, "behind-the-scenes" documentaries, and music videos. It is also possible that the inconvenience consumers face in copying and storing the broadcast content is sufficiently large to make the commercial purchase of media an attractive option.

Similarly, the finding that TV broadcasts primarily serve as complements to subsequent media purchases should also be encouraging for studios increasingly looking to monetize their content through digital download services such as the iTunes video store, Amazon Unbox, and other similar services. Indeed the immediate spike in media purchases after a movie is shown on television suggests there might be an opportunity for in-program promotion of broadcast content.

Second, our finding that the availability of pirated content does not seem to impact the demand for legitimate content suggests that, at least at the point in time where a movie is shown on television, demand from legitimate consumers and pirates is relatively segmented. That is, we do not see evidence that the availability of pirated content causes consumers who would have otherwise purchased a DVD after broadcast to consume pirated content instead. This result suggests that studios may wish to focus their scarce antipiracy resources on recent theatrical and DVD releases where the availability of pirated material may have a stronger negative impact on sales.

Finally, our findings may inform the recent debate on digital television content protection, such as the proposed broadcast flag legislation. Specifically, we find no empirical evidence to support the need for broadcast flag protection in digital television broadcasts, at least for movie content.[14] In our data, the dominant impact of unprotected over-the-air movie broadcasts is to increase DVD sales, the presence of pirated content at the time of broadcasts does not impact DVD sales, and digital television broadcasts do not serve as the source material for pirated content.

However, we also note that there are several important data and econometric limitations associated with this study. First, and most importantly, while our piracy regressions attempt to control for differences between movies that are and are not available on BitTorrent networks at the time of broadcast (e.g., viewership, movie-level fixed effects, propensity score analysis, and the use of proportional as opposed to absolute sales changes), like any observational study, we cannot completely rule out the possibility of selection bias.

Second, our sales results are based entirely on sales at Amazon.com. While Amazon.com has an estimated 90 percent share of the *online* DVD market (Netherby 2005), DVD News (2006) estimates that, overall, Amazon.com is the fourth largest seller of DVDs in the United States behind brick-and-mortar giants WalMart, Target, and Best Buy. Nonetheless, we believe that Amazon is an appropriate sales reference point in our context for two reasons. First, WalMart, Target, and Best Buy (and most other brick-and-mortar retailers) typically carry a very limited selection focused on recently released movies (see Brynjolfsson et al. 2003). Since movies are typically shown on broadcast television 12 to 18 months after their DVD release date, it seems likely that at the time a movie is broadcast on television, consumer demand will be focused on Internet retailers such as Amazon as opposed to brick-and-mortar retailers.

[14]Episodic or sports programming may have different behaviors and would be a fruitful area for future research.

Second, we believe that, at present, online retailers such as Amazon.com are the most appropriate reference point for measuring the trade-offs consumers make between satisfying the demand for movies through legitimate outlets and online pirate networks.

Third, our piracy results come from two public BitTorrent trackers and are not a comprehensive measure of the availability of pirated material. Rather, we are using these data as proxies for overall content availability and piracy levels. However, we believe these measures serve as valid proxies based on the popularity of the BitTorrent protocol for movie piracy and given the relative popularity of these two sites for posting trackers related to movie piracy.

Finally, it is possible that the post-broadcast sales increase observed in our data is driven by promotion unrelated to the television broadcast. However, we also note that we believe this is unlikely given that our results show a strong increase in movie sales the week after broadcast and no statistical change in the week before broadcast.

In addition to these limitations, we also note that our results should be viewed in their proper context. First, our results do not speak to the impact of piracy in the earlier part of a movie's lifecycle, where the availability of pirated content may have a negative impact on sales (see Rob and Waldfogel 2006 for example). Second, our findings may change in the future if the environment surrounding piracy changes. It is possible that the increasing penetration of digital video recorders, computer-based digital television recording and editing products, and an increasing integration between computing equipment and television viewing devices will change consumers' preferences for recorded television broadcasts relative to purchased content. Similarly, it is possible that increases in broadband Internet speeds and penetration will change consumers' preferences for purchased content relative to pirated content (see Smith and Telang 2007). Third, our results should not be viewed as a policy impact study as we do not observe what would happen to DVD sales in the presence of content protection on digital television broadcasts such as the proposed broadcast flag regulations. Indeed, each of these topics would represent a useful area for future research.

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Appendix

Table A1. Estimates with Different Starting Ranks

Independent Variables	Starting Rank 1,000–8,000	Starting Rank 10,000–20,000
D(–1)	–0.000 (–.013)	0.002 (1.6)
D(1)	–0.010** (–21.7)	–0.008** (–7.7)
D(2)	–0.004** (–7.4)	–0.005** (3.8)
D(3)	–0.001** (–2.6)	–0.001** (–0.7)
D(4)	–0.001 (–1.0)	–0.003 (2.2)
Amazon Price	0.115** (18.2)	0.083** (9.3)
Constant	6.872 ** (87.1)	8.401** (71.6)
Number of Observations	7,191	4,020
Number of Groups	332	170

Dependent variable is ln(sales rank). T-statistics are listed in parenthesis; ** and * denote significance at 0.01 and 0.05, respectively. All models use DVD-level fixed effects.

Table A2. Propensity Score Estimation (Probit)

Independent Variables	Estimate (Standard Error)
Average Price Before Broadcast	0.076** (–0.03)
Gross Revenues(log)	0.240** (0.09)
IMDB ratings	0.284** (0.1)
Movie Duration	–0.002 (0.01)
Number of discs	–0.543** (0.23)
Minutes edited	–0.007 (0.008)
DVD age	0.006 (0.03)
Constant	–5.43** (1.4)
Number of Observations (N)	231

The dependent variable is availability of BitTorrent at the time of broadcast (0/1). Notice that all the estimates are sensible: DVDs with higher price, higher box-office revenues, higher IMDB ratings, and fewer discs are more likely to be available on BitTorrent.