The Causal Effect of Video Streaming on DVD Sales:
Evidence from a Natural Experiment

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Abstract

Video streaming services recently become a revenue driver of the home entertainment industry. By contrast, revenue from physical media continuously declines. Content owners, such as movie studios, face the important question of whether streaming media cannibalize the sales of physical media and to what extent. We answer these questions by exploiting a natural experiment that occurred on October 1, 2015 when Epix switched its streaming partner from Netflix to Hulu. This event created an exogenous shock that reduced the streaming availability of Epix's content because of the significant difference in the market shares of the two video streaming sites. This occurrence allowed us to investigate the causal effect of streaming services on physical DVD sales. Our difference-in-difference analyses show that the decline in the streaming availability of Epix's content causes a 24.7% increase in their DVD sales in the three months after the event. Our results validate the industry's concern that video streaming services displace physical DVD sales. In addition, we find that cannibalization between the two media is stronger for DVDs released more recently and for movies with better box office performances. This study contributes to the understanding of the competition between streaming media and physical media and provides important managerial implications for content owners in selecting appropriate movies for streaming.

Keywords: video streaming, streaming media, physical media, DVD sales, cannibalization, natural experiment, difference-in-differences, motion picture industry

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1. Introduction

Digital Entertainment Group (DEG) reported that subscription-based video streaming has become the second largest revenue source for the home entertainment industry by delivering more than $5 billion to studios in 2015 (DEG 2016). Subscription-based video streaming platforms, such as Netflix and Hulu, allow subscribers to watch videos on demand on computers and mobile devices by paying a monthly subscription fee. Various contents are available on these platforms, including TV shows, recent blockbusters, classic films, small-budget independent films, and original programs produced by the platforms themselves. Video streaming services enjoyed a sustainable growth rate of 25% to 33% from 2013 to 2015 (DEG 2016; Variety 2016). Unlike the burgeoning streaming media, the largest revenue source, the sales of physical discs, contributed $6.1 billion in 2015 but declined by over 10% every year from 2013 to 2015.

The opposing trends in the revenues from streaming media and physical media led to the argument that the decrease in the sales of physical discs is partly attributed to the emergence of streaming media (e.g., Gruenwedel 2016; Tietjen 2015). Rather than purchasing a DVD or Blu-ray disc for a movie or TV show either online or in a physical store, consumers can subscribe to a streaming service to watch these shows immediately online. Gaining access to an extensive library of contents through streaming services is more convenient than purchasing DVDs one at a time. Streaming is also available on mobile devices, making it possible to watch videos anywhere and on the go.

However, the few disadvantages or limitations of streaming media may cause some consumers to prefer physical media. First, streaming services require an internet connection and impose a significant bandwidth burden to deliver high video quality (Hayes 2013). Second and perhaps more importantly, various good movies and TV shows are not available for streaming or the waiting period may be extensive. For example, in 2014, movies generally became available for subscription streaming around two years after their theatrical releases (Smith and Telang 2016; Stenovec 2014). Although technology is moving in the direction of streaming media, the market for physical discs is likely to remain relevant for

certain customer segments. For example, collectors and loyal fans prefer physical media because they want to build a collection and value the extras and bonus features packaged in discs. Physical discs are also suitable for children and family titles, which can be replayed easily for family time or during travel (Hayes 2013; Lincoln 2016).

In light of this issue, balancing between streaming and physical media has become a critical challenge for movie and television studios. Content owners must decide whether each video title should be made available for streaming or not in addition to selling it on physical copies. On one hand, content owners receive additional revenue by charging streaming service providers a licensing fee through either exclusive or nonexclusive agreements if a video title is made available for streaming. An article in *The Hollywood Reporter* reveals that Epix received $200 million per year from Netflix for the streaming rights of its titles starting in 2010 (Bond 2011). The popularity of streaming services also increased the licensing fees over the years. Hulu and Netflix were estimated to spend $1.5 billion and $3.3 billion in 2015, respectively, on content licensing and acquisition (Hagey and Ramachandran 2015). On the other hand, content owners can potentially suffer a loss in physical sales because some consumers may no longer purchase physical discs, especially streaming service subscribers. However, if physical and streaming media cater to different or non-overlapping customer segments, then the concern for cannibalization between these two media can be significantly lessened. The next decision for content owners is when a title should be made available for streaming. Although postponing the release of titles in a streaming distribution channel enables content owners to extract the most benefits from physical sales, it would certainly become less desirable to streaming service providers if streaming availability is delayed excessively.

Despite the importance of these issues for practitioners, no prior study has attempted to empirically investigate the competition between physical and streaming media and quantify the effect of streaming services on physical sales. The decrease in physical sales appears to be associated with the increasing popularity of streaming media in the past few years. However, is this decrease actually caused by the

cannibalization of streaming or perhaps is it caused by other factors, such as the growth of Internet and the resulting change in consumer behavior? If streaming services indeed cannibalize physical sales, how large is this cannibalization effect and how does this effect depend on the characteristics of video titles? Answering these questions can help content owners make informed decisions in evaluating whether or not a title should be made available for streaming and when it should be.

Several challenges pose difficulties in answering these questions. First, data availability is an issue for academic researchers because the sales of physical media are not publicly available, especially in offline channels. Thus, previous studies on movies mainly utilize Amazon sales rank as a proxy for physical media sales on Amazon or as a proxy for physical media sales in the online channel considering Amazon's dominant position in online retailing (e.g., Smith and Telang 2009; Danaher et al. 2010, among many others). To quantify the effect of streaming media on physical media, it is critical to obtain actual sales data of physical media in both online and offline channels. Second, perhaps a more difficult challenge is how various endogeneity concerns can be addressed so that causality can be inferred. In this study, our identification strategy is to utilize a natural experiment that creates an exogenous shock to the streaming availability of certain video titles, which allow us to tease out the effects of confounding factors that also influence physical sales.

The natural experiment we study occurred on October 1, 2015 involving Epix's content licensing agreements with two leading streaming platforms, namely, Netflix and Hulu. Epix is an entertainment network that features movies and TV shows distributed by three famous studios: Paramount, Lionsgate, and Metro-Goldwyn-Mayer (MGM). Its collections cover both Hollywood blockbusters and small-budget or niche titles. Netflix and Epix initially struck a licensing agreement in 2010. Their agreement would expire at the end of September 2015, and Netflix announced on August 30, 2015, which was a month earlier, that it decided not to renew it (Netflix 2015a). Several hours later, Hulu announced that it entered into a multi-year contract with Epix (Hulu 2015b). Thus, all movies featured by Epix became unavailable for streaming on Netflix on October 1, 2015 but started to appear on Hulu on the same day. Around the

time of this event (Q3 2015), Netflix's market share in the U.S. video streaming market was approximately four times that of Hulu. Netflix had 43.2 million streaming subscribers as of September 30, 2015 (Netflix 2015b), whereas the number of subscribers is estimated to be around 10.3 million[1] for Hulu according to the company's press releases on April 29, 2015 and May 4, 2016 (Hulu 2015a; Hulu 2016). The affected videos shifted from a larger streaming platform to a smaller one. Thus, the net effect of this event is an exogenous shock, which sharply reduced the streaming media availability of Epix's content.

We empirically assess the effect of this reduced streaming availability on physical DVD sales across both online and offline channels by adopting the difference-in-difference (DID) approach. We first select the movie titles featured by Epix as the treatment group; these titles were available only on Netflix between these two sites before the event but became available only on Hulu after the event. We then select all the other movie titles that were available on Netflix but not available on Hulu before the event and whose streaming availability remained unchanged after the event as the control group. In this way the streaming availability statuses for both groups are the same before the event (i.e., both are available only on Netflix) but differ after the event (i.e., the control group remains available only on Netflix and the treatment group becomes available only on Hulu). If this event did not occur, the difference in the physical DVD sales of these two groups before October 1, 2015 should be statistically the same as the difference in their physical DVD sales after that date. Therefore, any actual difference observed between these two aforementioned differences (so-called difference in differences) is attributed to the exogenous event that reduced the streaming availability of the treatment group.

The results show that reduced streaming availability increases physical DVD sales. Specifically, the shifting of Epix's movie titles from Netflix to Hulu causes a 24.7% increase in their DVD sales in the three months after the event. These findings imply that streaming services do cannibalize physical sales. To shed light on how content owners should strategically choose certain movies for streaming at the right

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[1] On April 29, 2015, Hulu reported that it had nearly 9 million subscribers. On May 4, 2016, the company announced that it would reach 12 million subscribers in the U.S. by the end of that month. Based on this information and assuming the growth in the number of subscribers is linear over the months, we estimate that Hulu had about 10.3 million streaming subscribers as of September 2015.

timing, we investigate whether movie characteristics, such as release time and theatrical performance, moderate the influence of streaming media on physical media. We find that the cannibalization of physical sales is more severe for DVDs released more recently and movies with better theatrical performances than those released earlier and those that performed poorly in theatres.

Our study makes several important contributions. First, to the best of our knowledge, this study is the first one to empirically quantify the effect of streaming media on physical media in the context of the motion picture industry. A few recent studies on streaming in the music industry examine how music streaming through Spotify affects digital sales (Aguiar and Waldfogel 2015) or the consumption and discovery of digital music (Datta et al. 2016). Our study adds to the growing streaming literature but differs from these studies by contributing to the understanding of the competition between streaming media and physical media (instead of digital sales). Second, we employ a natural experimental design that reduces the availability of one media and evaluate how it affects the outcome of the other media. This approach enables the causal effect of streaming media on physical media to be assessed, which is another key difference between this study and existing studies on music streaming in terms of research methodology. Third, this study extends the broad multi-channel distribution management literature both in the context of the motion picture industry (e.g., Smith and Telang 2009; Gong et al. 2015; Hashim et al. 2016, to name a few) and related product categories, including television programs (e.g., Danaher et al. 2010), music (e.g., Biyalogorsky and Naik 2003), books (e.g., Forman et al. 2009; Chen et al. 2016), and apparel (e.g., Avery et al. 2012). Previous studies in this literature focus on the distribution of physical products (e.g., apparel, print books, physical music albums) in online and offline channels, the distribution of digital products (e.g., digital movie in the format of electronic sell-through, digital music) in different online or digital channels, and the distribution of physical products and their digital counterparts (e.g., physical DVDs and digital television programs) in different online channels. We contribute to the literature by investigating the distribution of digital movies in the subscription streaming channel and their physical discs in both online and offline channels.

2. Related Literature

This study belongs to the literature investigating the distribution of products in different formats in various channels. With the development of the Internet, earlier studies in this literature examine how traditional offline channels, such as catalogs and retail stores, interact with the online channel for physical products, such as apparel and print books. As more products become digitized and available online, new digital channels emerge for information goods, such as ebooks, music, movies, and TV programs. For instance, consumers can now purchase ebooks from Kindle Store, download music songs or albums from iTunes Store, and stream movies and TV shows on Netflix. The emergence of these innovative channels led to an increase in recent studies that examine how different online or digital channels interact with each other for digital products and how both online and offline channels interact with each other for a product of different formats.

Table 1 provides a brief summary of previous studies in this literature, and they are categorized into three categories: distribution of physical products, digital products, and physical products and digital counterparts. The list of studies summarized is, by no means, exhaustive. A few studies are selected as examples to describe the products and channels covered in each category. Previous studies on information goods, especially music and movies, also examine how the distribution in illegal channels or pirating is related with the sales in legal channels (e.g., Aguiar and Waldfogel 2015; Danaher et al. 2010; Smith and Telang 2009). The review in Table 1 only covers legal channels.

The first category of studies seeks to understand the relationship between online and offline channels for physical products. The key concern is whether these two types of channels substitute or complement each other. For instance, Biyalogorsky and Naik (2003) use sales data for physical albums from an established music retailer and examine the interaction between online and offline retail channels. The results indicate that cannibalization does not occur between the retailer's own two channels, at least at the initial period after entering online retailing. In the context of introducing a physical channel to the pre-existing online channel, Avery et al. (2012) document that the opening of an offline store decreases sales in the catalog

but not the online channel of a retailer selling apparel, accessories, and home furnishings in the short run, and it increases sales in the retailer's own catalog and online channels over time. Forman et al. (2009) show that when a competitor opens a book store locally, consumers substitute away from online purchasing at Amazon.

The second category of studies focuses on the distribution of digital products in different online or digital channels. Digital downloads (or purchases), digital rentals, and subscription-based streaming are the three main online channels that are examined. A few recent studies investigated whether music streaming decreases or increases the demand of digital music downloads. For instance, Aguiar and Waldfogel (2015) show that Spotify use displaces digital downloads, whereas Datta et al. (2016) also find a similar result on the relationship between music streaming and digital downloads but discover that the adoption of the streaming service Spotify leads to a long-term increase of overall music consumption across all channels. In the motion picture context, Gong et al. (2015) conduct a field experiment and find that price promotions in a digital sales channel increase digital rentals, which indicates a synergistic effect between the two channels that may be likely attributed to information spillovers.

The third category of studies investigates the distribution of physical products and their digital counterparts in different channels. For instance, Deleersnyder et al. (2002) discover that the cannibalization between online channel and traditional print editions for newspapers is overstated. Danaher et al. (2010) show that the removal of digital downloads on iTunes does not affect the sales of physical DVDs on Amazon for the episodes of NBC TV programs. Chen et al. (2016) examine the relationship between digital and physical sales in the book industry and find that the delay of e-book releases does not lead to an increase of print books. Among studies that examine movies, Smith and Telang (2009) document that free movie broadcasts on over-the-air networks result in a significant increase in the sales of physical DVDs on Amazon. Hashim et al. (2016) find that the availability of a digital movie does not significantly affect the sales of physical DVDs on Amazon, but the availability of a digital rental movie is associated with a decrease in physical DVD sales on Amazon.

Table 1 Summary of Previous Studies

Category	Study	Product	Channel & Format			Methodology	Results
			Transaction-based		Subscription-based		
			Online	Offline	Streaming		
Distribution of Physical Products	Avery et al. (2012)	Apparel, accessories, and home furnishing	Online store	Catalogs and stores		Quasi-Experiment	Short-term cannibalization and long term synergy
	Biyalogorsky and Naik (2003)	Music albums	Physical CDs	Stores		Simultaneous dynamic equations	No cannibalization
	Forman et al. (2009)	Books	Amazon print books	Stores		Difference-in-differences (DID)	Cannibalization
Distribution of Digital Products	Aguiar and Waldfogel (2015)	Music	Digital purchase		Spotify	Panel data analysis	Cannibalization
	Datta et al. (2016)	Music	Digital music consumption and discovery		Spotify	Quasi-Experiment (PSM; DID)	Cannibalization between digital downloads and streaming; long-term growth in overall consumption
	Gong et al. (2015)	Movies	Digital purchase and digital rental			Field experiment	Synergy
Distribution of Physical Products and Digital Counterparts	Chen et al. (2016)	Books	Kindle ebooks and Amazon print books	Print books in stores		Natural experiment	No interaction
	Danaher et al. (2010)	NBC television programs	iTunes downloads and Amazon physical DVDs			Natural experiment	No interaction
	Deleersnyder et al. (2002)	Newspaper	Online editions	Physical copies in circulation		Time series analysis	No cannibalization
	Hashim et al. (2016)	Movies	Amazon digital purchase and digital rental, and Amazon physical DVDs			Panel data analysis	No cannibalization between digital purchase and physical purchase; cannibalization between digital rental and physical purchase
	Smith and Telang (2009)	Movies	Amazon physical DVDs	Over-the-air broadcast		Natural experiment	Synergy
	This study	Movies	Physical DVDs in all online stores	Physical DVDs in all offline stores	Netflix & Hulu	Natural experiment	Cannibalization

Our study belongs to the third category because both physical and digital formats of movies are considered. Unlike previous studies, we examine how subscription-based streaming affects physical sales in both online and offline channels. To our knowledge, no prior study has examined how subscription-based streaming interacts with other channels in the motion picture context, although a few recent studies were carried out on streaming media in the music industry (e.g., Aguiar and Waldfogel 2015; Datta et al. 2016). Previous studies on movies also primarily rely on Amazon sales ranks as a proxy of sales. By contrast, the current study utilizes actual sales data of physical DVDs in all channels.

3. Natural Experiment

3.1 Event Description

To quantify the effect of streaming media on physical media, one needs to vary the availability of streaming media and measure how the sales of physical media respond to this variation. The variation in the availability of streaming media must be exogenous to prevent the sales of physical media from influencing it. The natural experiment we utilize for an exogenous variation is a change in the content licensing agreements between a content owner and two streaming service providers. Epix is an entertainment cable network that features movies and TV shows distributed by three famous studios: Paramount, Lionsgate, and Metro-Goldwyn-Mayer. Epix's collections include both Hollywood blockbusters, such as *The Hunger Games: Catching Fire*, *The Wolf of Wall Street*, *Transformers: Age of Extinction*, and other small-budget and lesser-known titles. Epix signed a multi-year exclusive licensing agreement with Netflix in 2010 (Netflix 2010), and the exclusivity ended two years later (Reuters 2012). Netflix extended its non-exclusive rights to stream Epix's contents until the end of September 2015. On August 30, 2015, Netflix announced its decision not to renew the licensing contract with Epix any more (Netflix 2015a). Its Chief Content Officer, Ted Sarandos, explained in the company blog that this decision was part of Netflix's strategic move to shift away from nonexclusive contents and toward its own original programming and exclusive licensed contents. Several hours after Netflix's announcement, Epix and Hulu

entered a multi-year agreement (Hulu 2015b). As a result, all titles owned by Epix were removed from Netflix on October 1, 2015 but started to appear on Hulu for streaming on the same day.

The variation in the availability of streaming media comes from the substantial difference between Netflix and Hulu in the market share of the U.S. subscription streaming market. As the market leader, Netflix had 43.2 million streaming subscribers in the U.S. as of September 30, 2015 according to its quarterly letter to shareholders (Netflix 2015b). A specific subscriber number was not released by Hulu around the time of the event, but Hulu reported in its press releases that it had around 9 million and 12 million subscribers in April 2015 and May 2016, respectively (Hulu 2015a; Hulu 2016). Assuming that the growth in subscribers is linear between the two press releases, we estimate that Hulu had around 10.3 million subscribers at the end of September 2015. Thus, Netflix's market share in the U.S. subscription streaming market was approximately four times that of Hulu at the time of the event.

The sharp decrease in the streaming availability of Epix's contents can also be reflected in the Internet traffic associated with Netflix and Hulu. Broadband Internet service tracking firm Sandvine revealed in its report in December 2015 that Netflix dominated Internet usage in North America by accounting for 34.7% of the peak period traffic in 2015, dwarfing Hulu's 2.48% (Protalinski 2015). The search volumes for the two terms "Netflix" and "Hulu" on Google also indicate the popularity of the streaming sites. Figure 1 shows that the search volume for "Netflix" is consistently around five to six times that of "Hulu" in the U.S. from January 2015 to December 2016. In summary, the shifting of Epix videos from a larger streaming platform to a smaller one creates an exogenous shock that significantly reduces the reach of the streaming media for these titles.

It is noteworthy that the availability of Epix's contents on other streaming sites did not change during the study period. Apart from Netflix and Hulu, another major player in video streaming services is Amazon Video (Strategy Analytics 2016). Amazon Video initially set a licensing agreement with Epix in 2012 and later extended it for a few more years in February 2015 (Epix 2012; Epix 2015). This result implies that the availability of Epix's contents on Amazon Video remains constant during the study period, thus not a

confounding factor. On a related note, the removal of Epix's content from Netflix may push some Netflix

users to unsubscribe and switch to other streaming sites, such as Amazon and Hulu. However, the growth

in the number of subscribers for Amazon and Hulu after the event is substantially smaller than the large

difference in the subscriber base between Netflix and Hulu. Thus, we confirm that the treatment of the

decrease in the streaming availability is substantial and effective.
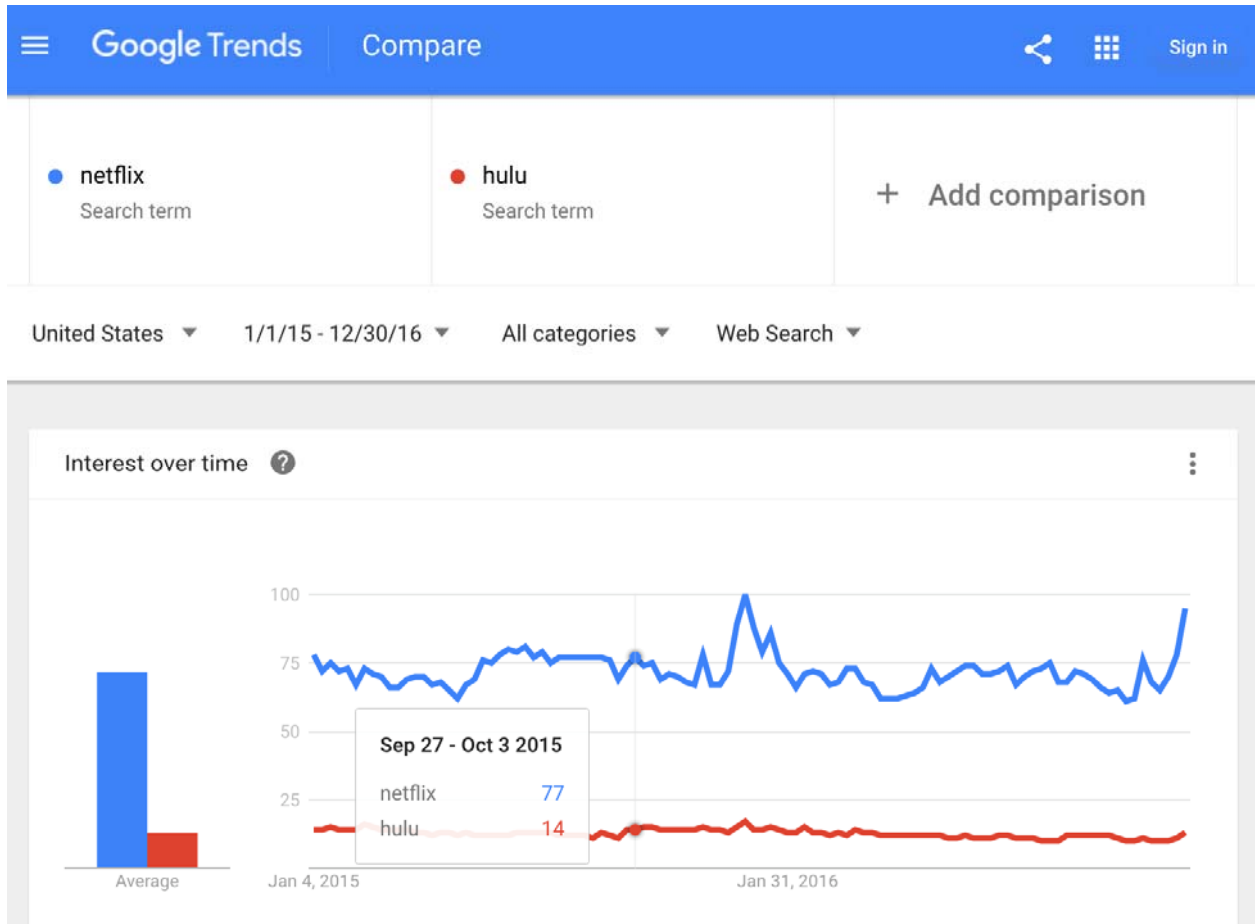
Figure 1 Search Volumes of Netflix and Hulu on Google in 2015–2016

3.2 Quasi-experiment Design

The difference between the DVD sales in the pre- and post-event periods alone may not be an accurate

assessment of the event's causal effect because of other factors that may influence DVD purchases, such

as seasonality. In this study, we employ a quasi-experimental design, which compares the sales

performances of a control group unaffected by the event described above and a treatment group affected

by the event. All the movie titles featured by Epix and with theatrical releases[2] are included in the treatment group. The control group consists of movie titles whose streaming availability is the same as the treatment group prior to the event and remains unchanged afterwards (i.e., available on Netflix but not available on Hulu). Figure 2 illustrates the treatment and control conditions. The control and treatment groups can be inherently different from each other. Thus, the DID approach is adopted to account for the difference between the two groups. The difference in DVD sales between the treatment and control groups after October 1 over and above the initial difference before that date is caused by the treatment, namely, the reduced streaming availability. If streaming media cannibalized DVD sales, then we would observe a post-event increase in the DVD sales of the treatment group relative to that of the control group after adjusting for the inherent difference between the two groups. Otherwise, if significant changes in the difference of DVD sales between pre- and post-event periods were not observed, then no interaction occurred between streaming and physical media.
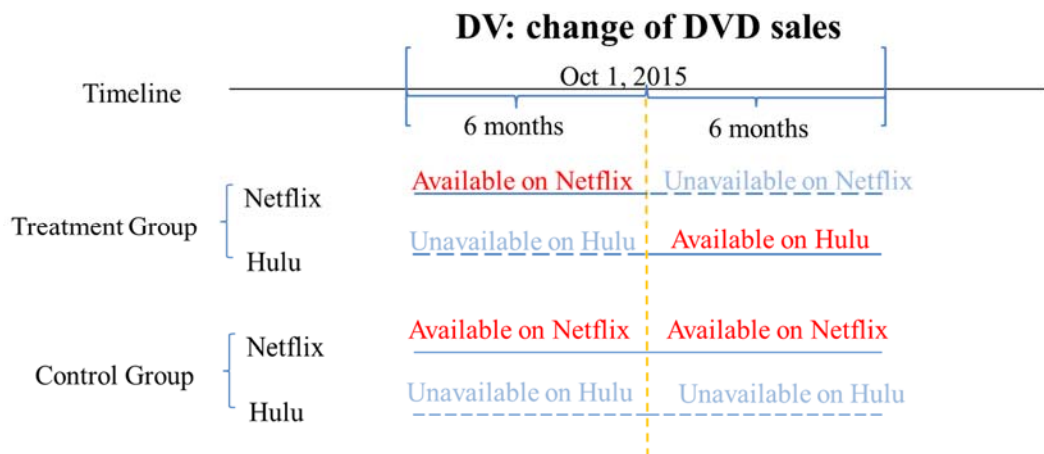
Figure 2 Illustration of the Treatment and Control Groups

One concern about the exogeneity of the event is that the news about the licensing agreements was released one month earlier than the actual date of effectiveness. This condition can potentially influence the behavior of different consumers and the physical sales. First, knowing that Epix titles will not be

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[2] Releasing movies first in theatres and then on DVDs is a standard film distribution strategy. Movies that are predicted to lack general public interest (e.g., independent movies and movies of particular category) can be released straightly on DVDs (Squire 2004).

available for streaming in one month, Netflix users can watch additional Epix titles in September 2015. These users would less likely purchase physical discs after the event because they already watched them. Hence, the result for the effect of reduced streaming availability on physical sales is on the conservative side (i.e., if the news and the actual content removal came out on the same day, our result could be stronger). Second, considering that Epix titles will be available in one month, Hulu users would be less likely to purchase their physical discs in September 2015. To address this concern, precautions are taken to eliminate or reduce the effect of this confounding factor. In the unreported results, we drop the month of September 2015 in our analyses and obtain the same findings (results are available upon request). To keep the data during this month in the analyses and reduce its confounding effect at the same time, the study period is set as one month, two months, until six months before and after the event. The effect of the confounding month reduces when the study period is longer. The longest study period spans from April 1, 2015 to March 31, 2016.

4. Data and Variables

We construct a rich dataset by combining information from multiple sources. For each movie title in the dataset, we collect its streaming availability, DVD sales, DVD prices, movie characteristics, and consumer reviews in the study period. For the outcome variable, we consider sales of DVDs instead of other physical formats such as Blu-ray discs to increase the sample size because most movies are available on DVDs but not necessarily available on other physical formats.

Netflix and Hulu do not provide historical information on the availability of movie titles on their websites. Thus, we collect the streaming availability information of movies from the two tracking websites, namely, usa.netflixable.com for Netflix and somethingtostream.com/hulu/ for Hulu. We first obtain the list of movies that were available on Netflix on September 30, 2015 but were not available on October 1, 2015. The distributor information of these movies was obtained from IMDb.com to screen out Epix titles. Next, we check the availability of the Epix titles on Hulu for streaming on October 1, 2015. To further ensure that these Epix titles are available on Hulu in the post-event period, we verify their availability by

examining the list of all videos on Hulu in March 2016. A few movies with missing values for certain variables are excluded from the sample. The final treatment group consists of 128 movies. For the control group, we select titles available on Netflix from the beginning of April 2015 to the end of March 2016 but unavailable on Hulu throughout this period, thus ensuring that the streaming availability of the control group is the same as that of the treatment group before the event but reversed after the event. We identify 734 movies that belong to the control group.

We purchase weekly DVD sales data from NPD VideoScan.[3] VideoScan provides point-of-sale retail tracking services for the home video market. It compiles data reported from both online and offline retailers, including major players such as Amazon.com, Barnes & Noble, Kmart, Target, and Walmart. $Unit_{it}$ is the unit sales of movie *i* in time period *t*. VideoScan also records the DVD release date of each title and its available price information in different retail channels. To control for the decreasing trend of DVD sales over time after release, we define $MonthSinceRetail_{it}$ as the number of months since the retail release of movie *i*'s DVD in time period *t*. $Price_{it}$ is the average price for movie *i*'s DVD in time period *t*, which is calculated as the total sales dollar amount divided by the total unit sales across different retail channels.

Movie characteristics, including theatrical release date, box office revenue ($Gross_i$), genre (e.g., action, animation, etc.), and MPAA rating (G, PG, PG-13, R, and unrated), movie awards, and cast members, are collected from IMDb and The Numbers. To control for the effect of online word of mouth on product sales, we collect the consumer reviews on all formats (DVD, Blu-ray, and digital video) for each movie title from Amazon. $Volume_{it}$ and $Valence_{it}$ are the total number of reviews on all formats and their average rating for movie *i* in time period *t*, respectively.

The effect of marketing promotions on DVDs is also considered. We purchased the advertising expenditure data for the movie titles' DVDs from Kantar Media, an ad intelligence company that records

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[3] The NPD Group acquired the VideoScan service from Nielsen in January 2016. Press release about this news is available at https://www.npd.com/wps/portal/npd/us/news/press-releases/2016/npd-acquires-nielsen-videoscan-service/.

all advertising expenses in various media channels. However, only 10 movie DVDs in the sample were promoted during the study period. DVDs are usually heavily advertised during the first several weeks after their retail release. Since all the DVDs in the sample were released at least six months before the event, most of these DVDs were not promoted during the study period. Thus, this advertising expenditure variable is not included in the analyses.

5. Analyses and Results

We conduct our analyses under the DID framework to evaluate the effect of streaming media on DVD sales. The DID model is an econometric technique commonly used in natural experiments. It measures the effect of the treatment by comparing the average change over time in the outcome variable for the treatment group with the average change over time for the control group. The DID approach estimates the average treatment effect on the treated group. We have a panel dataset that can be organized at either weekly or monthly level. Thus, we can utilize the DID estimation for panel data (i.e., multiple time periods both before and after the event). However, this approach may suffer from serial correlation issues because the dependent variable, DVD sales, is possibly serially correlated. This condition may lead to a downward biased estimation of the standard errors for model coefficients (Bertrand et al. 2004).

To address this estimation bias, we follow the suggestion provided by Bertrand et al. (2004) to simply aggregate the data into two periods, namely, pre- and post-events. This step removes the time series information but allows the standard two-period DID estimator to be implemented. One downside of this approach is the smaller number of observations, which causes difficulties in yielding a significant result. To examine the short- and long-term effects of the treatment, we set each time period to be one month, two months, and until six months, and then conduct a same set of analyses. We specify the following model:

$$Log(Unit_{it}) = \alpha_0 + \alpha_1 After_t + \alpha_2 Treatment_i \times After_t + \alpha_3 Log(MonthSinceRetail_{it}) +$$
$$\alpha_4 Log(Price_{it}) + \alpha_5 Log(Volume_{it}) + \alpha_6 Valence_{it} + f_i + \varepsilon_{it} \quad (1)$$

The dependent variable $Unit_{it}$ is the unit sales of DVD title i in time period t (i.e., before or after the event). $Treatment_i$ is an indicator variable equal to one if title i belongs to the treatment group and zero if it belongs to the control group. $After_t$ is another indicator variable equal to one if the observation is in the post-event period (i.e., after October 1, 2015) and zero otherwise. The interaction term $Treatment_i \times After_t$ is the main variable of interest, and its coefficient, α_2, captures the average effect of the event on the DVD sales of the treatment group. A positive value of α_2 indicates that the shifting of Epix's contents from Netflix to Hulu leads to approximately $100 \times \alpha_2$ percent increase of DVD purchases in the post-event period. $MonthSinceRetail_{it}$ denotes the number of months since DVD i's retail release until the beginning of time period t. $Price_{it}$ is the average price of DVD i across major retail channels in time period t. $Volume_{it}$ and $Valence_{it}$ are the total number and average rating of Amazon reviews for movie title i in time period t, respectively. DVD sales, average price, number of months since retail release, and Amazon review volumes are skewed. Thus, the log transformation on these variables is taken to provide a good model fit. Movie fixed effects f_i is included, so the time-invariant variable, $Treatment_i$, is absorbed into it. ε_{it} is the error term.

5.1 Descriptive Analysis

Table 2 indicates the descriptive statistics for the main variables in Equation (1) and presents a comparison between the treatment and control groups. The study period used to calculate these statistics is from three months before to three months after the event date. Different study periods result in similar patterns, as reported in Table 2. Except for the retail price and Amazon review ratings, movies in the treatment group are significantly different from those in the control group in terms of all other variables. The movies in the treatment group have more DVD sales on the average, have been released on DVDs for a longer time period, perform better in theatres, and also receive more customer reviews on Amazon compared with those in the control group.

A simple way to obtain an initial assessment of the event is to compare the average DVD sales of both groups before and after the event. This analysis is conducted graphically by drawing Figure 3. In this

figure, the two dots in the "Pre-event" period represent the average DVD sales in the three months before the event for the treatment and control groups, respectively. A significant difference is observed between the average DVD sales of the two groups. The two dots in the "Post-event" period represent the average DVD sales in the three months after the event for the two groups. We line up the two points in each group and obtain two solid lines as shown in the figure. The dotted line denotes the sales trend for the treatment group if the event did not occur. By comparing this dotted line with the actual line for the treatment group, we identify a positive effect of the event on the average DVD sales for the treatment group.

Table 2 Descriptive Statistics

Variables	Group	#Obs	#Movies	Mean	Median	Min	Max	Std
$Unit_{it}$	Treatment	256	128	5,272.11	76.5	0	243,261	22,070.26
	Control	1,468	734	1,659.26	34.5	0	183,353	9,786.11
$MonthSinceRetail_{it}$	Treatment	256	128	87.93	71	6	223	62.18
	Control	1,468	734	55.67	43	4	207	47.98
$Price_{it}$	Treatment	256	128	6.78	6.89	0.86	14.99	2.21
	Control	1,468	734	7.27	6.81	0.37	19.99	2.72
$Gross_i$ (in million)	Treatment	256	128	31.26	12	0.005	245	46.65
	Control	1,468	734	16.37	0.58	0.001	659	41.12
$Volume_{it}$	Treatment	256	128	119.14	12	0	3,122	350.21
	Control	1,468	734	11.97	4	0	556	29.63
$Valence_{it}$	Treatment	256	128	3.98	4.17	1	5	0.80
	Control	1,468	734	4.15	4.33	1	5	0.82

Note: Descriptive statistics are based on data covering the period of three months before and after the event.
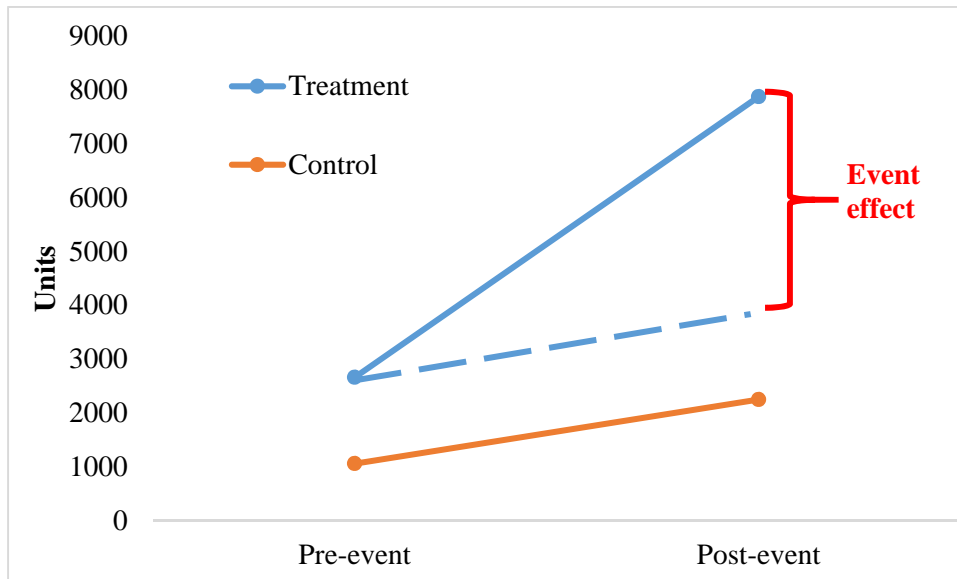
Figure 3 Average DVD Sales in the Pre- and Post-event Periods

5.2 Effect of Reduced Streaming Availability on DVD Sales

In this section, we investigate the effect of the reduced streaming availability by using a regression framework and control for movie heterogeneity and other factors that could also affect DVD sales. Table 4 presents the results of the regression model in Equation (1). Columns (1) to (6) report the coefficient estimates for the study periods of including one to six months in both pre- and post-event periods, respectively. The coefficient estimates on the interaction term between $Treatment_i$ and $After_t$ range from 0.241 to 0.272 and are consistently statistically significant at least at the 5% level in Columns (2) to (6). This result indicates that the decrease in the streaming availability of videos leads to a significant increase in their DVD sales. In other words, streaming media on the average cannibalize the sales of physical media. The results are robust to the specification of different time windows except for one month. The event does not have a significant effect during the first month after the event probably because consumers require time to discover that the movies they want to watch are no longer available on Netflix. The coefficient estimates for two to six months are similar in magnitude. Thus, the influence of the reduced streaming availability is relatively consistent and stable over time.

We interpret the economic value of the focal event using the result of a three-month window for each time period as an example. The coefficient estimate on the interaction term in Column (3) is 0.247, indicating that the shifting of Epix's contents from Netflix to Hulu increased their DVD sales by 24.7% over and above those of the control group after accounting for the difference between the two groups. The mean value of the DVD sales for the treatment group in the three months before the event is 2,667. That is, on the average, each movie in the treatment group had an additional DVD sales of 659 (=2667×24.7%) units. As the price for an average movie DVD is $7, we estimate that the change of streaming partners from Netflix to Hulu can generate an increase of $590,464 (=128×659×7) in DVD sales for the affected 128 movie titles in three months.

The results related to the control variables are largely consistent with previous literature and expectations. The coefficient estimates on $Log(MonthSinceRetail_{it})$ are generally negative, indicating that DVD

sales gradually decrease over time. The coefficient estimates on $Log(Price_{it})$ are also often negative because high prices lead to low sales. In line with previous literature on online word of mouth (e.g., Duan et al. 2008; Liu 2006), the volume of Amazon reviews positively influences DVD sales, whereas the effect of valence is statistically insignificant.

Table 4 Effect of Reduced Streaming Availability on DVD Sales

VARIABLES	(1) 1 Month	(2) 2 Months	(3) 3 Months	(4) 4 Months	(5) 5 Months	(6) 6 Months
			Log($Unit_{it}$)			
$After_t$	−0.235***	0.172***	0.219***	0.183***	0.148***	0.066
	(0.036)	(0.051)	(0.055)	(0.055)	(0.054)	(0.050)
$Treatment_i \times After_t$	0.004	0.269***	0.247**	0.272***	0.241**	0.246***
	(0.065)	(0.092)	(0.096)	(0.097)	(0.099)	(0.093)
Log ($MonthSinceRetail_{it}$)	−0.975	0.082	−0.469	−0.840***	−0.937***	−0.813***
	(0.796)	(0.553)	(0.339)	(0.245)	(0.170)	(0.119)
Log($Price_{it}$)	0.036	−0.462***	−0.471***	−0.547***	−0.687***	−0.621***
	(0.165)	(0.125)	(0.134)	(0.136)	(0.144)	(0.143)
Log($Volume_{it}$)	0.038	0.139***	0.158***	0.163***	0.158***	0.158***
	(0.037)	(0.047)	(0.050)	(0.049)	(0.049)	(0.046)
$Valence_{it}$	0.003	−0.011	0.029	0.0347	0.026	0.036
	(0.025)	(0.035)	(0.039)	(0.042)	(0.044)	(0.042)
Constant	6.225**	3.650*	5.841***	7.538***	8.353***	7.911***
	(3.012)	(2.100)	(1.315)	(0.989)	(0.743)	(0.588)
DVD fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	1,724	1,724	1,724	1,724	1,724	1,724
#Movies	862	862	862	862	862	862
Within R^2	0.138	0.093	0.074	0.060	0.077	0.105

Note: (1) Robust standard errors in parentheses; (2) *** p<0.01, ** p<0.05, * p<0.1.

5.3 Moderating Effects of DVD Release Time and Theatrical Performance

In this section, we test the effects of two moderators: recency of the DVD's retail release and the movie's theatrical performance. Both moderators are demand-related characteristics and important factors to consider when movie studios choose appropriate titles for a streaming channel. In general, DVD sales decrease after the retail release and become trivial after a certain period of time (Squire 2004). If streaming media indeed attract consumers away from physical media, the cannibalization will be more severe for DVDs that are recently released than those released earlier. By contrast, the physical sales of titles released long ago became marginal. Thus, the influence of cannibalization is also minimal.

Regarding the success level of a movie's theatrical release, movies with a strong box office performance are expected to generate high DVD sales because of the public awareness and demand from the substantial built-in audience base created by the theatrical release (Squire 2004). Making the titles available for streaming will likely result in a large decrease in DVD sales. Therefore, both release recency and the success level of movies' theatrical releases are hypothesized to moderate the interaction between streaming media and physical media.

We use the median split to separate movies in our sample into two subgroups with high and low levels for two variables, a movie's DVD release date, and its overall box office revenue. For both variables, movies are classified as belonging to the high level if the value of a variable is above the median and the low level otherwise. We then conduct the same set of DID analyses with different time windows, in which is similar to Section 5.2 for each subgroup. The subgroup analyses help us compare the effects of the reduction in streaming availability between two subgroups, so that content owners can learn which subgroup faces a high level of cannibalization and thus make appropriate choices in selecting certain movie titles for streaming. The regression results for the sample splits by a movie's DVD release date and its box office revenue are reported in Tables 5 and 6, respectively. For ease of comparison, we present only the main results regarding the effect of the treatment and omit the coefficient estimates on all control variables. In Table 5, the coefficient estimates for the high-recency subgroup (Panel A) on the interaction term $Treatment_i \times After_t$ are positive and statistically significant at the 1% level across different time windows from two to six months for each time period, which is consistent with the results for the event's average effect estimated for the whole sample. Additionally, the magnitudes of these coefficient estimates are significantly larger than those reported in each corresponding column or time window in Table 4 are. For example, for the time window of three months in each time period (Column 3 of Table 5), the coefficient estimate is 0.648, indicating that the reduced streaming availability leads to a roughly 64.8% increase in sales for the subgroup of DVDs released after the end of 2010, where the median is located. By contrast, the coefficient estimates for the effect of the treatment for the subgroup with low recency

(Panel B) are statistically insignificant. In summary, the recency of the DVD retail release exhibits a strong moderating effect on the influence of reduced streaming availability on DVD sales. For DVDs released more recently, streaming media displaces physical sales more severely. In a similar vein, a movie's overall box office revenue ($Gross_i$) has a significant moderating effect, as shown in Table 6. For the high gross subgroup, whose office box revenue is above \$0.883 million, the event's effect is positive and statistically significant for the time windows of two to six months in each time period. However, for the low gross subgroup, the effect of the treatment becomes insignificant. That is, video streaming is more likely to cannibalize DVD sales for movies with a better box office performance than those with a poor box office performance.

Table 5 Moderating Effects of DVD Recency

	(1) 1 Month	(2) 2 Months	(3) 3 Months	(4) 4 Months	(5) 5 Months	(6) 6 Months
VARIABLES	$\text{Log}(Unit_{it})$					
	Panel A: High Recency					
$Treatment_i \times After_t$	0.114	0.692***	0.648***	0.579***	0.553***	0.422***
	(0.101)	(0.140)	(0.147)	(0.148)	(0.152)	(0.145)
	Panel B: Low Recency					
$Treatment_i \times After_t$	–0.098	–0.082	–0.101	–0.028	–0.039	–0.022
	(0.084)	(0.124)	(0.129)	(0.132)	(0.135)	(0.125)

Note: (1) Movie fixed effects and all control variables are included in the regressions but omitted here for ease of comparison; (2) robust standard errors in parentheses; (3) *** p<0.01, ** p<0.05, * p<0.1.

Table 6 Moderating Effects of Box Office Performance

	(1) 1 Month	(2) 2 Months	(3) 3 Months	(4) 4 Months	(5) 5 Months	(6) 6 Months
VARIABLES	$\text{Log}(Unit_{it})$					
	Panel A: High Gross					
$Treatment_i \times After_t$	0.044	0.301**	0.279**	0.288**	0.244*	0.246**
	(0.080)	(0.123)	(0.126)	(0.128)	(0.130)	(0.118)
	Panel B: Low Gross					
$Treatment_i \times After_t$	–0.184	–0.023	–0.088	–0.000	–0.011	0.024
	(0.129)	(0.155)	(0.170)	(0.170)	(0.177)	(0.176)

Note: (1) Movie fixed effects and all control variables are included in the regressions but omitted here for ease of comparison; (2) robust standard errors in parentheses; (3) *** p<0.01, ** p<0.05, * p<0.1.

5.4 Robustness Check

The descriptive statistics in Table 2 show that movies in the treatment group differ in various aspects from those in the control group even before the event, and this difference should not be attributed to the

effect of the treatment. The DID approach allows the two groups to be different from each other because it can cancel out the difference between two groups over two periods. To select a control group of movies that resembles the treatment group, we further perform a robustness check by utilizing the matching technique to eliminate the differences between the treatment and control groups. Specifically, we employ propensity score matching (PSM) (Caliendo and Kopeining 2008; Dehejia and Wahba, 2002; Rosenbaum and Rubin 1983) to find a matched control observation with similar observable pre-event characteristics for each treated observation to mimic a randomized experiment design, thereby strengthening the causal inference of the subsequent analysis. Comparing observations across a set of high-dimensional characteristics directly is difficult. Thus, a propensity score, which is the probability of each observation receiving the treatment conditional on the set of observable characteristics, is calculated to facilitate the matching.

We collect various movie characteristics from IMDb (imdb.com) and The Numbers (the-numbers.com), including production budget, opening weekend revenue, gross revenue, theatrical release date, cast members, awards won by either the movie or its cast members, MPAA rating (G, PG, PG-13, R, and unrated), and genres (e.g., animation, horror, romance, etc.). These characteristics are used because they are relevant to the decisions of streaming service providers regarding the titles to license from content owners. We conduct PSM using a Probit model. The dependent variable is a binary variable equal to one if the observation belongs to the treatment group and zero otherwise. Independent variables include the overall box office revenue *Gross*, *YearSinceRetail* (the number of years since the movie's theatrical release), *Award* (a dummy variable equal to 1 if the movie won at least one award such as Oscar and Golden Globe and 0 otherwise), *StarPower* (a dummy variable equal to 1 if at least one of the cast members had won an Oscar award before the movie *i*'s release year and 0 otherwise), MPAA rating dummies, and genre dummies[4]. We perform the single nearest neighbor matching method to obtain a one-

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[4] The variable production budget is dropped because its value is missing for a number of observations (in both the treatment and control groups), and its coefficient is statistically insignificant in the regression. The variable opening weekend box-office revenue is dropped because it is highly correlated with the overall gross revenue.

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to-one matched control movie for each of the 128 treated movies. With the common support option and a caliper of 0.05, 238 movies are obtained in the sample, with 119 movies in each group. The Probit regression results are shown in Table 7. The column "Before-matching" presents the result of the Probit regression on all observations. The column "After-matching" indicates the result of the Probit model on the matched control and treatment observations only. After matching, all the coefficient estimates on the independent variables are statistically insignificant at the 10% level and that the pseudo R^2 drops dramatically. This result indicates that these pre-event observable characteristics used in the model are balanced between the treatment and control groups after matching.

Table 7 Results of the Probit Model

| VARIABLES | Treatment Dummy | | | |
| | Before-matching | | After-matching | |
	Coefficient	Std. error	Coefficient	Std. error
$\text{Log}(Gross_i)$	0.149***	0.044	0.008	0.063
$YearSinceRelease_i$	0.035***	0.007	−0.001	0.008
$Star\_power_i$	−0.200*	0.103	−0.240	0.155
$Award_i$	−0.541***	0.155	−0.711	0.261
G	−0.168	0.831	0.604	1.159
PG	1.025***	0.364	0.199	0.647
PG-13	1.017***	0.353	0.184	0.646
R	0.992***	0.174	0.030	0.616
Action	0.063	0.399	0.078	0.258
Animation	0.040	0.400	−0.382	0.423
Biography	0.160	0.241	0.192	0.334
Comedy	−0.129	0.140	0.199	0.234
Crime	0.163	0.173	−0.124	0.243
Documentary	−0.258	0.291	−0.183	0.501
Drama	0.089	0.150	0.160	0.245
Horror	0.375*	0.216	0.225	0.316
Music	0.236	0.222	0.027	0.314
Romance	−0.267	0.165	0.170	0.266
Scifi	0.453**	0.229	0.008	0.338
Thriller	−0.283	0.202	0.073	0.296
Constant	−2.222***	0.390	0.378	0.738
Pseudo R^2	0.195		0.049	
Observations	862		238	

Note: *** p<0.01, ** p<0.05, * p<0.1

A figure is drawn to illustrate the change in DVD sales for both groups before and after the event in Figure 4. Similar to Figure 3, we identify a positive event effect, i.e., the shifting of Epix's movies from

Netflix to Hulu is associated with additional DVD sales for Epix's movies. The difference between Figures 3 and 4 is that the average DVD sales of the two groups in the pre-event period are close to each other in Figure 4. A t-test of pre-event DVD sales shows that after matching the DVD sales for the treatment and control groups do not significantly differ from each other before the event (t-statistics=0.282, p-value=0.778).
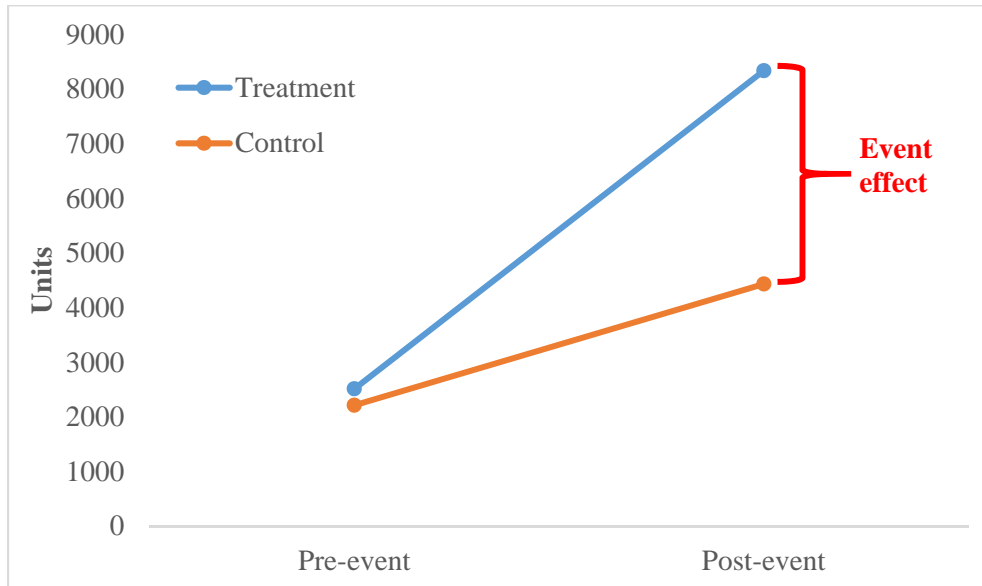
Figure 4 Average DVD Sales in the Pre-event and Post-event Periods after Matching

We re-estimate our model in Equation (1) using the matched sample and report the regression results in Table 8. The results are largely consistent with those obtained on the whole sample in all six time windows. The DVD sales of Epix's movies increased after their streaming availability were reduced, implying the presence of sales displacement between these two media. The coefficient estimates on the interaction terms in Columns (2) to (6) of Table 8 are larger in magnitude than those in the corresponding columns of Table 4, suggesting that the main result based on the whole sample is a conservative one. We also test the two moderating effects, the results of which are shown in Tables 9 and 10. The moderating effect of the recency of the DVD retail release remains strong, although the significance level of the moderating effect of the gross box office revenue is weaker than before. Specifically, the coefficient estimates on the interaction term for the subgroup whose DVDs were released recently are significantly

positive for the time windows of two to six months in each time period but insignificant for the subgroup with a low level of recency, implying that the cannibalization is more severe for recently released DVDs than those released earlier.

Table 8 Effect of Reduced Streaming Availability on DVD Sales after Matching

	(1) 1 Month	(2) 2 Months	(3) 3 Months	(4) 4 Months	(5) 5 Months	(6) 6 Months
VARIABLES			$\text{Log}(Unit_{it})$			
$After_t$	−0.269***	−0.039	0.000	0.010	0.026	0.002
	(0.074)	(0.107)	(0.109)	(0.109)	(0.110)	(0.099)
$Treatment_i \times After_t$	0.029	0.431***	0.400***	0.393***	0.327**	0.305**
	(0.083)	(0.123)	(0.124)	(0.126)	(0.128)	(0.118)
$\text{Log}(MonthSinceRetail_{it})$	−0.774	1.932	0.754	−0.142	−0.539	−0.786***
	(1.705)	(1.190)	(0.742)	(0.524)	(0.390)	(0.270)
$\text{Log}(Price_{it})$	−0.182	−0.501***	−0.461***	−0.100	−0.146	−0.274*
	(0.207)	(0.173)	(0.166)	(0.173)	(0.176)	(0.149)
$\text{Log}(Volume_{it})$	−0.004	0.078	0.115	0.120	0.107	0.075
	(0.058)	(0.079)	(0.081)	(0.080)	(0.079)	(0.071)
$Valence_{it}$	−0.037	0.017	0.078	0.045	0.039	0.072
	(0.053)	(0.079)	(0.082)	(0.089)	(0.096)	(0.095)
Constant	6.949	−3.095	1.583	4.650**	6.579***	8.015***
	(6.880)	(4.897)	(3.081)	(2.257)	(1.767)	(1.324)
DVD fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
#Observations	476	476	476	476	476	476
#Movies	238	238	238	238	238	238
Within R^2	0.156	0.168	0.140	0.073	0.055	0.084

Note: (1) Robust standard errors in parentheses; (2) *** p<0.01, ** p<0.05, * p<0.1.

Table 9 Moderating Effects of DVD Recency after Matching

	(1) 1 Month	(2) 2 Months	(3) 3 Months	(4) 4 Months	(5) 5 Months	(6) 6 Months
VARIABLES			$\text{Log}(Unit_{it})$			
			Panel A: High Recency			
$Treatment_i \times After_t$	−0.157	0.775***	0.706***	0.689***	0.644***	0.554***
	(0.120)	(0.200)	(0.208)	(0.218)	(0.227)	(0.198)
			Panel B: Low Recency			
$Treatment_i \times After_t$	−0.226	0.191	0.189	0.212	0.147	0.157
	(0.157)	(0.150)	(0.149)	(0.145)	(0.145)	(0.142)

Note: (1) Movie fixed effects and all control variables are included in the regressions but omitted for ease of comparison; (2) robust standard errors in parentheses; (3) *** p<0.01, ** p<0.05, * p<0.1.

Table 10 Moderating Effects of Box Office Performance after Matching

	(1) 1 Month	(2) 2 Months	(3) 3 Months	(4) 4 Months	(5) 5 Months	(6) 6 Months
VARIABLES	$Log(Unit_{it})$					
Panel A: High Gross						
$Treatment_i \times After_t$	0.080	0.340*	0.323*	0.326*	0.285	0.213
	(0.104)	(0.179)	(0.188)	(0.188)	(0.198)	(0.179)
Panel B: Low Gross						
$Treatment_i \times After_t$	−0.033	0.175	0.131	0.227	0.170	0.222
	(0.120)	(0.160)	(0.156)	(0.156)	(0.149)	(0.144)

Note: (1) Movie fixed effects and all control variables are included in the regressions but omitted for ease of comparison; (2) Robust standard errors in parentheses; (3) *** p<0.01, ** p<0.05, * p<0.1.

6. Conclusion

Subscription-based video streaming services, which are a growing business model in the motion picture industry, have profoundly changed the way consumers watch videos and exerted a huge impact on the sales of physical media. Previous literature has not examined the competition between streaming media and physical media. Thus, the current research fills this gap by quantifying the causal effect of subscription streaming on physical sales. To achieve this goal, we utilize a natural experiment, the shifting of Epix's contents from Netflix to Hulu on October 1, 2015, which creates an exogenous shock to the streaming availability of Epix's contents. The results show that the decrease in the streaming availability of Epix's movie titles leads to a 24.7% increase in their DVD sales following the event.

Our study also offers insights for content owners in selecting appropriate video titles at the right time by examining two moderators, namely, DVD release time and the theatrical performance of movies. The results indicate that the cannibalization between streaming and physical media is more severe for movies with more recent retail releases and better theatrical performances. Consumers' demand for the physical formats of these video titles is likely to be high. Thus, content owners should delay or even avoid offering these titles in the streaming media to reduce cannibalization. On the contrary, making titles released a long time ago or without great box office revenues available for streaming can generate additional revenue.

The study bears a few limitations. First, the specific event examined in the study only involves movie titles that were available for streaming for some time. Various streaming subscribers may have already watched these titles. Thus, their demand for physical discs would be lower when the streaming option is gone. Future research can investigate the competition between streaming and physical media for titles that were never available for streaming before. One possible research design is to investigate how physical sales respond when a title is made available for streaming for the first time. The problem then needs to be addressed is how to deal with potential endogeneity concerns because the decision and scheduling of making a title available for streaming are likely affected by physical sales.

Second, aside from streaming and physical media, movies are also distributed in digital formats, such as electronic sell-through and digital rentals. Some consumers may switch to other digital outlets after the supply on streaming platforms decreases instead of purchasing physical discs. Future research can test and verify this type of behavior. The treatment of reduced streaming availability is exogenous. Thus, without controlling for this behavior does not affect the causal inference of streaming media on physical media. Furthermore, given that the effect of switching to digital downloads or rentals on physical sales is expected to be negative, the estimation of the influence of reduced streaming availability on physical sales would be on the conservative side if the behavior of switching to digital downloads or rentals was indeed an omitted variable.

Third, pirating is not considered in the study. Although online pirating may still exist, its popularity decreased significantly, particularly after legal digital distribution channels are made available. One industry report shows that the major peer-to-peer sharing website BitTorrent only accounts for 4.35% of the peak internet traffic in 2015, which declined from 31% in 2008 (Protalinski 2015). By contrast, the leading video streaming platform Netflix accounts for 34.7% of the peak traffic. Future research may examine if decreasing streaming availability increases online pirating. However, in the context of the current study, without accounting for pirating results in a conservative estimation because the effect of pirating on physical sales is also expected to be negative.

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