An Empirical Analysis of the Impact of Pre-Release Movie Piracy on Box-Office Revenue

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Abstract

Digital distribution channels raise many new challenges for managers in the media industries. This is particularly true for movie studios where high-value content can be stolen and released through illegitimate digital distribution channels even prior to the release of the movie in legal channels. In response to this potential threat, movie studios have spent millions of dollars protecting their content from unauthorized distribution throughout the lifecycle of the film, but have focused their efforts on the pre-release period under the assumption that pre-release piracy could be particularly harmful for a movie's success.

However, surprisingly, there has been very little rigorous research to analyze whether, and how much, pre-release movie piracy diminishes legitimate sales. In this paper, we analyze this question using data collected from a unique Internet file-sharing site. We find that the net effect of pre-release piracy can be a 20% decrease in revenue compared to piracy that occurs post-release.

Our study contributes to the growing literature in the Information Systems community on piracy and digital media consumption by presenting evidence of the impact of Internet-based movie piracy, by taking a pre-release perspective to strengthen causal inference, and by examining a piracy setting that is distinct from the other types of piracy considered by the literature previously.

Keywords: Movies, Box Office Revenue, Piracy, Forecasting

1. Introduction

Digital distribution channels raise many new challenges for the creative industries. One notable challenge comes from digital piracy where firms must understand whether and how much digital piracy impacts revenue, how the threat from piracy may differ across the lifecycle of the product, and how to develop strategies to respond to any threat posed by piracy. The challenge from piracy is particularly important for motion picture studios where movies can cost hundreds of millions of dollars to produce and where these investments are "sunk" prior to the movie's release. Understanding the impact of piracy early in a movie's lifecycle has become more salient for movie studios with pre-release piracy leaks occurring for a variety of prominent movie releases. For example, a workprint copy of "Star Wars Episode III: Revenge of the Sith" appeared several hours before the release of movie's theatrical release, pirated copies of the horror sequel "Hostel: Part II" appeared a month before the official theatrical release in June 2008, a pirated copy of the movie "X-Men Origins: Wolverine" appeared on the Internet weeks before its official theatrical release, garnering huge attention (Stelter 2009) with some content sharing sites showing more than 200,000 downloads shortly after it appeared on their site, and a copy of the Avengers appeared on the Internet several weeks before its U.S. premiere.

However, while studios spend millions of dollars in an attempt to prevent these sorts of pre-release piracy leaks, there is no rigorous empirical evidence regarding the impact of pre-release piracy. In the absence of solid empirical evidence there are a number of opinions in the industry about the impact of pre-release piracy. On one hand, the Motion Picture Association of American championed passage of the Family Entertainment Copyright Act of 2005 which made pre-release distribution of movies a felony offense under U.S. law, punishable by up to 5 years in prison for a first offender and up to 10 years in prison for repeat offenders. These severe punishments are consistent with the dominant view in the motion picture industry that pre-release piracy results in significant harm to the movie. For example, when a copy of "Wolverine" was

leaked prior to its release, Fox issued a statement saying that the theft of the movie "undermines the enormous efforts of the filmmakers and actors and, above all, hurts fans of the film."[1]

However, others in the industry have taken a much softer view of pre-release piracy. For example, when Hostel: Part II leaked, Lionsgate Entertainment's President Tom Ortenberg said "It's distressing and disappointing, but it will have no meaningful impact on the box office."[2] Still others in the industry see piracy as potentially helping box office revenue: when a bootleg copy of the movie "Soul Plane" leaked prior to its release, one of its stars said "I don't think the bootleg is going to stop anything. I think people will want to see more of this because… a bootleg is like a buzz."[3]

In the context of these important managerial and policy questions, our research is the first paper we are aware of that empirically analyzes the impact of pre-release piracy on theatrical revenue. As such, our paper informs an active managerial and policy question while also informing the academic literature where there are several insights that pre-release piracy offers to the growing information systems, marketing, and economics literatures on digital piracy. First, pre-release piracy provides a cleaner view of the potential impact of piracy than what is likely available in other settings. Consider that most of the existing research on piracy looks at "simultaneous" piracy (i.e., a pirated version is available with the legitimate version), making it challenging to draw causal conclusions. In contrast, our research studies the effect of piracy in an arguably cleaner context: the pirated version is available before the first legitimate version is available, thus making it easier to draw causal inference. Secondly, pre-release piracy differs from other types of piracy in terms of the clientele it attracts. One major argument for the claim that piracy does not matter is that if the consumer is really interested in the content, then the consumer would buy the legitimate version—which usually has higher quality. Whereas those who are satisfied with the lower quality pirated version have low willingness-to-pay for the content and would not have bought the legitimate version anyway. However, this claim is harder to justify in the context of pre-release piracy. If the pirated version is made available before the legitimate one, it is not clear that people who download the pirated version are those with low willingness-to-pay. On the

[1] http://insidemovies.ew.com/2009/04/01/wolverine-leak/
[2] http://articles.latimes.com/2007/jun/01/business/fi-hostel1
[3] http://www.blackfilm.com/20040521/features/snoopdogg.shtml

contrary, the very fact that these people would spend time downloading a low quality version online, knowing that if they just wait for a few days they could get the high quality version, suggests they are likely enthusiastic consumers who would have bought the legitimate one were the pirated one not available. To the best of our knowledge, this clientele effect has not been discussed in literature.

Finally, we note that in addition to studying the impact of piracy prior to the legitimate release of the content, ours is also one of a small number of papers in the literature to study the impact of piracy in the theatrical window. From a revenue standpoint, the theatrical window continues to be an important source of revenue for studios. In 2002, when the BitTorrent protocol was first introduced, the theatrical window represented $9.2 billion in revenue to studios,[4] compared with $20.3 billion in revenue in the home entertainment window (through DVD and VHS sales and rentals).[5] In comparison, in 2012 theatrical revenue represented a slightly higher proportion of studio revenue, with the theatrical window representing $10.8 billion in revenue,[6] versus $18.0 billion in the home entertainment window (through DVD and digital sales and rentals).[7] It may also be important to study the impact of *digital* piracy in the theatrical window because, unlike most subsequent release windows for movies, there is typically no legitimate alternative digital channel available during the theatrical window: During the DVD window, consumers who want digital content can purchase using services such as iTunes, but owing to concerns from exhibitors[8] movie studios have generally avoided digital availability during the theatrical window.

To study the effect of pre-release piracy in the theatrical window we adapt standard forecasting models from the marketing literature (Sawhney and Eliashberg 1996). We use data on major movie releases in the United States during a three-year period from 2006 to 2008. Our data include piracy information collected from a unique Internet file-sharing site, allowing us to analyze the impact of the existence of pre-release piracy on movie box office revenue. We find that pre-release piracy reduces predicted box office revenue by up to 20% relative to movies where piracy occurs after release, and that pre-release piracy has a larger impact

[4] http://www.the-numbers.com/market/2002/summary
[5] http://www.dvdinformation.com/news/press/010903.htm
[6] http://www.the-numbers.com/market/2012/summary
[7] http://www.degonline.org/pressreleases/2013/DEG%202012%20Home%20Entertaiment%20Spending%20Final%20Ext.pdf
[8] See, for example, http://usatoday30.usatoday.com/life/movies/news/2011-05-25-video-on-demand_n.htm, and http://www.deadline.com/2011/03/nato-responds-to-premium-vod-plan-between-directv-studios/

in the early periods after release than in later periods, resulting in a slower rate of revenue decline over time for these movies. We believe our answers to these questions provide useful guidance to both industry managers and to policymakers about the impact of pre-release piracy on sales, and also contribute to the growing academic literature on the impact of piracy.

2. Literature Review

The motion picture industry has attracted much attention from the information systems and marketing research communities over the last decade.[9] Research has analyzed various factors that can contribute to a movie's success, including the movie's script (Eliashberg et al. 2007), advertising (Rennhoff and Wilbur 2008), the presence of star actors (Elberse 2007), critical reviews (Eliashberg and Shugan 1997), user reviews (Dellarocas et al. 2007, Duan, Gu, and Whinston 2008), screen distributions (Swami et al. 1999), and seasonality and competition (Krider and Weinberg 1998).

The impact of piracy on sales is a particularly important question for the motion picture industry, and one that has been debated both in industry and academia over the past decade. Two notable questions within this literature are first, does piracy impact legal consumption and second, how might the impact of piracy vary at different points within a media product's lifecycle?

With respect to the first question, while not uniform in their findings, the vast majority of papers in the literature find that piracy reduces sales in legal channels (see Danaher, Smith, and Telang (2014) for a recent review of this literature). Most of these papers focus on the impact of piracy on music sales, although a subset of papers have analyzed the impact of piracy on motion picture sales. Specifically, Bounie, Bourreu, and Waelbroeck (2006) used an online survey to analyze piracy and consumption behavior among students, staff, and faculty members at 31 French Universities. Their results suggest that piracy has a strong impact on video purchases and rentals, but no statistical impact on theatrical revenue. Similarly, Hennig-Thurau, Henning, and Stattler (2007) use a survey of German consumers' intentions to consume 25 new motion pictures and find that piracy reduces theatrical revenue, DVD rentals, and DVD purchases, potentially

[9] A thorough overview of the industry, open issues, and trends can be found in Eliashberg et al. (2006).

resulting in $300 million in annual revenue losses in Germany in 2006. Likewise, Rob and Waldfogel (2007) survey 500 University of Pennsylvania student's movie viewing habits in the theatrical, purchase, rental, and television distribution windows and find that consumption of one pirated copy of a movie reduces paid consumption by approximately one unit. Zentner (2010) uses country-level data on movie consumption and broadband penetration and concludes that peer-to-peer file sharing has a large and negative impact on retail purchases but no statistically significant impact on theatrical revenue or video rentals. Finally, Danaher and Waldfogel (2012) analyze the impact of delaying the release of movies in international markets after their initial release in a domestic markets, finding that delayed international release windows reduce box office revenue by an estimated 7%.

Each of these papers focuses on the impact of piracy after the release of the content in its initial channel. In contrast, ours is the only paper we are aware of in the literature to focus on the impact of piracy that occurs before the initial release of the product in any market.[10] Focusing on the impact of "pre-release" piracy also helps answer the second question above: Where might piracy be most harmful to sales? Our results shed light on this question and are consistent with the dominant view in the motion picture industry that pre-release piracy is particularly harmful to movie sales. Our results also complement results in the literature such as Smith and Telang (2009) who find no impact of piracy on movies shown on television, which occurs relatively late in a movie's lifecycle (typically 2-3 years after the movie was released in theaters).

We conclude this discussion with two specific hypotheses. Our first hypothesis is that the substitution effect of pre-release piracy will dominate any potential beneficial impact. Hence, we expect that pre-release piracy will decrease box-office revenue relative to piracy that occurs after release. Secondly, we hypothesize that consumers who are more eager to watch the movie are also more likely to search for a pre-release pirated version before the theatrical release. If a pirated version is available, these consumers are less likely to go to the theaters in the early weeks after the movie is released since they have viewed the pre-release pirated copy. Therefore, our second hypothesis is that we expect the reduction in box office revenue from pre-release piracy to be more significant in the early weeks of the theatrical release than in the later weeks.

[10] This distinguishes our work from the Danaher and Waldfogel (2012) paper, which focuses on the impact of piracy in an international market after the movie was released in a different international market.

3. Data

We collect our data from five sources: BoxOfficeMojo, IMDB, Nielsen Research, Vcdquality.com, and Yahoo Movies.[11] Our data consist of all movies whose wide release occurred between February 2006 and December 2008. We collect various characteristics of these movies from both IMDB and BoxOfficeMojo, including distributor, genre, MPAA rating, director appeal, star appeal, user rating, and critic rating. Additionally, we obtained box office revenue information from Nielsen Research. Table 1 lists all the variables collected from these sources for our study, the description of the variable, and information source.

Our information about pre-release movie piracy comes from vcdquality.com. This is not an Internet file-sharing site, but instead is a site that monitors popular Internet file sharing sites. It posts messages on its website once a pirated copy of a movie becomes available at other piracy sites. Each message includes the date of availability, which allows us to infer the presence of piracy that occurred prior to the general release date for the movie. Specifically, we know the date on which a pirated copy is posted from vcdquality.com and we compare this to the official theatrical release date of the corresponding movie listed by BoxOfficeMojo. The difference between these two dates allows us to detect whether pre-release piracy is present for a particular movie.[12] Vcdquality.com also tracks user ratings of the video and audio quality of the pirated content allowing us to collect a measure of the quality of the pirate release by averaging these values.

[11] All information is available on the Internet, either for free or via a subscription.

[12] As noted above, in this paper we define pre-release piracy as piracy that occurs prior to the widespread theatrical release of the movie. This sort of piracy can result from a variety of sources, but notably from leaks in the production process (e.g., leaked workprints as in the case of "Hostel II" and "X-Men Wolverine" or through leaks from pre-release viewings of the movies through previews, screeners, or film festivals.

Variable	Description	Source
Box Office	The US box office revenue of a movie in a week.	Nielsen Research
Budget	The estimated production budget of the movie. (This information is not available for all movies.)	IMDB.com, BoxOfficeMojo.com
Opening Screens	The number of screens on which the movie was shown in the opening weekend.	BoxOfficeMojo.com
Director Appeal	A binary indicator of the presence of a star director in the movie. The indicator is set to one if the past average box office revenue of the director is higher than $50 million. The average box office revenue of this director's past movies was collected from BoxOfficeMojo.com.	BoxOfficeMojo.com Inferred
User Rating	The average movie rating posted by viewers. The rating is given on a scale of 1 (worst) to 10 (best).	IMDB.com
Critic Rating	The average critic rating of the movie. The rating is given on a scale of 1 (worst) to 10 (best).	Yahoo Movies
Star Appeal	A binary indicator of the presence of stars in the cast of the movie. A movie is considered to have a star if any of the top four actors/actresses have either been nominated for or won an academy award before the playing in the movie.	IMDB.com Inferred
Distributor	The distributor of the movie.	BoxOfficeMojo.com
Rating	The MPAA rating of the movie.	BoxOfficeMojo.com
Genre	The genre of the movie.	BoxOfficeMojo.com
Pirated Quality	The average of video and audio quality rating of the pirated copy according to vcdquality.com. (Not all copies received a rating.)	Vcdquality.com
Pre-Release Piracy Indicator	An indicator variable for the existence of pre-release piracy. This is inferred when the piracy date occurs before the wide release date.	Inferred from Vcdquality.com and BoxOfficeMojo.com
Pre-Release Piracy Week	The number of weeks before the wide release date that a pre-release pirated version became available (only movies with pre-release piracy are used to compute this value)	Inferred from Vcdquality.com and BoxOfficeMojo.com

Table 1. Description of Variables

There are two variables in our data that have missing values. First, there are 117 movies for which production budget information is missing. To handle this issue, we set the production budget of all these movies to the mean of the known production budgets, and create an indicator variable to identify that the production budget for these movies are missing. The coefficient of the indicator variable captures any systematic difference between the group of movies with known budgets and those with unknown budgets, should such a difference exist. (In section 5.3 we consider the robustness of our findings by removing these

missing observations.) Secondly, there are 109 movies with missing piracy quality, for which we also set the missing value to the mean of the movies with known piracy quality.

Variable		Mean	Standard Deviation	Minimum	Maximum
Box Office ($ million)		52.61	63.78	0.13	533.35
Budget ($ million)		47.15	40.70	0.5	300
Opening Screens		2349	967	2	4366
Director Appeal		0.21	0.41	0	1
Star Appeal		0.47	0.50	0	1
User Rating		6.10	1.32	1	8.9
Critic Rating		39.68	17.55	1	84
Distributor	Warner	0.11	0.32	0	1
	Universal	0.10	0.29	0	1
	Paramount	0.11	0.31	0	1
	Fox	0.14	0.34	0	1
	Sony	0.14	0.35	0	1
	Newline	0.06	0.23	0	1
	Lionsgate	0.08	0.26	0	1
	MGM	0.06	0.23	0	1
Rating	G	0.04	0.20	0	1
	R	0.36	0.48	0	1
	PG13	0.42	0.49	0	1
Genre	Action	0.12	0.32	0	1
	Comedy	0.31	0.46	0	1
	Drama	0.23	0.42	0	1
	Adventure	0.06	0.23	0	1
	Horror	0.12	0.33	0	1
	Thriller	0.13	0.34	0	1
	Animation	0.17	0.25	0	1
Pirated Quality		6.22	1.58	1	9.5
Pre-Release Piracy Indicator		0.10	0.30	0	1
Pre-Release Piracy Week		7.04	11.07	1	65
Number of Movies		533			

Table 2. Descriptive Statistics for our entire dataset.

The descriptive statistics of all our variables are reported in Table 2. For distributor, MPAA rating, and genre, indicator variables were created representing each value. The data set consists of 533 movies, which is the entire set of all movies identified by BoxOfficeMojo as having wide release during our time

period. The average production budget of a movie is $47.15 million, the average number of opening screens is 2,349, and the average box office revenue of a movie is $52.61 million. Production budgets are as low as $500 thousand and as high as $300 million, while box office revenue ranges from $130 thousand to $533 million. This shows the broad coverage of the movie spectrum of our dataset, and illustrates the large disparity in terms of quality and popularity of the movies.

3.1 Pre-release Piracy

As reported in Table 2, 52 of the 533 movies in the dataset had pre-release piracy: a pirated version became available before the official release of the movie in theaters. This suggests that while pre-release piracy occurs for slightly less than 10% of all movies, it is still significant enough level to warrant detailed empirical investigation. For movies that have pre-release piracy, the pirated version becomes available on average 7 weeks before the theatrical release. Figure 1 shows the number of weeks before release when the pre-release piracy occurs. This figure shows that while half of pre-release piracy occurs within two weeks before the official release, six movies had pre-release pirated versions available more than fifteen weeks before the theatrical release date. This suggests that, in addition to analyzing the average effect of pre-release piracy, it may be valuable to analyze whether the effect depends on how early piracy happened.

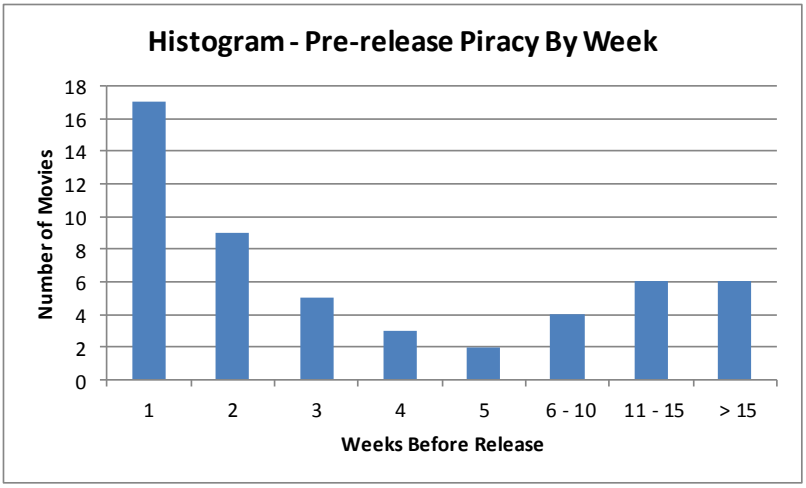

Figure 1. Histogram of Number of Weeks that a Pre-Release Pirated Version is available (for the 52 movies in our dataset with pre-release piracy).

Variable		With Pre-release Piracy		Without Pre-release Piracy	
		Mean	Standard Deviation	Mean	Standard Deviation
Box Office ($ million)		52.65	62.58	52.61	63.98
Budget ($ million)		46.31	40.74	47.23	40.74
Opening Screens		1799	1071	2409	938
Director Appeal		0.25	0.44	0.21	0.40
Star Appeal		0.52	0.50	0.47	0.50
User Rating		7.00	1.06	6.00	1.31
Critic Rating		48.83	20.29	38.69	16.95
Distributor	Warner	0.10	0.30	0.11	0.32
	Universal	0.12	0.32	0.09	0.29
	Paramount	0.12	0.32	0.10	0.31
	Fox	0.10	0.30	0.14	0.35
	Sony	0.10	0.30	0.15	0.36
	Newline	0.02	0.14	0.06	0.24
	Lionsgate	0.06	0.24	0.08	0.27
	MGM	0.08	0.27	0.06	0.23
Rating	G	0.04	0.19	0.04	0.2
	R	0.50	0.50	0.34	0.48
	PG13	0.35	0.48	0.43	0.5
Genre	Action	0.12	0.32	0.12	0.32
	Comedy	0.17	0.38	0.32	0.47
	Drama	0.40	0.50	0.21	0.40
	Adventure	0.08	0.27	0.05	0.23
	Horror	0.12	0.32	0.12	0.33
	Thriller	0.10	0.30	0.14	0.34
	Animation	0.04	0.19	0.07	0.26
Pirated Quality		7.13	1.53	6.12	1.55
Pre-Release Piracy Indicator		1.00	0.00	0.00	0.00
Pre-Release Piracy Week		7.04	11.07	NA	
Number of Movies		52		481	

Table 3. Descriptive Statistics for Movies with and without Pre-release Piracy

In Table 3, we compare descriptive statistics for all movies with pre-release piracy versus those where piracy occurs after widespread release.[13] This table shows that movies with pre-release piracy are fairly similar to those without. Box office revenue is almost identical between movies with ($52.65 million) and without

[13] We note that essentially every movie experiences piracy at some point in its lifecycle and thus our distinction is only between movies that experience piracy prior to their release and movies that experience piracy after release.

($52.61 million) pre-release piracy, as is production cost ($46.31 million for pre-release piracy movies versus $47.23 million for other movies). Likewise, while movies with pre-release piracy open on fewer screens than other movies do (1,700 versus 2,409) the difference is not statistically significant. There are some differences between the two groups however. First, movies with pre-release piracy have slightly higher user ratings (7.13 vs. 6.12) and critic ratings (48.83 vs 38.69). Second, movies with pre-release piracy are slightly more likely to be "R" rated than those without (0.5 vs. 0.34). Finally, drama movies are more likely (0.40 vs. 0.21) and comedies less likely (0.17 vs. 0.32) to experience piracy prior to release than other movies in our sample.

4. An Exponential Model of Movie Box Office Revenue

The preceding discussion suggests that it is important to account for a large set of movie characteristics to reliably identify the effect of pre-release piracy. In this section, we develop a regression model to better understand the nature of the relationship between pre-release piracy and movie box office revenue. Most movies see their highest level of sales in the opening week of wide-release, with sales declining exponentially over time. Consistent with the existing literature (e.g. Sawhney and Eliashberg 1996, Krider and Weinberg 1998), we model movie box office revenue using an exponentially declining model:

$$y_{it} = m_i e^{-\eta_i t + \varepsilon_{it}} = e^{\ln(m_i) - \eta_i t + \varepsilon_{it}} \quad (1)$$

where y_{it} is the box office revenue of movie i at time t, and, m_i and η_i represent the market potential[14] and the rate of decline of movie sales, respectively.

Market potential and rate of decay likely depend on movie characteristics and pre-release piracy, and we model these variables in the context of a hierarchical (or equivalently a random effects) model as follows:

$$\ln(m_i) = \mathbf{X'_i \beta_i} + \rho Pir_i + \zeta_i \quad (2)$$

[14] If the first period is indexed by 0, then the total box-office revenue if the movie is played perpetually is $\sum_{t=0}^{\infty} m_i e^{-\eta_i t} = \frac{m_i}{1-e^{-\eta_i}}$, which is proportional to m_i when the rate of decay, η_i, is held constant. In another words, m_i represents the size of the market while η_i represents the distribution of the sales over time. Hence we term m_i the market potential in the context of the model, which follows terminology used in the marketing literature (Lehmann and Weinberg 2000, Lee, Boatwright and Kamakura 2003, Dellarocas et al 2007). Although market potential can also be described as market attractiveness (Ainslie, Dreze and Zufryden 2005), box office attraction (Sawhney and Eliashberg 1996), or simply "potential" (Eliashberg et al 2000).

$$\eta_i = \mathbf{Z'_i \gamma_i} + \tau Pir_i + \xi_i \quad (3)$$

where $\mathbf{X_i}$ is a $k\times1$ vector of the characteristics of movie i which are related to market potential, $\mathbf{Z_i}$ is an $l\times1$ vector of the characteristics of movie i that influence the rate of decay, and Pir_i is an indicator for the existence of pre-release piracy for the movie (e.g., the pre-release piracy indicator in Table 1).

Taking the logarithm of (1) and substituting in (2) and (3) yields a log-linear model:

$$\ln(y_{it}) = \mathbf{X'_i \beta_i} - \mathbf{Z'_i \gamma_i} t + \rho Pir_i - \tau Pir_i t + \varepsilon^*_{it}, \text{where } \varepsilon^*_{it} = \varepsilon_{it} + \zeta_i + t\xi_i \quad (4)$$

The hierarchical nature of the model induces heteroskedasticity across movies, but otherwise can be estimated through standard econometric methods. Our main hypothesis is that pre-release piracy lowers market potential (i.e., we expect $\rho < 0$).[15] We also hypothesize that the reduction in revenue will be larger in early periods than in later periods, resulting in a slower rate of decline over time for movies with pre-release piracy (i.e., $\tau < 0$). Additionally, because nearly all movies in our data experience piracy after release we cannot use our model to separately estimate the impact of post-release piracy (versus a hypothetical world where piracy does not exist). Thus, one should interpret our estimates in terms of the additional impact of pre-release piracy over and above any impact that would exist from piracy that occurs after release.

Our dataset contains a total of 533 movies, but we have a number of movies that were shown for a brief period of time. Therefore to ensure that we have adequate information to fit a movie's revenue curve, we kept only the movies that were exhibited in theaters for at least six weeks. This removed 58 movies, leaving 475 remaining in the dataset. Among them, 48 movies had pre-release piracy. The descriptive statistics of the most important variables for the movies used in this analysis are given in Table 4. The statistics are very close to those of the overall dataset provided in Tables 2 and 3.

[15] Furthermore, to be consistent with the hypothesis, the reduction in the market potential parameter should outweigh any positive effect of a reduced rate of decay, so that the net effect on overall revenue is reduced.

Variable		With Pre-release Piracy		Without Pre-release Piracy	
		Mean	Standard Deviation	Mean	Standard Deviation
Box Office ($ million)		55.78	64.03	58.17	65.79
Budget ($ million)		48.63	41.67	49.76	42.33
Opening Screens		1795	1077	2509	920
Director Appeal		0.25	0.44	0.22	0.42
Star Appeal		0.56	0.50	0.47	0.50
User Rating		7.18	0.88	6.08	1.27
Critic Rating		50.98	19.50	39.44	16.47
Distributor	Warner	0.10	0.31	0.13	0.34
	Universal	0.13	0.33	0.09	0.29
	Paramount	0.13	0.33	0.11	0.32
	Fox	0.10	0.31	0.16	0.36
	Sony	0.08	0.28	0.14	0.35
	Newline	0.02	0.14	0.06	0.24
	Lionsgate	0.04	0.20	0.06	0.24
	MGM	0.08	0.28	0.06	0.24
Rating	G	0.04	0.20	0.05	0.21
	R	0.50	0.50	0.32	0.47
	PG13	0.33	0.48	0.45	0.5
Genre	Action	0.13	0.33	0.11	0.32
	Comedy	0.19	0.39	0.34	0.47
	Drama	0.44	0.50	0.19	0.39
	Adventure	0.08	0.28	0.06	0.24
	Horror	0.04	0.20	0.12	0.33
	Thriller	0.08	0.28	0.13	0.33
	Animation	0.04	0.20	0.07	0.26
Pirated Quality		7.09	1.57	6.13	1.57
Pre-Release Piracy Indicator		1.00	0.00	0.00	0.00
Pre-Release Piracy Week		7.46	11.43	NA	
Number of Observations		48		427	

Table 4. Descriptive Statistics for Movies with and without Pre-release Piracy used for model estimation

4.1 Empirical Results with Homogenous Rate of Decline

We first analyze a parsimonious model setup in which we assume a homogeneous rate of decline across movies. The prior literature has shown that most movie characteristics included in our dataset impact market potential (Sawhney and Eliashberg 1996, Dellarocas et al. 2007). Therefore, we include all movie

characteristics that are available to us in vector $\mathbf{X_i}$ (as listed in Table 1). This includes movie distributor, genre, MPAA rating, director appeal, star appeal, budget, screen, user rating, and critic rating. In this first analysis, we assume a homogeneous rate of decline, i.e. all movies have the same rate of revenue decline over time, unless altered by pre-release piracy: $\eta_i = \lambda + \tau Pir_i$. Equation (4) thus becomes:

$$\ln(y_{it}) = \mathbf{X'_i}\boldsymbol{\beta_i} - \lambda t + \rho Pir_i - \tau Pir_i t + \varepsilon^*_{it} \quad (5)$$

Equation (5) includes movie-specific random effects to account for potential unobserved effects at the movie level. Such effects may induce correlated residuals, rendering the standard error estimate invalid if Pooled OLS is used. Therefore, we estimate the model using Feasible GLS. The residuals are further diagnosed for potential serial correlation over time for the same movies, with no such correlations detected. The result of the estimation is reported in Table 5.

Parameter	Estimate	Parameter	Estimate
Constant	7.4631(***)	Warner	0.2319
τ	-0.1929(***)	Universal	0.4701(*)
ρ	-0.7399(***)	Paramount	0.2955(.)
λ	0.7600(***)	Fox	0.1793
Budget	0.3878(***)	Sony	0.4489(**)
MissingBudget	-0.9032(***)	Newline	-0.0329
Screen	0.4233(***)	Lionsgate	0.5159(*)
Director Appeal	0.2358(*)	MGM	-0.5277(*)
User Rating	0.1703(**)	Action	0.0044
Critic Rating	0.0198(***)	Comedy	0.4414(**)
Star Appeal	0.0953	Drama	-0.1411
G	0.6104(*)	Adventure	0.3821(.)
R	-0.7920(***)	Horror	0.4361(*)
PG13	-0.1962	Thriller	0.1055
		Animation	0.0337

The significance of the estimates are denoted by the following codes: <0.001: '***', <0.01: '**', <0.05: '*' <0.1: '.'

Table 5. Estimation Results for Homogeneous Rate of Decay

The results on the control variables in Table 5 are generally in line with expectations. These results show that the production budget and the number of screens both positively influence movie revenue (i.e., the

market potential parameter). The coefficient on the missing budget indicator variable is negative and statistically significant, suggesting that, movies with missing budgets on IMDB are typically smaller than those with known budget information. Also as expected, movies with star directors have higher expected revenue, as do movies with better user and critic ratings. Most major studios produce movies with higher expected revenue (compared with the baseline which is non-brand-name studios), though not all are statistically significant and there are exceptions (e.g., Newline and MGM). Movies rated R have lower expected revenue, potentially due to the restriction on the number of potential viewers. This is in contrast to movies rated G, which have higher expected revenue than other movies do. Finally, comedy and horror movies have higher expected revenue. These results are in line with our expectations and with the prior literature.

With respect to our variable of interest, the results in Table 5 show the coefficient of piracy on market potential is -0.7399 (statistically significant at 0.01). This suggests that pre-release piracy reduces the expected revenue of movies. The results also show that the coefficient of piracy on rate of decay is -0.1929 (statistically significant at .001). This is also consistent with the hypothesis that pre-release piracy has a stronger impact on revenue early in the movie's lifecycle.

Since the rate of decay without pre-release piracy is 0.76, these parameter estimates imply a 28.9% revenue loss arising from pre-release piracy, assuming the movie is played for 12 weeks (which is the average theatrical run in our dataset). This is a substantial reduction in revenue, suggesting that pre-release piracy significantly harms movie sales. Moreover, as noted above, this revenue loss is relative to the baseline case of a movie that experiences piracy only after release, not the absence of piracy altogether.

4.2 Empirical Results for Heterogeneous Rate of Decline

The assumption of a homogeneous rate of revenue decline in the previous analysis, while parsimonious, is strong. Not all movies are the same, and some movies see their sales decline much faster than others do. To control for the many factors that may influence this rate of decline in this section we introduce heterogeneity into the rate of decline across movies. In determining $\mathbf{Z_i}$, a matrix of movie characteristics that may influence decline, we note that the rate of decline in revenue should be primarily

driven by quality-related characteristics, e.g., higher quality movies may receive more positive word-of-mouth after release and would see slower rate of revenue decline than lower quality movies do. Among the movie characteristics that we gathered, we include director appeal, star appeal, user ratings, and critic ratings in vector $\mathbf{Z_i}$. We again estimate the model using Feasible GLS. The residuals are further diagnosed for potential serial correlations over time for the same movies, with no such correlations detected.

Parameter	Estimate	Parameter	Estimate
Constant	7.4290(***)	Warner	0.2319
τ	-0.0965(***)	Universal	0.4701(*)
ρ	-0.4024(*)	Paramount	0.2955(.)
λ	0.7503(***)	Fox	0.1793
Budget	0.3878(***)	Sony	0.4489(**)
MissingBudget	-0.9032(***)	Newline	-0.0329
Screen	0.4233(***)	Lionsgate	0.5159(*)
Director Appeal	0.0256	MGM	-0.5278(*)
User Rating	0.1418(*)	Action	0.0044
Critic Rating	-0.0044	Comedy	0.4414(**)
Star Appeal	-0.1451	Drama	-0.1411
G	0.6104(*)	Adventure	0.3821(.)
R	-0.7920(***)	Horror	0.4361(*)
PG13	-0.1962	Thriller	0.1055
		Animation	0.0337
Rate of Decline			
User Rating	-0.0081	Director Appeal	-0.0615(***)
Critic Rating	-0.0069(***)	Star Appeal	-0.0687(***)

The significance of the estimates are denoted by the following codes: <0.001: '***', <0.01: '**', <0.05: '*' <0.1: '.'

Table 6. Estimation Results for Heterogeneous Rate of Decay

The result of this estimation is reported in Table 6. Consistent with our hypotheses, the coefficient of pre-release piracy on market potential is negative (-0.40), and statistically significant at the .05 level. The coefficient of piracy on the rate of sales decay is also negative, (-0.10), and statistically significant at the .01 level. With the rate of decline in revenue prior to accounting for piracy varying from movie to movie, the total reduction in box office revenue arising from pre-release piracy also depends on other movie characteristics. Based on the average movie characteristics in our data, the average rate of decline in revenue before accounting for piracy is 0.75 (very close to the estimate in the previous section). These coefficient

estimates imply a 19.1% total reduction in box office revenue arising from pre-release piracy, assuming as before that the movie is played for 12 weeks.

The coefficients for the rate of decline parameters show that higher critic rating, star appeal, and director appeal all slow the rate of revenue decline. The coefficient for user rating is very close to zero, suggesting that this variable does not significantly influence the rate of decline. Also note that the estimated revenue loss is lower in this version of the model than in the previous version using a homogeneous rate of decline. This suggests it is important to account for heterogeneous rates of sales decline in our model.

We can further investigate whether the quality of the pirated copy moderates the effect on box office revenue. To do this, we extend equation (4) as follows:

$$\ln(y_{it}) = \mathbf{X'_i\beta_i} - \mathbf{Z'_i\gamma_i}t + \rho_1 Pir_i + \rho_2 Pirqual_i - \tau_1 Pir_i t - \tau_2 Pirqual_i t + \varepsilon^*_{it} \quad (6)$$

Where $Pirweek_i$ is the Pirated Quality variable described in Table 1. The result of the estimation is reported below in Table 7. While the moderating effect of piracy quality on market potential and on the rate of sales decline are both negative as expected, they are both statistically insignificant. This suggests that the measures of quality available in our data have no statistically significant moderating effect on the impact of pre-release piracy on sales.

Parameter	Estimate
τ_1	-0.0963(***)
τ_2	-0.0162
ρ_1	-0.4022(*)
ρ_2	-0.0669

Table 7. Impact of Piracy Quality

In summary, our estimates show that pre-release piracy leads to a reduction in theatrical revenue, and that the impact more pronounced in the earlier weeks after a movie's theatrical release. The net effect of pre-release piracy is an almost 20% revenue loss compared with piracy that only occurs post-release. As such, our estimated 20% revenue loss should not be interpreted as the total impact of piracy on movie revenue, but

rather is only the additional impact from pre-release piracy compared with the more typical case of piracy which occurs at or after release.

5. Alternative Analyses and Robustness Check

In this section, we discuss several alternative models and robustness checks on our main results. These analyses help ensure the reliability and robustness of our analysis, and shed light on additional factors that may influence our results. We discuss four analyses in this section: propensity-score matching of pre- and post-release pirated movies, incorporating timing of piracy relative to release, an alternative estimation without imputation of production budget, and robustness checks on the number of weeks used in our analysis.

5.1 Propensity-Score Matching

Because pre-release piracy pre-dates the official release of the movie, and therefore box office revenue, simultaneity is not a major concern in evaluating the causal impact of our analysis. However, other potential sources of endogeneity may still exist. While, we have made efforts to control for as many other variables as our data allow, in this section we further address potential endogeneity concerns by performing a pair-wise propensity score matching approach, and repeating our test on the matched dataset.

Propensity score matching is a powerful technique to address selection bias. Our exploratory data analysis shows that while pre-release pirated movies are similar to other movies, certain types of movies are still overrepresented in the pre-pirated set. As such, it is prudent to perform propensity score matching to ensure the robustness of our results. Propensity score matching in this way will address possible selection bias by ensuring that pirated movies are compared with movies that are similarly likely to be pirated, but were not. In our analysis, we calculate the propensity scores of a movie being pirated prior to release by using a binary-logit model to regress the piracy indicator variable over all observed movie characteristics. Each pirated movies is then paired with a movie with a similar propensity score of pre-release piracy, but which was not pirated prior to the theatrical release. We then repeat the estimation we conducted in section 4.2 to evaluate the effect of piracy on these matched titles.

We report our estimates using these paired samples in Table 8. Compared with the estimates reported in Table 6, we can see that fewer parameters are statistically significant in this estimation. This is as expected since the propensity score matching technique results in fewer movies used for estimation. However, most results remain qualitatively the same, including the effect of budget, screen, director and user ratings, and genre, rating, and distributor effects. More importantly, the estimates of pre-release piracy's effect on market potential and rate of decline, -0.4874 and -0.1204 respectively, are both close to the corresponding estimates reported in Table 6 (-0.4024 and -0.0965). This confirms that our estimated effects of pre-release piracy are robust to selection effects.

Parameter	Estimate	Parameter	Estimate
Constant	7.9259(*)	Warner	-0.5336
τ	-0.1204(***)	Universal	0.5473
ρ	-0.4874(*)	Paramount	-0.175
λ	0.8232(***)	Fox	0.9990(*)
Budget	0.3814(*)	Sony	0.4926
MissingBudget	-1.8128(***)	Newline	1.1203(.)
Screen	0.3458(*)	Lionsgate	0.1972
Director Appeal	0.4061	MGM	-0.8595(.)
User Rating	0.2665	Action	0.5540(.)
Critic Rating	-0.0046	Comedy	0.5199
Star Appeal	-0.056	Drama	0.292
G	-0.4504	Adventure	0.4485
R	-0.9812(**)	Horror	1.5606(**)
PG13	0.0447	Thriller	0.6404
		Animation	0.5896
	Rate of Decline		
User Rating	-0.0050(.)	Director Appeal	-0.0368
Critic Rating	-0.0077(***)	Star Appeal	-0.0730(*)

The significance of the estimates are denoted by the following codes: <0.001: '***', <0.01: '**', <0.05: '*' <0.1: '.'

Table 8. Estimation Results for Propensity Score Matching

5.2 The Timing of Piracy on Sales

As Figure 1 illustrates, although clustered around a movie's theatrical release, there is significant variation in the timing of pre-release piracy. A natural question to ask is whether the timing of the pre-release

pirated version moderates its effects on box office revenue. To investigate this, we extend equation (4) as follows:

$$\ln(y_{it}) = \mathbf{X'_i\beta_i} - \mathbf{Z'_i\gamma_i}t + \rho_1 Pir_i + \rho_2 \ln(Pirweek_i) - \tau_1 Pir_i t - \tau_2 \ln(Pirweek_i)t + \varepsilon^*_{it} \qquad (7)$$

In equation (7), $Pirweek_i$ is the number of weeks before release that a pirated version became available (ln(*Pirweek*) is set to zero if no pre-release piracy occurs). The estimation result for this model is reported in Table 9.

Parameter	Estimate	Parameter	Estimate
Constant	7.5555(***)	Warner	0.2324
τ_1	-0.0964(***)	Universal	0.4713(*)
ρ_1	-0.3992(*)	Paramount	0.2893
ρ_2	-0.1999	Fox	0.1779
λ	0.7503(***)	Sony	0.4536(**)
Budget	0.3826(***)	Newline	-0.0428
MissingBudget	-0.8917(***)	Lionsgate	0.5001(*)
Screen	0.4200(***)	MGM	-0.5458(*)
Director Appeal	0.0311	Action	-0.0016
User Rating	0.1420(*)	Comedy	0.4380(**)
Critic Rating	-0.0045	Drama	-0.1596
Star Appeal	-0.1379	Adventure	0.3676(.)
G	0.6083(*)	Horror	0.4324(*)
R	-0.7945(***)	Thriller	0.1066
PG13	-0.2014	Animation	0.0267
	Rate of Decline		
User Rating	-0.0082	Director Appeal	-0.0613(***)
Critic Rating	-0.0069(***)	Star Appeal	-0.0685(***)
τ_2	-0.0058		

The significance of the estimates are denoted by the following codes: <0.001: '***', <0.01: '**', <0.05: '*' <0.1: '.'

Table 9. Estimation Results for Timing of Pre-release Piracy

The results are very close to those reported in Table 6. Specifically, pre-release piracy both reduces the expected revenue ($\rho_1 = -0.3992$) and flattens the sales curve ($\tau_1 = -0.0964$). In addition to this average effect, however, this is no conclusive evidence on the effect of the timing of pre-release piracy: while

the coefficient of $Pirweek_i$ for market potential is -0.1999, suggesting that earlier pre-release piracy reduces expected revenue, this result is not statistically significant. Furthermore, while coefficient of $Pirweek_i$ for the rate of decline is -0.0058, suggesting that the earlier a movie had pre-release piracy the flatter the sales curve, this result is also statistically insignificant.

Variable		With Pre-release Piracy		Without Pre-release Piracy	
		Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Box Office ($ million)		59.88	66.50	65.84	70.91
Budget ($ million)		48.43	45.74	49.80	47.81
Opening Screens		1910	1090	2590	927
Director Appeal		0.25	0.44	0.25	0.43
Star Appeal		0.58	0.50	0.47	0.50
User Rating		7.16	0.89	6.18	1.23
Critic Rating		50.03	18.83	40.04	16.86
Distributor	Warner	0.13	0.33	0.14	0.34
	Universal	0.15	0.36	0.09	0.29
	Paramount	0.15	0.36	0.12	0.32
	Fox	0.10	0.30	0.16	0.37
	Sony	0.08	0.27	0.15	0.36
	Newline	0.03	0.16	0.05	0.23
	Lionsgate	0.05	0.22	0.06	0.24
	MGM	0.05	0.22	0.06	0.24
Rating	G	0.05	0.22	0.02	0.15
	R	0.50	0.51	0.33	0.47
	PG13	0.30	0.46	0.46	0.5
Genre	Action	0.13	0.33	0.13	0.34
	Comedy	0.16	0.36	0.30	0.46
	Drama	0.48	0.51	0.19	0.39
	Adventure	0.10	0.30	0.08	0.27
	Horror	0.03	0.16	0.13	0.33
	Thriller	0.08	0.27	0.13	0.34
	Animation	0.05	0.22	0.07	0.26
Pirated Quality		7.25	1.31	6.07	1.57
Pre-Release Piracy Indicator		1.00	0.00	0.00	0.00
Pre-Release Piracy Week		6.53	11.38	NA	
Number of Observations		40		335	

Table 10. Descriptive Statistics for Movies with and without Pre-release Piracy, but only for those movies whose production budget is known.

Parameter	Estimate	Parameter	Estimate
Constant	6.4507(***)	Warner	0.1473
τ	-0.1201(***)	Universal	0.4273(*)
ρ	-0.4874(**)	Paramount	0.292
λ	0.7310(***)	Fox	0.243
Budget	0.5121(***)	Sony	0.5252(**)
		Newline	-0.0929
Screen	0.2534(**)	Lionsgate	0.6541(**)
Director Appeal	0.0163	MGM	-0.283
User Rating	0.1815(*)	Action	0.0404
Critic Rating	-0.0062	Comedy	0.5497(***)
Star Appeal	-0.2158(.)	Drama	-0.0064
G	0.6799(.)	Adventure	0.4493(*)
R	-0.8144(***)	Horror	0.6000(**)
PG13	-0.2377	Thriller	0.1287
		Animation	0.0628
Rate of Decay			
User Rating	0.0004	Director Appeal	-0.0592(***)
Critic Rating	-0.0072(***)	Star Appeal	-0.0494(***)

The significance of the estimates are denoted by the following codes: <0.001: '***', <0.01: '**', <0.05: '*' <0.1: '.'

Table 11. Estimation Results Using only Movies with Known Product Budget

5.3 Estimation without Imputation of Production Budgets

As noted above, 117 movies in our data are missing production budget information. In our main analysis, we set the production budget of all these movies to the population average and use an indicator variable to capture the missing budget status. This is a standard imputation method in the literature, and it allows us to utilize more data for analysis. However, one may argue that a smaller dataset without this imputation is less subject to model misspecification. To address this concern, in this section we estimate the model using only movies with known production budgets. This smaller dataset consists of 375 movies, 40 of which have pre-release piracy (see Table 10 for descriptive statistics). The estimation results for this limited sample is reported in Table 11. Most estimates in Table 11 are fairly close to those reported in Table 6, further validating the robustness of our main analysis.

5.4 Alternative Number of Weeks

Our main analysis only uses movies that have been in theaters for at least six weeks. To demonstrate that the choice of this threshold is not driving our results we repeated our analysis using different thresholds, ranging from 4 to 9. The estimates of the effects of piracy on market potential and rate of decline are reported in Table 12. The estimates are similar across different threshold values.

Number of Weeks	τ	ρ
4	-0.0716(*)	-0.3231(*)
5	-0.1013(***)	-0.4048(*)
6	-0.0965(***)	-0.4024(*)
7	-0.0963(***)	-0.4212(*)
8	-0.0841(***)	-0.4673(*)
9	-0.0937(***)	-0.4654(*)

Table 12. Estimation Results using Alternative Week Thresholds

6. Discussion

Motion picture studios have limited resources to fight piracy, and must allocate these resources intelligently across different portions of a product's lifecycle. Many in the industry believe that period prior to a movie's first release is an important period in a movie's lifecycle, and one where piracy could be particularly harmful because there is no legitimate alternative channels and because pre-release piracy presumably comes disproportionately from those individuals most passionate and interested in consuming the movie. However, some argue that pre-release piracy will have no impact on movie revenue or could even help theatrical revenue by increasing buzz for the movie or by complementing the higher quality experience consumers get from viewing the movie in the theater. As such, the impact of pre-release piracy on movie box office revenue has important implications for managers, in terms of allocating scarce resources for piracy protection. Likewise, the impact of pre-release piracy has important implications for policymakers in the context of balancing the benefits and costs of potential policy interventions.

Our research informs this managerial and policy question by being the first paper we are aware of that empirically analyzes the impact of piracy prior to the first release of the motion picture product in the U.S. market. Using data collected from a unique Internet site providing information about the timing and

quality of pirate sources and combining this with information on various movie characteristics, we find that pre-release piracy significantly reduces a movie's expected box office revenue and that this impact is stronger early in a movie's lifecycle than in later periods. When these effects are combined, we find that pre-release piracy reduces box office revenue by about 20% on average compared to an environment where piracy happened after the theatrical release. Our results are robust to a variety of alternative model specifications and validations.

Our results contribute to the literature in several ways. First, it fills a gap in the literature by presenting evidence of the impact of Internet-based movie piracy on important managerial and policy questions regarding box office revenue. Second, by taking a pre-release perspective, we address several factors that complicate the analysis in most existing studies of piracy. This helps us draw causal inference in a more direct way. Finally, pre-release piracy may be qualitatively different than other types of piracy: whereas in other types of piracy those with low willingness to pay may disproportionately use the pirated copies, in the case of pre-release piracy those who download the pirated copy are likely to be the most enthusiastic customers, potentially making the threat of sales loss more severe.

We note that there are several limitations of the data used in this study. First, although we can infer the existence of pre-release piracy from our data, we do not have information on the intensity of pre-release downloads of the pirated copies. Having download intensity information could further strengthen the causal inference of the impact of piracy. Second, piracy may impact different types of movies to different extents. With a richer dataset, we could analyze these differential effects. Third, our information on piracy quality is limited to self-reported subjective evaluations of users of a single website. Having more robust "quality" information would allow us to better evaluate the differential impact of "high" and "low" quality piracy leaks on theatrical revenue. Fourth, in our data we only observe box-office revenue and not subsequent revenues from other important sources like DVD sales. These data limitations point to potential useful directions for future research on this important topic.

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