



Management Science

Publication details, including instructions for authors and subscription information:
<http://pubsonline.informs.org>

Culling the Herd: Using Real-World Randomized Experiments to Measure Social Bias with Known Costly Goods

Miguel Godinho de Matos, Pedro Ferreira, Michael D. Smith, Rahul Telang

To cite this article:

Miguel Godinho de Matos, Pedro Ferreira, Michael D. Smith, Rahul Telang (2016) Culling the Herd: Using Real-World Randomized Experiments to Measure Social Bias with Known Costly Goods. *Management Science* 62(9):2563-2580. <https://doi.org/10.1287/mnsc.2015.2258>

Full terms and conditions of use: <http://pubsonline.informs.org/page/terms-and-conditions>

This article may be used only for the purposes of research, teaching, and/or private study. Commercial use or systematic downloading (by robots or other automatic processes) is prohibited without explicit Publisher approval, unless otherwise noted. For more information, contact permissions@informs.org.

The Publisher does not warrant or guarantee the article's accuracy, completeness, merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications, or inclusion of an advertisement in this article, neither constitutes nor implies a guarantee, endorsement, or support of claims made of that product, publication, or service.

Copyright © 2016, INFORMS

Please scroll down for article—it is on subsequent pages

INFORMS is the largest professional society in the world for professionals in the fields of operations research, management science, and analytics.

For more information on INFORMS, its publications, membership, or meetings visit <http://www.informs.org>

Culling the Herd: Using Real-World Randomized Experiments to Measure Social Bias with Known Costly Goods

Miguel Godinho de Matos

UCP–Católica Lisbon School of Business and Economics, 1649-023 Lisbon, Portugal,
miguel.godinhomatos@ucp.pt

Pedro Ferreira

Heinz College and Department of Engineering and Public Policy, Carnegie Mellon University,
Pittsburgh, Pennsylvania 15213, pedrof@cmu.edu

Michael D. Smith, Rahul Telang

Heinz College, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213
{mds@cmu.edu, rtelang@cmu.edu}

Peer ratings have become increasingly important sources of product information, particularly in markets for information goods. However, in spite of the increasing prevalence of this information, there are relatively few academic studies that analyze the impact of peer ratings on consumers transacting in “real-world” marketplaces. In this paper, we partner with a major telecommunications company to analyze the impact of peer ratings in a real-world video-on-demand market where consumer participation is organic and where movies are costly and well known to consumers. After experimentally changing the initial conditions of product information displayed to consumers, we find that, consistent with the prior literature, peer ratings influence consumer behavior independently from underlying product quality. However, we also find that, in contrast to the prior literature, there is little evidence of long-term bias as a result of herding effects, at least in our setting. Specifically, when movies are artificially promoted or demoted in peer rating lists, subsequent reviews cause them to return to their true quality position relatively quickly. One explanation for this difference is that consumers in our empirical setting likely had more outside information about the true quality of the products they were evaluating than did consumers in the studies reported in prior literature. Although tentative, this explanation suggests that in real-world marketplaces where consumers have sufficient access to outside information about true product quality, peer ratings may be more robust to herding effects and thus provide more reliable signals of true product quality than previously thought.

Keywords: herding behavior; randomized experiment; likes; video on demand

History: Received May 28, 2014; accepted March 2, 2015, by Lorin M. Hitt, information systems. Published online in *Articles in Advance* February 15, 2016.

1. Introduction

Consumers constantly acquire information to make purchase decisions. This is particularly true in the context of “experience goods” where the quality and fit of the product are important to the consumer but difficult to evaluate *ex ante* (Nelson 1970). In this context, the Internet makes it easier for users to both acquire and provide product information and feedback. As a result, ratings, rankings, and review information have all become more prevalent online, particularly for experience goods—and the literature suggests that their increasing prevalence may result in increased market efficiency and consumer surplus if the reported product quality accurately reflects the underlying sentiment of the community (Brynjolfsson et al. 2003).

However, in spite of the increasing prevalence of peer review systems and their potential importance for market efficiency, there are relatively few studies that empirically analyze consumer behavior in the context of user-generated product information and even fewer papers that analyze the impact of user-generated reviews in markets with real consumers, real products, and real monetary transactions. The scarcity of academic studies in real-world marketplaces is of course understandable: the simultaneity between user ratings and product quality makes it nearly impossible to make causal statements about the impact of user-generated information from observational data (Aral et al. 2009), and running a randomized field experiment in a real-world marketplace is extremely challenging because of the difficulty in

obtaining merchant cooperation to conduct experiments for academic research.

Our research seeks to contribute to the literature by running such a real-world field experiment through a unique collaboration with a prominent telecommunications provider—hereafter called OurTelco—who conducted an experiment using their video-on-demand (VoD) system. During this experiment a new menu was introduced in this VoD system that showed the “most popular movies during the past weeks.” OurTelco randomly changed the order of movies (and number of reported “likes”) displayed in this menu as a way of experimentally identifying their impact on consumption decisions. This experiment ran for 24 weeks starting in July 2012. During this time, 22,043 users leased movies from this new menu at prices ranging from \$1.30 to \$5.20.

The experimental approach described above allows for separating the role played by the number of likes from the underlying (unobserved) quality of the product. Consistent with the existing literature, we find that an increase in the number of likes of a movie (that is, user-generated promotion) increases its sales independently of its underlying quality. However, in contrast to the existing literature, our results reveal little evidence of herding effects; that is, manipulated initial conditions do not lead to significantly different market outcomes in the long run. We find that, on average, weekly movie sales increase by 4% when a movie is promoted one rank. However, across all manipulations introduced during this experiment, a movie promoted to a better rank receives, on average, 15.9% fewer sales and 33.1% fewer likes than a movie naturally placed at that rank would receive. Likewise, a movie demoted to a worse rank receives 27.7% more sales and 30.1% more likes than a movie naturally placed at that rank would receive. We further find that these differences are moderated by how well known the manipulated movie is (as measured by number of IMDb votes)—in particular, better-known movies are less sensitive to manipulations than other movies are. For example, the effect of a rank manipulation per rank manipulated is 84% lower for more popular movies—measured as being in the top quartile of the distribution of the IMDb votes—relative to movies in the other quartiles. Thus, our results suggest that promotion through user-generated likes can increase sales, but that, at least in our context, the wisdom of the crowds can correct both positive and negative manipulations, neutralizing the impact of potential herding effects.

One possible explanation for the difference between our results and those reported in the prior literature is that, in our case, consumers likely had more outside information about the products being evaluated (i.e., widely promoted movies) than did consumers in

existing studies (e.g., obscure songs in Salganik et al. 2006, wedding vendors in Tucker and Zhang 2011, and breaking news in Muchnik et al. 2013). Although tentative, and perhaps context specific, this explanation raises the possibility that an increase in the availability of outside information to consumers, combined with the “wisdom of the crowds” present in user-generated reviews, may neutralize rating bias from herding effects in real-world marketplace settings.

2. Related Work

Our research is most closely related to the academic literature analyzing the impact of social cues on user behavior and, particularly, the impact of herding behavior on peer evaluations of quality. Many papers have noted the difficulty in separating social influence from actual product quality given the natural relationship between the underlying “quality” of the product and the resulting social cues (see, for example, Manski 1993, Aral et al. 2009, Aral 2010, Aral and Walker 2011, Shalizi and Thomas 2011, and Bapna and Umyarov 2015). Several papers have overcome these challenges using randomized experiments. For example, in a seminal paper, (Salganik et al. 2006) created two virtual markets for songs from unknown bands and recruited a group of subjects on a teen interest website. Each subject was randomly assigned to one of these markets. Songs were ordered randomly in one of the markets and ordered according to the number of downloads in the other market. Subjects were asked to choose songs to listen to, to rate these songs, and then to download them for free if they wished. The authors found that reported popularity was self-reinforcing for all but the very best or worst songs.

In a follow-up study, (Salganik and Watts 2008) ran a similar experiment using similar songs and a similar pool of subjects. In the setup phase, they asked participants to listen to the songs and rate them. Then they ordered songs according to these ratings so that better songs would come last and thus seem worse. In this setting, they observed that, over time, all songs (good or bad) tended to converge to their true download rank. Taken together, these studies show that self-fulfilling prophecies in these markets are constrained by the individuals’ private preferences.

Tucker and Zhang (2011) developed a similar experiment using an online hub for wedding service vendors to explore the impact of popularity on the number of clicks that each vendor obtained. This experiment was conducted in a real-world setting with organic consumers, which obviates some of the concerns with the lab experiments described in Salganik et al. (2006) and Salganik and Watts (2008). During their experiment, the authors displayed vendors in three different categories. In one category

vendors were sorted in decreasing order of the number of clicks received. In another category vendors were sorted in increasing order of the number of clicks received. In both cases, vendors were listed along with the number of clicks received. In the last category vendors were sorted alphabetically, and no information was displayed regarding the number of clicks the vendor received. The authors compared vendors across different categories, before and during their experiment, to determine the impact of popularity (measured by the number of clicks received) on future clicks. They conclude that popularity is self-reinforcing and that vendors that operate in narrower markets benefit the most from this dynamic.

More recently, Muchnik et al. (2013) examined the behavior of consumers in a social news aggregator website. The authors ran a large-scale organic experiment, which obviates most of the concerns with the lab experiments that Salganik et al. (2006) and Salganik and Watts (2008) ran into, and observed user feedback, as opposed to just clicks received as in Tucker and Zhang (2011). During this experiment, users were put in three conditions: in one treatment condition, users saw a positive vote on a comment; in another treatment, users saw a negative vote; and the control group was not manipulated. The authors found that the probability of an “up vote” was much higher when users initially saw a positive vote than in the control condition, which suggests a herding effect, but they found no significant effect when users saw a negative vote. They conclude that herding effects are asymmetric: users seemed to exhibit a desire to correct negative bias but otherwise follow the herd. Positive herding was also different for different topics and shaped by whether users were commenting on friends’ or enemies’ opinions. The authors conclude that herding increased the likelihood of positive ratings by 32%, resulting in a 25% increase, on average, in ratings after five months, a large bias driven solely by initial conditions.

Our paper differs from these studies along several important dimensions. In our setting the goods provided are not free. Subscribers have to make explicit decisions that involve financial risks. The price to lease movies in our VoD setting varied between \$1.30 and \$5.20. In Salganik et al. (2006) and Salganik and Watts (2008), songs could be downloaded for free, and as such, subjects did not incur any financial risk in either listening to or downloading a song. Likewise, Tucker and Zhang (2011) observed click-through rates on websites but did not observe actual purchase decisions. In addition, consumers in our setting (i.e., widely promoted movies) may have relatively more outside information about the quality of the products than did consumers in the studies outlined above (e.g., obscure songs, wedding vendors,

news stories). This may mediate the effects observed. Finally, Salganik et al. (2006) and Tucker and Zhang (2011) measured the impact of popularity on sales, versus our setting in which we measure the impact of user feedback (likes) on sales. It is possible that likes reflect subscribers’ tastes and their assessment of quality differently.

In addition to these papers, our research relates to the literature analyzing the impact of quality signals on user behavior. In the context of the movie industry, most papers have used observational data (as opposed to experimental results) for their analysis. For example, Litman (1983) analyzed 125 movies released in the United States between 1972 and 1978, and Wallace et al. (1993) analyzed 1687 movies released in the United States between 1956 and 1988. Both papers report a positive correlation between box office sales and reviews by movie critics. However, in a later paper, (Eliashberg and Shugan 1997) found that ratings from movie critics are not good predictors of sales during the opening week, arguing that despite being correlated with cumulative movie sales, critics’ ratings do not causally influence sales.

Likewise, Godes and Mayzlin (2004) studied 44 TV shows released in the United States between 1999 and 2000. They found that the dispersion in word of mouth (WoM) about these shows across distinct groups in Usenet groups was positively correlated to their ratings. However, they were unable to establish a link between WoM, measured by number of conversations about a show, and future rankings, which correlate to sales. Similarly, Liu (2006) studied data from message boards at Yahoo! Movies for about 40 movies released between May and September 2002 in the United States, finding that the volume of WoM was positively correlated with box office sales but that there was no statistically significant relationship between the sentiment implied in the messages (positive/negative comments) and sales.

These findings suggest a potential correlation between unobserved quality and ratings that might be driving any observed impact of reviews on sales. Some papers have attempted to disentangle this correlation. For example, Reinstein and Snyder (2005) applied a difference in difference model on a sample of more than 600 movies rated by two influential movie critics to identify the marginal impact of reviews on sales. Using the fact that some movie reviews were issued prior to the release of the movie and others were issued after the opening week, they showed that—in contrast to Eliashberg and Shugan (1997)—ratings from movie critics were positively correlated with sales and influenced box office sales during the opening week.

In a similar context, Zhang and Dellarocas (2006) developed a structural model to study the impact

of consumer and movie critic ratings on sales. They showed that good reviews drove movie sales but that the volume and dispersion of reviews did not. Likewise, Dellarocas et al. (2007) developed a predictive model for movie sales showing that the volume, valence, and dispersion of reviews were all positive and statistically significant predictors of box office sales. Finally, Duan et al. (2008) proposed a model with simultaneous equations to estimate both user movie ratings and movie box office sales. They conclude that WoM is a strong driver of box office sales, in contrast to the findings in Zhang and Dellarocas (2006).

3. Experimental Context

3.1. The Company and Its Data Set

The experiment analyzed in this paper was performed using a real-world VoD system from a multinational telecommunications provider, hereinafter called OurTelco. OurTelco offers TV, Internet, telephone, and mobile phone service and is the market leader for pay-TV services in the geography that we study. It serves over one million households, 69% of which purchase triple-play bundles that include TV, Internet, and fixed telephony.

We had access to OurTelco's VoD database between February 2009 and December 2012. During this period we observe 89,074,657 transactions, of which 6,293,557 correspond to paid leases.

We have the anonymized identifier of the subscriber requesting each transaction as well as the anonymized identifier for the media access control address of the specific set-top box (STB) that did so. For each transaction we have a time stamp, the price, and the identifier of the leased movie. For each movie in OurTelco's

database, we have the title, director, studio, play length, synopses, cast, genres, and asset type (movie, music, documentary, etc.). We also have information on the daily layout of the TV screen that subscribers saw when they logged into the VoD system. This information includes the tree of menus displayed as well as the rank order in which movies were displayed under each menu on the screen from left to right. Menus are associated with different editorial lines as described in the next section. We also have daily information on the number of likes issued to each movie.

3.2. VoD Service and Interface

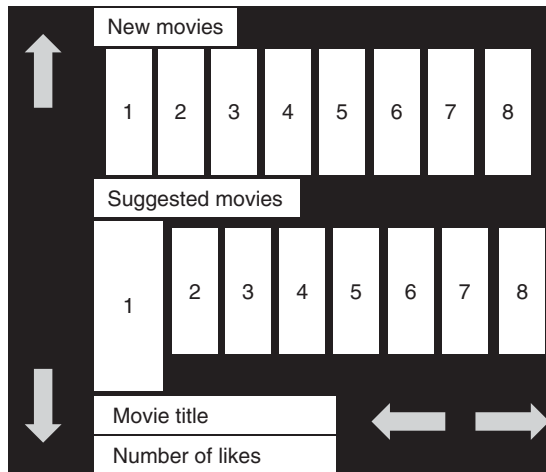
OurTelco provides service over wired and satellite infrastructure. Subscribers can obtain one of three types of services: basic, standard, or premium. All subscribers, regardless of type, can watch TV and subscribe to specific channels such as movies, sports, children's, and adult content. Figure 1 summarizes the services available to each subscriber. For our setting it is important to note that only standard and premium subscribers can use the VoD service and only premium subscribers can issue likes for VoD movies and TV programs. As such, in this paper, we will focus only on standard and premium subscribers (respectively, 84% and 16% of OurTelco's VoD-enabled subscribers in January 2012).

The look and feel of the VoD screen for standard and premium subscribers is different, but the organization of the content into menus is hierarchically similar. Both standard and premium subscribers can access the VoD system using a hot key in their STB remote control. Pressing this hot key displays the entry screen of the VoD system. This screen, called the "highlights section," contains a set of menus filled with movies, chosen by an editorial team, which are

Figure 1 Summary of the Main Features Available to Subscribers of OurTelco

Feature	Basic/Legacy	Standard	Premium
Watch TV	Yes	Yes	Yes
Subscribe to thematic channels	Yes	Yes	Yes
Video on demand	No	Yes	Yes
DVR capabilities	No	Yes	Yes
Restart TV features	No	No	Yes
Like ability and Facebook link	No	No	Yes
Mandatory Internet connection service	No	No	Yes

Figure 2 Example of the Interface Look and Feel in the Highlights Section

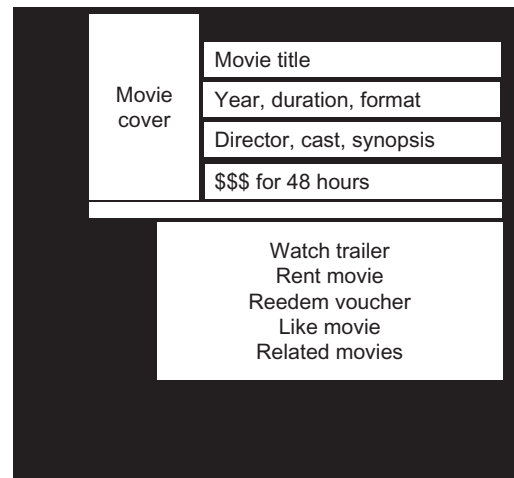


easy to access based on their location on the screen. Movies are organized into menus such as promotions, suggestions, and newest releases. Each menu has a header with a name that clearly identifies the type of movies it contains. Menus are horizontal lines on the screen. Different menus are stacked vertically. Two menus fit the screen at each time. A cursor highlights a single movie cover at a time. Users can scroll across menus. The natural scrolling direction is down, though premium consumers can also scroll up. Figure 2 depicts the look and feel of the main screen of the highlights section for premium consumers.

Upon scrolling to a new menu, a number of movie covers are visible under that menu, and the cursor highlights the movie farthest to the left. Premium users see eight movie covers under each menu immediately. Standard subscribers see either four or eight movie covers under each menu, depending on whether they connect their TV to their set-top box using a SCART or a HDMI cable. Unfortunately, we do not know the type of cable used by each standard subscriber. Users can also scroll right and left within the same menu. All users can scroll past the last movie cover on the screen to unveil hidden movies under the same menu. OurTelco displays at most 15 movies per menu. Premium and standard subscribers see the same number of movies under the same menu.

The title of the movie highlighted by the cursor is shown on the screen. Premium consumers also see the number of likes for this movie. Clicking on the cover of a movie leads to a new screen with the year of release, play length, cast, and synopsis. A number of actions are then available, including the ability to lease the movie, use a promotional coupon, or watch the movie trailer (if one is available). Figure 3 provides an illustration of the title page of a movie.

Figure 3 Example of the Movie Page in the Video-on-Demand System



Finally, subscribers can leave the Highlights Section of the VoD interface and search for movies in the complete *catalog*. The catalog is hierarchically organized into content categories such as movies, music, TV shows, and documentaries. Within each of these categories, screens are organized as described above with menus for genres. In addition to browsing through the entire catalog, subscribers can use a keyword search function to look for specific content based on movie titles, movie directors, and actors' names.

The number of likes shown along with movie covers is cumulative from the movie's debut at OurTelco's VoD system. Subscribers do not know who liked a particular movie or how many people leased a particular movie.

4. Experimental Design

The experiment discussed here is based on a new menu, named "the most popular movies during the past weeks," that was introduced in the highlights section of OurTelco's VoD system on July 3, 2012. This menu was available for both standard and premium subscribers and included the 15 movies that obtained the highest number of likes in the last few weeks. These movies were shown under this menu in decreasing order of number of likes from left to right. The experiment ran in one-month cycles for a period of six consecutive months. Each cycle was further split into mini-cycles of one week each. Each week started at a time of low VoD usage—namely, Tuesdays at approximately 2 P.M. Weeks were named true or false. During a true week, all movies under this menu were shown in their true rank. The true number of likes they obtained in the recent past was shown to premium consumers. During a false week, a randomized procedure was used to swap some movies under this menu.

Formally, the experiment ran as follows: Let t_i represent the time at which cycle i began, with $i \in \{1, 2, 3, 4, 5, 6\}$. Let x represent a week's time. At time t_i , all movies in OurTelco's VoD system were sorted according to the number of likes received between $t_i - 2x$ and t_i . All movies that OurTelco decided to use in other menus under the highlights section were removed from this sorted list. For example, some movies were displayed under the promotions or newest releases menus. Cleaning these movies from the above list avoided displaying them under more than one menu in the highlights section. OurTelco's log system does not allow for identifying the menu under the highlights section from which a lease originates, and thus this cleaning procedure ensures that leases of movies under the new menu came only from this menu. The 45 movies at the head of the resulting list were used in the experiment, which we call list L . Movies in list L had, on average, more likes than the movies displayed in other menus ($p < 0.001$) of the highlights section.

After the setup phase described above, which took place at the beginning of each cycle, a true week ensued to adjust the subscribers' expectations to the true quality of the movies shown under the new menu. The nature of each of the other three weeks within every cycle was determined at random. This allowed for preventing a static pattern of true/false weeks that subscribers could perceive. Table 1 shows the order of true and false weeks during the experiment.

At the beginning of every week, all movies in L were sorted according to the number of likes that they obtained between $t_i - 2x$ and $t_i + nx$ with $n \in \{1, 2, 3\}$ indicating how many weeks elapsed since the start of the current cycle. In a true week, the first 15 movies in L were displayed under the new menu from left to right on the TV screen. In false weeks, list L was partitioned into three sublists. List L_1 comprised the 15 movies at the head of list L . List L_2 included the movies between ranks 16 and 30 in list L . Finally, list L_3 contained the movies positioned between ranks 31 and 45 in list L . Then, the following swaps were performed:

- *Within swap*: y_i and y_j were selected randomly from $\{1, \dots, 15\}$ such that $y_i \neq y_j$, and the number of likes associated with the y_i th and y_j th movies in list L_1 were swapped.
- *Between swap*: z_i was selected randomly from $\{1, \dots, 15\}$ such that $z_i \neq y_i$ and $z_i \neq y_j$, and z_j was selected randomly from $\{1, \dots, 15\}$. Then, the number of likes of the z_i th movie in list L_1 was swapped with the number of likes of the z_j th movie in either list L_2 or list L_3 .

Two within swaps and one between swap were performed at each false week during the first three cycles of the experiment. The latter alternated between

Table 1 Cycles and the Nature of Subcycles During Our Experiment

Cycle 1	t_1 : True	$t_1 + x$: True	$t_1 + 2x$: False	$t_1 + 3x$: False
Cycle 2	t_2 : True	$t_2 + x$: False	$t_2 + 2x$: True	$t_2 + 3x$: False
Cycle 3	t_3 : True	$t_3 + x$: False	$t_3 + 2x$: False	$t_3 + 3x$: True
Cycle 4	t_4 : True	$t_4 + x$: False	$t_4 + 2x$: False	$t_4 + 3x$: False
Cycle 5	t_5 : True	$t_5 + x$: False	$t_5 + 2x$: False	$t_5 + 3x$: False
Cycle 6	t_6 : True	$t_6 + x$: False	$t_6 + 2x$: True	$t_6 + 3x$: False

lists L_2 and L_3 . Three within swaps and two between swaps were performed at each false week, one involving L_2 and one involving L_3 , during the last three cycles of the experiment. The frequency of swaps in the final three cycles of the experiment was increased to obtain more treated observations.

The movies in list L_1 were then displayed under the new menu from left to right on the TV screen. The two types of random swaps introduced with this experiment were aimed at capturing the particular characteristics of the look and feel of OurTelco's VoD interface. Within swaps allow for determining whether changes in ranks across the movies displayed under the new menu have an impact of sales. Between swaps allow for determining the impact of bringing movies from the catalog into the new menu and of removing movies from the new menu into the catalog. A within swap changes the search cost of the swapped movies only slightly, but a between swap reduces substantially the search costs for a movie that is promoted from the catalog to the new menu and increases substantially the search costs for a movie that is demoted from the new menu into the catalog. Figure 4 illustrates the swap procedures that take place in false weeks.

5. Empirical Model

5.1. Movie-Level Specification

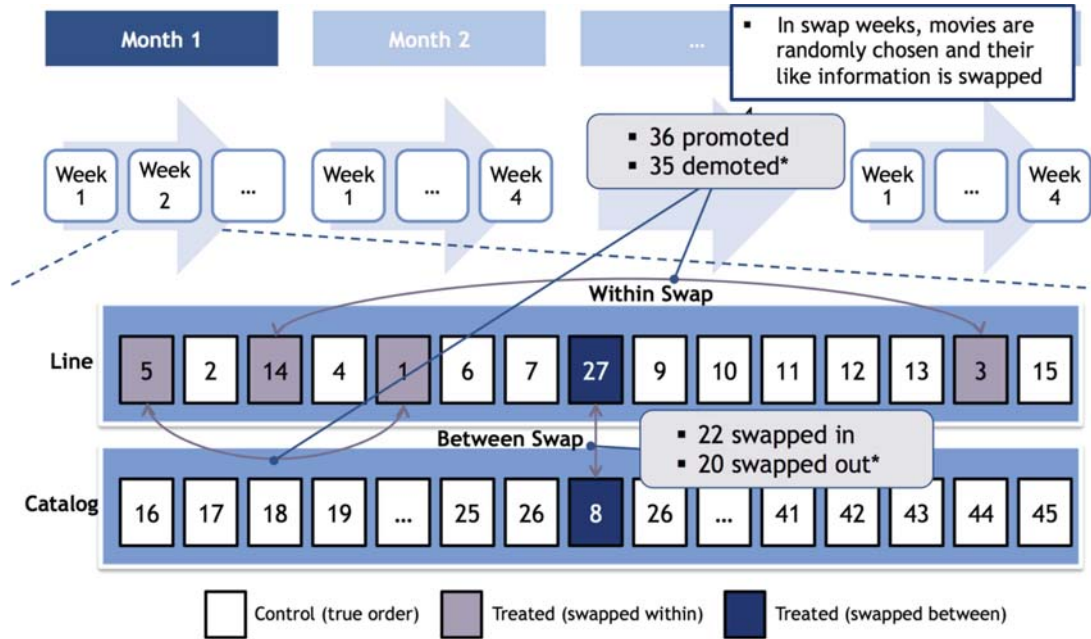
We use the following reduced form equation to study the effect of rank on sales:

$$y_{it} = \alpha + x_{it}\beta + w_{it}\gamma + m_i + u_{it}, \quad t = 1, \dots, T, \quad (1)$$

where y_{it} represents the sales of movie i during week t ; x_{it} includes time-varying observed movie characteristics such as age, rank, and the number of distinct menus where the movie is displayed;¹ w_{it} is the vector of exogenous random treatments; m_i are time-constant movie fixed effects such as price; and u_{it} is an idiosyncratic error term. This equation represents the classic fixed effects specification, which we

¹ The same movie can be labeled under several genres and therefore appears in several menus in the VoD catalog. We control for how many times the movie appears in all menus because this affects exposure to consumers.

Figure 4 (Color online) Graphical Illustration of the Randomization Procedure Used to Swap Movie Positions and Likes Under the New Menu That Was Introduced in the Video-on-Demand Interface During the Experiment



* We discarded 3 swaps because such movies were simultaneously used by OurTelco in other menus in the highlights.

estimate using first differences with robust standard errors. Therefore, we estimate the following model:

$$\Delta y_{it} = \Delta x_{it}\beta + \Delta w_{it}\gamma + \Delta u_{it}, \quad t = 2, \dots, T. \quad (2)$$

Note that the time-constant movie fixed effects in Equation (1) drop despite being observed. In particular, the retail price drops from our regression. Price includes a fixed margin on the top of the royalty fee, and the latter did not change during our experiment. Furthermore, prices do not change in response to changes in demand in our setting as OurTelco does not engage in dynamic pricing.

5.2. The Magnitude of Treatment

Consider movies A and B under the new menu in ranks a and b , respectively, at time $t_i + nx$, with $n < 3$. When these movies are swapped, their new ranks in list L are, momentarily, b and a , respectively. At time $t_i + (n+1)x$, movies in this list are reordered according to number of likes, as described before. As a result, assume that the movie at rank a shifts to rank a' and the movie at rank b shifts to rank b' . Subscribers see only the cumulative effect of swaps and sorting. Thus, from their perspective, movie A moved from rank a to rank b' (a change of $b' - a$ ranks) and movie B moved from rank b to rank a' (a change of $a' - b$ ranks).

If the swap did not occur, subscribers would have seen that movie A moved from rank a to rank a' and movie B moved from rank b to rank b' . Therefore, the effect of the random exogenous swap is given by $(b' - a) - (a' - a) = b' - a'$ for movie A and by $(a' - b) -$

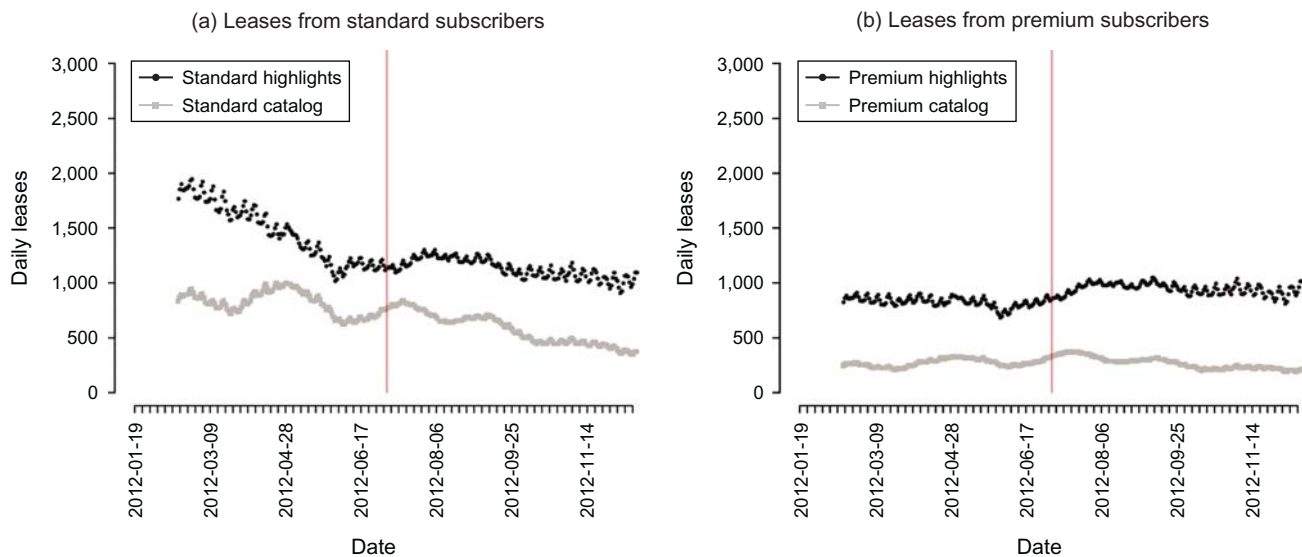
$(b' - b) = a' - b'$ for movie B . Note that this difference is zero for control movies. We introduce this difference, which hereafter we call *rank_manipulation*, into Δw_{it} in Equation (2). We code it so that it is positive when a movie is promoted and negative when a movie is demoted. Also, a' and b' are the true ranks for movie A and B , respectively, which hereafter we call *TrueRank*. Therefore, we have $Rank = TrueRank - RankManipulation$.

5.3. Identification and Exogeneity

Identification is obtained by design in our setting. In Equation (2), Δw_{it} is not correlated to Δu_{it} because movie swaps are randomly and exogenously determined. The two movies involved in a swap are randomly selected and the timing of the swap is also random. Therefore, movies are treated at random and the magnitude of the treatment is also random. Random assignment of the treatment also ensures that Δw_{it} is uncorrelated to Δx_{it} . Therefore, our estimates for γ in Equation (2) obtained with ordinary least squares are unbiased.

5.4. Rank-Level Specification

Movies are reordered according to the number of likes at the beginning of each week. This establishes a truthful relationship between rank and perceived quality for control movies in the eyes of OurTelco's subscribers. Therefore, we can compare the sales obtained by control and treated movies at each rank and determine whether promoted or demoted movies

Figure 5 (Color online) Thirty-Day Moving Average of Daily Leases in Highlights and Catalog in OurTelco's VoD

sell differently than true movies placed at that rank. A true movie at a rank is a movie that was placed at this rank as a result of the number of likes obtained from subscribers, as opposed to being manipulated. If sales at a rank are not different when the movie at that rank is manipulated, then rank alone determines movie sales. We test this hypothesis with the following model:

$$y_{rt} = \alpha + x_{rt}\beta + w_{rt}\gamma + m_r + u_{rt}, \quad t = 1, \dots, T, \quad (3)$$

where y_{rt} represents the sales of the movie at rank r during week t ; x_{rt} includes observed characteristics of the movie at rank r in week t , such as age, price, IMDb rating, and the number of distinct menus where the movie appears; m_r is the intrinsic perceived quality of rank r ; and u_{rt} is an idiosyncratic error term. The term w_{rt} is a vector of exogenous random treatments indicating whether the movie at rank r in week t was promoted, demoted, or neither. A promoted movie should have, on average, lower quality than the movie it displaces and as a result may possibly sell less. Conversely, a demoted movie should have, on average, higher quality than the movie it displaces and may possibly sell more. We estimate Equation (3) using a dummy variable for each rank.

6. Results and Discussion

6.1. Descriptive Statistics

The combined stock of standard and premium consumers at OurTelco grew from 607,000 in January 2012 to 633,000 in December 2012.² Figure 5 shows the 30-day moving average of daily sales in the highlights section

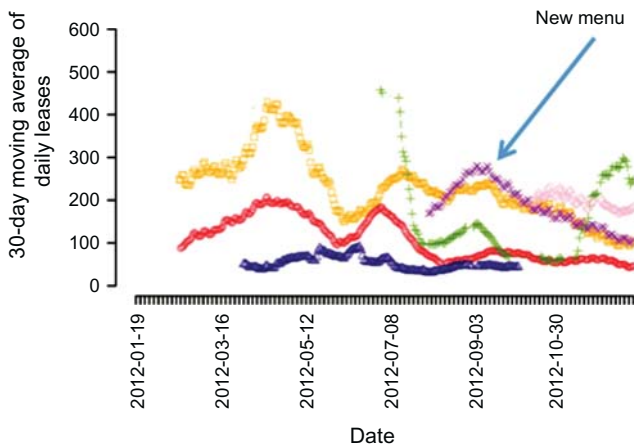
and in the catalog for premium and standard subscribers. Most sales came from standard subscribers, though this gap reduced significantly toward the end of the year as the number of standard subscribers decreased and they started leasing fewer movies. Sales increased both in the highlights section and in the catalog around the time the experiment started. Figure 6 shows the 30-day moving average of daily sales for menus under the highlights section (except for the most seen during the last week and newest releases, which sold more than the menus shown in this figure). This figure shows that the new menu was well received by consumers and started selling well. The new menu sold more than any other menu shown in this figure during the first 10 weeks of the experiment. At week 10, OurTelco introduced two new menus into the highlights section, called “the most seen of all times” and “the most popular on IMDb.” These menus competed with the menu used for the experiment both in terms of consumer attention and movies. In fact, when a movie under “the most popular during the past weeks” was also among the most seen of all times or the most popular on IMDb, it would be pulled into the latter two menus and deleted from the former to avoid duplication.

Figure 7 shows the weekly sales in the new menu over time. Unlike overall VoD consumption, the

premium users leased an average of 1,100 movies per day. This increased to 1,200 during the second half of the year. These statistics were 2,300 and 1,700, respectively, for standard users. Yet the average number of leases per subscriber decreased from 3.2 to 1.1 from the first to the second half of the year for premium subscribers. These statistics were 1.8 and 1.5 for standard subscribers, respectively. During the first half of 2012, 75% of the leases from premium users originated in the highlights section. This statistic increased to 79% in the second half of the year. These statistics were 64% and 68% for standard users, respectively.

² The share of VoD-enabled premium subscribers increased from 16% to 34% during the same period. In the first half of 2012,

Figure 6 (Color online) Thirty-Day Moving Average of Daily Leases in Highlights per Menu in OurTelco's VoD



majority of sales under this menu came from premium subscribers. The new menu was visible in the entry screen of the VoD system for premium subscribers and reachable with one click up, whereas standard subscribers did not see this menu immediately when they entered the highlights section and needed to click 10 times down to reach it. In addition, standard subscribers do not see the number of likes, which might have rendered this menu less meaningful to them.

A total of 22,043 subscribers leased movies from the new menu. Roughly 80% of the subscribers leasing movies from the new menu did so only once during the experiment.

Panel (a) in Figure 8 shows the number of likes per rank in the beginning of each week. This is a decreasing function by design and we observe a clear exponential decay in likes as a function of rank. Panel (b) in Figure 8 shows the number of leases during the

Figure 7 (Color online) Sales in the New Menu During the Experiment

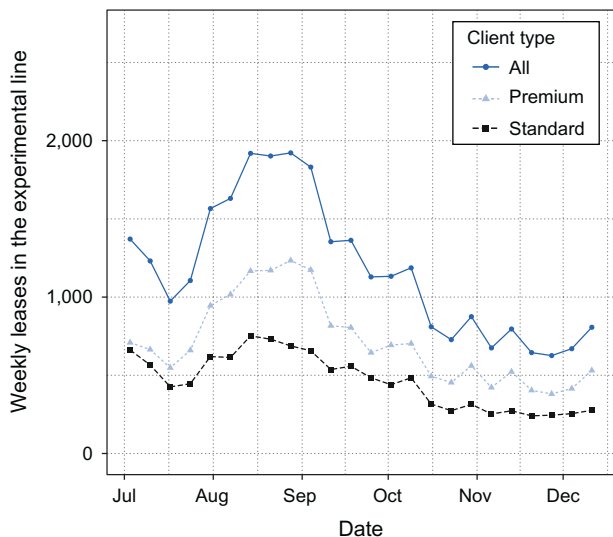
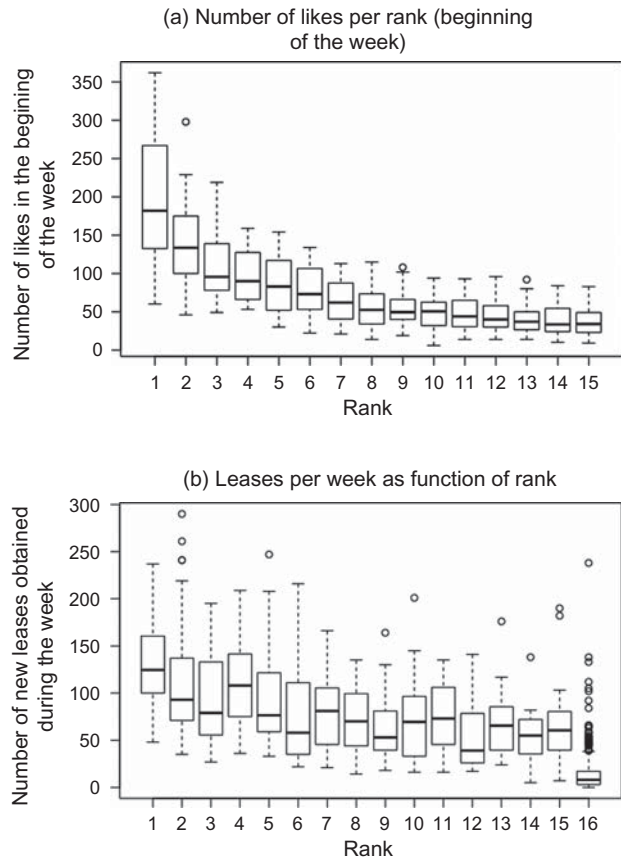


Figure 8 Likes in the Beginning of the Week and Leases per Week as Function of Rank at the New Menu



week per rank. This function, however, is far from monotonic, which might suggest that subscribers use information besides rank and number of likes to decide which movies to watch.

Figure 9 shows the relationship between the change in the number of leases obtained per week and the manipulation in rank introduced during the experiment.

Figure 9 (Color online) Relationship Between Changes in Sales and Rank Manipulation During the Experiment

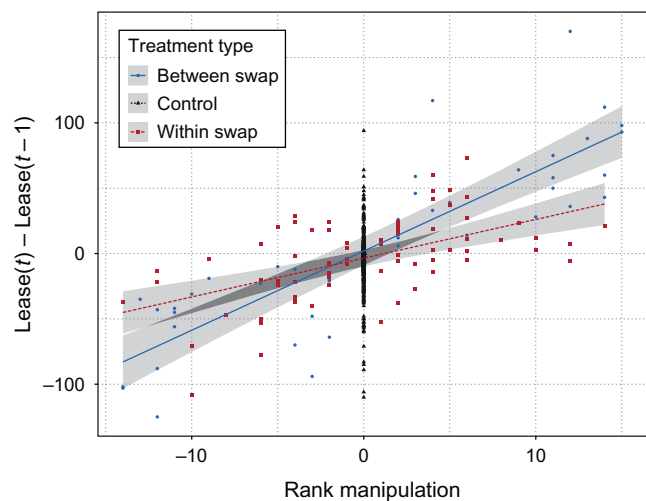
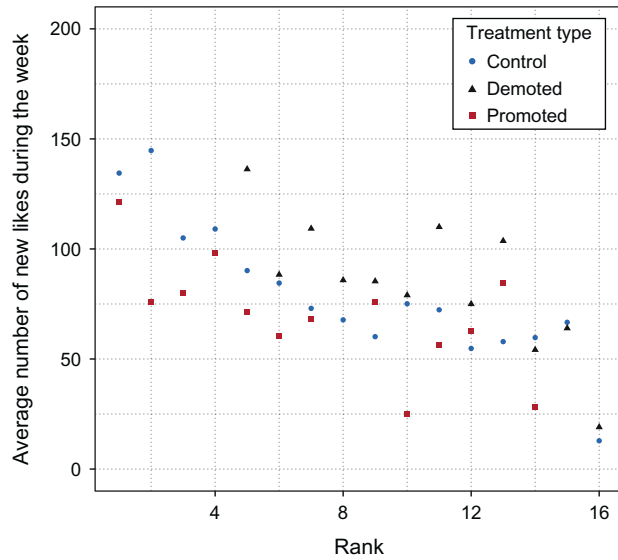


Figure 10 (Color online) Likes per Week as a Function of Rank for All, Control, and Treated Movies at the New Menu



This figure provides preliminary evidence that promoted (demoted) movies sold more (less) and that the effect of between swaps dominates the effect of within swaps. Figure 10 shows that, on average, promoted (demoted) movies tend to receive fewer (more) likes than untreated movies do. This provides preliminary evidence that manipulated movies might return

to their true ranks when they are reordered in subsequent weeks according to the number of likes.

Finally, Table 2 shows descriptive statistics for the covariates used in this paper separately for all movies and for control and treated movies in the catalog and in the highlights section. *t*-Tests to compare means between control and treated movies show they are all similar, which is as expected given our random treatment assignment. Treated movies in the catalog are movies in lists *L2* and *L3* that are randomly selected to be displayed in the highlights section. All other movies in these two lists are control movies in the catalog. We code the rank of all movies in these two lists as 16.

6.2. The Effect of Movie Swaps

We estimate Equation 4 (which resembles Equation 1) to learn the effect of rank on leases. In this regression, *Treated_Within* × *Rank_Manipulation* denotes the size of a rank manipulation within the top 15 ranks. *Promoted_to_Line* and *Demoted_from_Line* denote the size of rank manipulations that lead a movie to go from the catalog into the new menu or to move from the new menu into the catalog, respectively. These three types of manipulations constitute a partition of the space of possible manipulations, and therefore their coefficients must be interpreted relative to our

Table 2 Descriptive Statistics for All Covariates Used by Catalog (*L2* and *L3*) and Highlights (*L1*)

Variable	Stats	All	Catalog (<i>L2</i> and <i>L3</i>)		Highlights (<i>L1</i>)	
			Control	Treated	Control	Treated
<i>Number_of_Leases</i>	Mean	36.341	12.85	19.05	80.461	82.29
	SD	45.788	18.201	18.735	50.758	45.904
<i>Number_of_Leases_(Premium)</i>	Mean	19.648	4.174	6.9	48.23	51.527
	SD	29.136	6.124	7.247	33.785	30.23
<i>Number_of_Leases_(Standard)</i>	Mean	16.693	8.676	12.15	32.23	30.763
	SD	19.262	12.644	12.123	20.839	20.25
<i>Rank</i>	Mean	13.311	16	16	8.531	7.151
	SD	4.487	0	0	4.197	4.369
<i>True_Rank</i>	Mean	13.348	16	8	8.531	9.28
	SD	4.438	0	4.472	4.197	5.247
<i>Rank_Manipulation</i>	Mean	0.037	0	−8	0	2.129
	SD	2.5	0	4.472	0	6.811
<i>Number_of_Menus</i>	Mean	1.984	1.708	1.65	2.609	2.258
	SD	1.058	0.932	0.813	1.193	0.674
<i>Price</i>	Mean	287.741	260.883	324	331.617	346.312
	SD	92.662	84.763	96.655	90.21	74.951
<i>IMDb_Rating</i>	Mean	6.328	6.31	5.98	6.427	6.253
	SD	1.242	1.215	1.485	1.261	1.304
<i>IMDb_Votes</i>	Mean	82,434.666	87,387.516	73,270.75	80,008.728	58,978.022
	SD	114,271.836	117,701.293	168,947.22	111,504.825	76,944.554
<i>Movie_Age</i>	Mean	250.257	291.779	266.294	166.844	187.112
	SD	380.553	415.368	429.838	277.441	314.458
Observations		1,017	648	20	256	93

control movies. *Treated* indicates whether a movie has been treated:

$$\begin{aligned}
 Leases_{it} &= \lambda + \beta_1 \log(Movie_Age_{it}) + \beta_2 Number_of_Menus_{it} \\
 &+ \beta_3 Treated_{it} + \beta_4 True_Rank_{it} \\
 &+ \beta_5 Treated_Within \times Rank_Manipulation_{it} \\
 &+ \beta_6 Promoted_to_Line_{it} + \beta_7 Demoted_from_Line_{it} \\
 &+ Week_Dummies + m_i + \epsilon_{it}. \quad (4)
 \end{aligned}$$

Table 3 shows the results obtained with first differences for all subscribers and separately for standard and premium subscribers. The coefficient on *Treated_Within* × *Rank_Manipulation* shows that a promoted (demoted) movie receives more (fewer) leases than other movies do. This result is statistically significant for both standard and premium subscribers, although less for the former. On average, a manipulation that increases rank by one leads to 2.3 (0.5) more leases from premium (standard) subscribers. This corresponds to a 4.7% (1.6%) increase in the number of leases. Promoting a movie to the new menu increases 7.2 (2.1) times the number of leases from premium (standard) subscribers, on average. This significant jump is associated with the difference in search costs between the catalog and the highlights section. Demoting movies from the new menu

yields the opposite effect for premium subscribers: the number of leases reduces by 37%. The effect of demotions from the new menu is not statistically significant for standard subscribers. The new menu was much harder to reach for standard subscribers, and thus standard subscribers that use this menu might already be more willing to search for good movies. We also note that, as expected, given the random assignment of treatments in our experiment, the coefficient on *Treated* is not statistically significant.

Other covariates behave as expected. The effect of age is negative, showing that movies tend to sell less as they become old. The effect of number of menus is positive, showing that movies displayed in more menus tend to sell more. The effect of true rank is negative for premium consumers, showing that better-ranked movies tend to sell more. This coefficient is not statistically significant for standard subscribers, which again might indicate that these consumers are more willing to search for good movies to watch.

Swapping the order in which movies were displayed under the new menu was accomplished by swapping their number of likes as described in §4. Therefore, we can also look at the effect of the number of likes on sales. In fact, and on average across all manipulations introduced during our experiment, promoting a movie by one rank was associated with an increase of 12 likes. We define *Likes_Manipulation* to indicate the exogenous change in the number of likes of the manipulated movies. This covariate is 0 by design for control movies. If movie *A* at rank *a* with *l_a* likes swaps with movie *B* at rank *b* with *l_b* likes, with *a* > *b* and thus *l_a* > *l_b*, then *Likes_Manipulation* = *l_a* − *l_b* for movie *B* and *Likes_Manipulation* = *l_b* − *l_a* for movie *A*. Table 4 shows the effect of likes on leases. Each additional like increases weekly sales by 0.22 units.

The effect of rank on sales reported before was assumed constant across ranks, but in fact, promoting a movie from rank 15 to rank 14 may be very different from promoting a movie from rank 2 to rank 1. Ideally, we would measure each of these effects separately, but we do not have enough data to do so. However, we can still show that promoting a movie by one rank changes sales differently at different ranks if, for example, we assume a linear trend for this effect. Such a trend can be captured by interacting *Rank_Manipulation* with *True_Rank*. Table 5 shows the results obtained. We estimate the average effect of rank manipulation to be 5.18 and the effect of the interaction to be −0.31. These results suggest, as expected, that promotions have a stronger effect for higher ranks than for lower ranks: a promotion from rank 2 to rank 1 increases weekly sales by 4.56, whereas a promotion from rank 8 to rank 7 increases weekly sales by 2.69 only.

Table 3 The Effect of Swaps Within the New Menu and Between the New Menu and the Catalog on Sales

Subscribers = Model = Dependent variable =	All FD <i>Leases_{it}</i>	Standard FD <i>Leases_{it}</i>	Premium FD <i>Leases_{it}</i>
(Intercept)	−5.621* (3.083)	−2.693 (1.637)	−2.928 (1.805)
$\log(Movie_Age)$	−11.852** (5.617)	−11.775*** (3.657)	−0.076 (2.788)
<i>Number_of_Menus</i>	12.3*** (3.253)	5.731*** (1.678)	6.569*** (1.824)
<i>Treated</i>	1.356 (3.039)	0.387 (1.039)	0.969 (2.571)
<i>True_Rank</i>	−0.62 (0.752)	0.137 (0.555)	−0.756** (0.321)
<i>Treated_Within</i> × <i>Rank_Manipulation</i>	2.821*** (0.488)	0.509* (0.278)	2.313*** (0.333)
<i>Promoted_to_Line</i>	36.31*** (6.091)	9.366*** (2.084)	26.945*** (4.579)
<i>Demoted_from_Line</i>	−23.039*** (7.091)	−4.848 (3.131)	−18.191*** (4.646)
Week dummies	Yes	Yes	Yes
Observations	817	817	817
R-squared	0.448	0.264	0.478
R-squared adj.	0.431	0.254	0.461
F-stat (<i>p</i> -value)	0	0	0

Note. Robust standard errors are in parentheses; first differences (FD) estimator.

p* < 0.1; *p* < 0.05; ****p* < 0.01.

Table 4 The Effect of Swapping Likes Within the New Menu and Between the New Menu and the Catalog on Sales

Subscribers = Model = Dependent variable =	All FD <i>Leases_{it}</i>	Standard FD <i>Leases_{it}</i>	Premium FD <i>Leases_{it}</i>
(Intercept)	−6.824** (3.266)	−2.865* (1.683)	−3.959** (1.893)
$\log(\text{Movie_Age})$	−10.687* (5.967)	−11.92*** (3.857)	1.233 (3.028)
<i>Number_of_Menus</i>	13.062*** (3.283)	5.649*** (1.607)	7.413*** (1.89)
<i>Treated</i>	0.974 (2.291)	0.317 (0.973)	0.657 (1.98)
<i>True_Likes</i>	−0.011** (0.005)	−0.002 (0.003)	−0.009** (0.004)
<i>Treated_Within</i> × <i>Likes_Manipulation</i>	0.219*** (0.03)	0.038* (0.02)	0.181*** (0.021)
<i>Promoted_to_Line</i>	35.659*** (5.551)	9.494*** (2.01)	26.166*** (4.094)
<i>Demoted_from_Line</i>	−21.599*** (5.296)	−5.352** (2.413)	−16.247*** (3.5)
Week dummies	Yes	Yes	Yes
Observations	817	817	817
R-squared	0.472	0.266	0.513
R-squared adj.	0.455	0.256	0.495
F-stat (<i>p</i> -value)	0	0	0

Note. Robust standard errors are in parentheses; first differences (FD) estimator.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Another way to see that the effect of manipulations is not constant across ranks is to consider what happens in the visible and in the hidden parts of the menu. Table 6 shows the results obtained when we interact *Rank_Manipulation* with whether the manipulation occurs within ranks 1–8 (visible part), within ranks 9–15 (hidden part), from ranks 1–8 to ranks 9–15, or from ranks 9–15 to 1–8. Swaps within the visible part of the menu have a significant impact on sales (2.5 times more than that associated to swaps between the visible and the hidden parts of the menu), but swaps within the hidden part of the menu do not seem to change sales. Note, however, that this analysis is performed only for premium subscribers because we cannot know for sure how many movies are shown in the visible part of the menu to standard subscribers.

6.3. Robustness Check

Treated movies receive a number of likes that is different from what they otherwise would. Consequently, they might be displayed in a rank different from the rank they would otherwise occupy when at the end of a false week swaps are reverted. One approach to circumvent this problem is to ignore treated movies within the same month after they are first treated. Yet some treated movies remain in our panel from one month to the next. Thus, a second approach to address this problem is to ignore treated movies once

Table 5 The Effect of Swaps on Sales Across Ranks Within the New Menu

Subscribers = Model = Dependent variable =	All FD <i>Leases_{it}</i>	Standard FD <i>Leases_{it}</i>	Premium FD <i>Leases_{it}</i>
(Intercept)	−5.948* (3.116)	−2.854* (1.635)	−3.095* (1.828)
$\log(\text{Movie_Age})$	−11.291** (5.608)	−11.5*** (3.573)	0.209 (2.856)
<i>Number_of_Menus</i>	12.188*** (3.254)	5.676*** (1.664)	6.512*** (1.836)
<i>Treated</i>	6.951* (3.593)	3.136** (1.31)	3.815 (2.908)
<i>True_Rank</i>	−0.481 (0.754)	0.205 (0.556)	−0.686** (0.325)
<i>True_Rank</i> × (<i>Rank_Manipulation</i> × <i>Treated_Within</i>)	−0.312*** (0.11)	−0.153*** (0.041)	−0.159* (0.088)
<i>Treated_Within</i> × <i>Rank_Manipulation</i>	5.184*** (0.918)	1.669*** (0.504)	3.515*** (0.63)
<i>Promoted_to_Line</i>	30.913*** (6.382)	6.713*** (2.175)	24.199*** (4.833)
<i>Demoted_from_Line</i>	−28.528*** (7.245)	−7.545** (3.28)	−20.983*** (4.631)
Week dummies	Yes	Yes	Yes
Observations	817	817	817
R-squared	0.464	0.284	0.488
R-squared adj.	0.447	0.273	0.469
F-stat (<i>p</i> -value)	0	0	0

Note. Robust standard errors are in parentheses; first differences (FD) estimator.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 6 The Effect of Manipulations in the Visible and Hidden Parts of the New Menu

Subscribers = Model = Dependent variable =	Premium FD <i>Leases_{it}</i>	Premium FD <i>Leases_{it}</i>
<i>Rank_Manipulation</i>	2.282*** (0.329)	
<i>Rank_Manipulation</i> × <i>To_01_08</i>		1.762*** (0.344)
<i>Rank_Manipulation</i> × <i>To_09_15</i>		1.726** (0.723)
<i>Rank_Manipulation</i> × <i>Within_01_to_08</i>		4.448*** (0.687)
<i>Rank_Manipulation</i> × <i>Within_09_to_15</i>		0.478 (1.371)
<i>Promoted_to_Line</i>	31.700*** (3.024)	31.570*** (3.046)
<i>Demoted_from_Line</i>	−19.700*** (3.347)	−19.590*** (3.372)
<i>Constant</i>	−3.191** (1.589)	−3.190** (1.607)
Week dummies	Yes	Yes
Observations	817	817
R-squared	0.447	0.476
R-squared adj.	0.433	0.459
F-stat (<i>p</i> -value)	0	0

Note. Robust standard errors are in parentheses; first differences (FD) estimator.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 7 Movie-Level Regression Results Ignoring Treated Movies After Treatment

Subscribers = Model =	All Original	All Trimmed month	All Trimmed whole	Standard Original	Standard Trimmed month	Standard Trimmed whole	Premium Original	Premium Trimmed month	Premium Trimmed whole
Dependent variable =	$Leases_{it}$	$Leases_{it}$	$Leases_{it}$	$Leases_{it}$	$Leases_{it}$	$Leases_{it}$	$Leases_{it}$	$Leases_{it}$	$Leases_{it}$
(Intercept)	-5.621* (3.083)	-5.068* (2.711)	-5.4* (2.83)	-2.693 (1.637)	-2.419 (1.565)	-2.567 (1.601)	-2.928 (1.805)	-2.649* (1.559)	-2.833* (1.608)
$\log(Movie_Age)$	-11.852** (5.617)	-15.077** (6.026)	-16.646*** (6.284)	-11.775*** (3.657)	-13.841*** (4.035)	-14.634*** (4.169)	-0.076 (2.788)	-1.235 (3.24)	-2.013 (3.218)
$Number_of_Menus$	12.3*** (3.253)	7.009** (2.773)	6.76** (2.767)	5.731*** (1.678)	3.641** (1.49)	3.643** (1.494)	6.569*** (1.824)	3.369** (1.606)	3.117** (1.585)
<i>Treated</i>	1.356 (3.039)	-0.386 (3.361)	2.68 (5.318)	0.387 (1.039)	0.407 (1.528)	1.542 (2.421)	0.969 (2.571)	-0.794 (2.484)	1.138 (3.523)
<i>True_Rank</i>	-0.62 (0.752)	0.618 (1.043)	0.73 (1.142)	0.137 (0.555)	0.878 (0.881)	0.926 (0.976)	-0.756** (0.321)	-0.26 (0.372)	-0.196 (0.383)
<i>Treated_Within</i> × <i>Rank_Manipulation</i>	2.821*** (0.488)	3.108*** (0.667)	3.2*** (0.895)	0.509* (0.278)	0.478 (0.325)	0.491 (0.55)	2.313*** (0.333)	2.63*** (0.459)	2.709*** (0.635)
<i>Promoted_to_Line</i>	36.31*** (6.091)	54.33*** (7.82)	55.661*** (10.475)	9.366*** (2.084)	15.722*** (3.109)	16.268*** (4.34)	26.945*** (4.579)	38.608*** (5.381)	39.393*** (6.813)
<i>Demoted_from_Line</i>	-23.039*** (7.091)	-45.169*** (10.206)	-42.083*** (13.879)	-4.848 (3.131)	-14.677*** (4.756)	-11.093* (6.116)	-18.191*** (4.646)	-30.492*** (6.308)	-30.99*** (8.789)
Week dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	817	687	596	817	687	596	817	687	596
R-squared	0.448	0.502	0.493	0.264	0.321	0.326	0.478	0.524	0.53
R-squared adj.	0.431	0.48	0.469	0.254	0.307	0.31	0.461	0.501	0.504
F-stat (p-value)	0	0	0	0	0	0	0	0	0

Note. Robust standard errors are in parentheses; first differences (FD) estimator.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

they are first treated until the end of the experiment. In this section, we test the degree to which prior treatment may bias our results by conducting a robustness test using both approaches described above.

Table 7 shows the results obtained using these approaches for all consumers, standard consumers alone, and premium consumers alone. The columns marked “Trimmed month” refer to the former approach; the columns marked “Trimmed experiment” refer to the latter. Columns marked “Original” replicate the results in Table 3 to facilitate the comparison. Our results remain unchanged when we ignore treated movies after first treatment, although this, of course, results in fewer observations, which increases our standard errors. Therefore, it is reasonable to believe that this type of contamination does not hurt our findings.

6.4. The Role of Rank in the VoD System

During the experiment, some movies were sometimes exogenously and randomly swapped and thus shown in fake ranks. This variability allows us to study whether a movie placed in a fake rank sells differently from a true movie placed at that rank. To do so, we estimate Equation (5) (which resembles Equation (3)):

$$Leases_{rt} = \lambda + \beta_1 \log(Movie_Age_{rt}) + \beta_2 Number_of_Menus_{rt} + \beta_3 Price_{rt} + \beta_4 IMDb_Rating_{rt}$$

$$+ \beta_5 Promoted \times Treated_Within_{rt} + \beta_6 Demoted \times Treated_Within_{rt} + \beta_7 Promoted \times Treated_Between_{rt} + \beta_8 Demoted \times Treated_Between_{rt} + Week_Dummies + Rank_Dummies + Genre_Dummies + Year_Release_Dummies + \epsilon_{rt}. \quad (5)$$

This regression allows us to compare the number of leases obtained by treated and control movies at each rank. *Promoted* (*Demoted*) indicates a movie that was promoted (demoted) to a fake rank. *Treated_Between* indicates whether a rank manipulation entails moving a movie from the catalog to the new menu, or vice versa. Therefore, the four types of manipulations included in this regression constitute a partition of the space of possible manipulations, and thus their coefficients should be interpreted relative to our control movies.

Table 8 shows the results obtained. The first three columns in this table show the effect of rank manipulations on the number of leases, and the last column shows the effect of rank manipulations on the number of likes. A movie that is demoted to a fake rank within the new menu sells 27.7% more than a true movie at that rank. Consumers are still able to spot high-quality movies even if they have been shifted to the right on the TV screen under the new

Table 8 The Effect of Promotions and Demotions on Sales Relative to Movies at True Ranks

Subscribers = Dependent variable =	Leases			Likes
	All <i>Leases_{rt}</i>	Standard <i>Leases_{rt}</i>	Premium <i>Leases_{rt}</i>	Premium <i>Likes_{rt}</i>
(Intercept)	63.134*** (18.904)	0.986 (10.935)	62.148*** (10.906)	45.615*** (5.808)
<i>Promoted</i> × <i>Treated_Within</i>	-12.184* (7.308)	-2.789 (3.221)	-9.396* (5.108)	-7.614*** (2.584)
<i>Demoted</i> × <i>Treated_Within</i>	22.348*** (7.034)	7.756* (4.501)	14.592*** (4.21)	6.955*** (2.511)
<i>Promoted</i> × <i>Treated_Between</i>	-4.331 (8.566)	1.09 (3.391)	-5.421 (5.832)	-7.853** (3.156)
<i>Demoted</i> × <i>Treated_Between</i>	5.686 (4.448)	4.35* (2.451)	1.336 (2.524)	1.241 (1.051)
<i>log(Movie_Age)</i>	-3.103*** (1.178)	-1.814*** (0.689)	-1.289** (0.633)	-0.305 (0.275)
<i>Number_of_Menus</i>	4.000* (2.106)	3.891*** (1.207)	0.109 (1.063)	1.276** (0.531)
<i>Price</i>	-0.005 (0.026)	-0.006 (0.016)	0.002 (0.013)	0.01* (0.006)
<i>IMDb_Rating</i>	3.541** (1.429)	1.005 (0.717)	2.536** (1.096)	1.112* (0.576)
Week dummies	Yes	Yes	Yes	Yes
Rank dummies	Yes	Yes	Yes	Yes
Genre dummies	Yes	Yes	Yes	Yes
Year release dummies	Yes	Yes	Yes	Yes
Observations	1,001	1,001	1,001	1,001
<i>R</i> -squared	0.759	0.631	0.775	0.777
<i>R</i> -squared adj.	0.697	0.58	0.713	0.714
<i>F</i> -stat (<i>p</i> -value)	0	0	0	0

Note. Robust standard errors are in parentheses.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

menu. This is true for both standard and premium subscribers, though the result is less statistically significant for the former. These results suggest that subscribers use additional information besides rank to decide which movies to watch. We provide more detail on this hypothesis below. Conversely, a movie that is promoted to a fake rank within the new menu sells 15.9% less than a true movie at that rank. However, this result is weaker than the effect of demotions within the new menu. Both its magnitude and its statistical significance are lower. In fact, this effect is only statistically significant for premium subscribers.

The last column in Table 8 shows the effect of promotions and demotions on the number of likes obtained. A movie promoted to a fake rank receives 33.1% fewer likes than a true movie at that rank, and a movie demoted to a fake rank receives 30.1% more likes than a true movie at that rank. This result suggests that, over time, manipulated movies are likely to come back to their true ranks. We explore this hypothesis in more detail below. In addition, note that the coefficients for the effects of manipulations interacted with *Treated_Between* are statistically

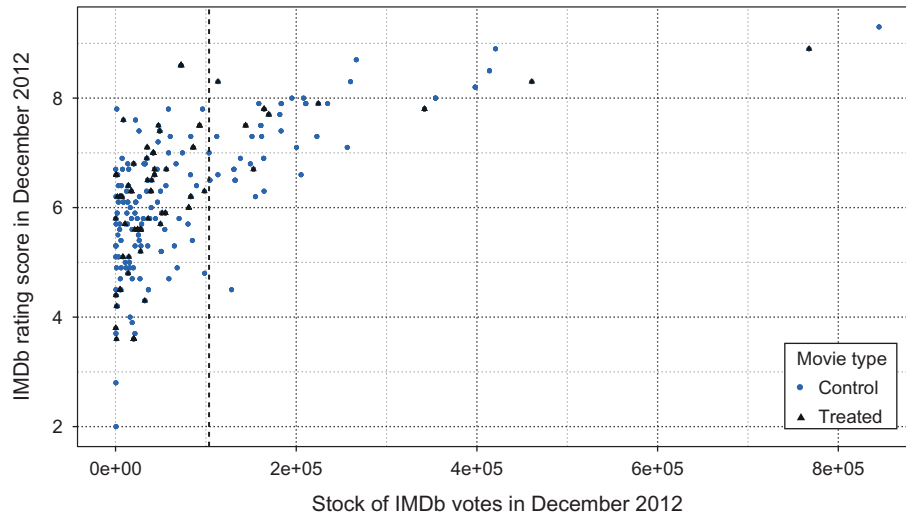
insignificant, which means that search costs dominate the effect of manipulations. If anything, standard subscribers lease demoted movies more than true movies, suggesting that standard subscribers are more willing to search for movies to watch than premium subscribers are.

6.5. The Role of Outside Information

In this section we test whether outside information about the movies shown at OurTelco's VoD system mediates the effect of promoting and demoting movies. We use the number of IMDb votes as a proxy for how well movies are known to consumers in general. The number of IMDb votes indicates how many people evaluated a movie irrespective of the rating provided. Figure 11 shows that there is significant variation in the number of IMDb votes across movies in our sample. This is not surprising given the well-established superstar effect in the movie industry, whereby a disproportionate amount of attention is concentrated on a small number of movies (Elberse and Oberholzer-Gee 2007). In addition, both IMDb votes and IMDb ratings are similar between control and treated movies. We hypothesize that the movies in OurTelco's VoD system that have more outside information are less sensitive to the exogenous random manipulations introduced in this experiment. This would be consistent with the findings in Tucker and Zhang (2011) showing that products with broader appeal are less likely to benefit from the popularity they obtain at the specific platforms where they are sold. Salganik and Watts (2008) also report similar results, but their measure of appeal is endogenous to the population of subjects used in their experiment.

We classify each movie in our sample according to the number of IMDb votes it received prior to December 2012. We define a dummy variable called *Top_25_IMDb_Votes* to indicate whether a movie is in the top quartile of the distribution of IMDb votes in our sample. (Movies in the top quartile of the IMDb votes distribution are to the right of the dashed lined in Figure 11.) We estimate Equation 4, adding an interaction term between *Rank_Manipulation* and this dummy variable. In this regression, the interaction term captures the difference in the effect of rank manipulations for movies in the top quartile of the distribution of IMDb votes relative to the effect on all the other movies in our sample that were also manipulated. Table 9 presents the resulting estimates. The effect of the interaction between *Rank_Manipulation* and *Top_25_IMDb_Votes* is negative and statistically significant, confirming our hypothesis. The effect of a rank manipulation per rank manipulated is 84% lower for movies in the top quartile of the distribution of the IMDb votes relative to movies in the other quartiles, indicating that better-known movies are less susceptible to manipulations.

Figure 11 (Color online) IMDb Votes and Ratings Across Movies in Our Sample



6.6. The Effect of Price

Although price is static in this experiment, we can still observe whether it moderates the effect of manipulations. To do so, we interact price with the size of our manipulations. We create two dummy variables: (1) *Price* > \$3.99, which identifies movies in the top half of the price distribution; and (2) *Price* = \$5.19,

which identifies movies in the top quartile of the price distribution. Table 10 shows the results obtained for all consumers and for standard and premium consumers separately. As expected, users seem to follow more the number of likes for more expensive movies—in particular, premium consumers who can issue likes and see the number of likes in the VoD system.

Table 9 The Role of IMDb Votes on the Effect of Rank Manipulations on Leases

Subscribers = Model = Dependent variable =	All FD <i>Leases_{it}</i>	Standard FD <i>Leases_{it}</i>	Premium FD <i>Leases_{it}</i>
(Intercept)	-5.698* (3.092)	-2.723* (1.647)	-2.975* (1.802)
log(<i>Movie_Age</i>)	-11.932** (5.624)	-11.807*** (3.665)	-0.125 (2.78)
<i>Number_of_Menus</i>	12.346*** (3.268)	5.749*** (1.682)	6.597*** (1.833)
<i>Treated</i>	1.193 (2.901)	0.323 (1.037)	0.87 (2.479)
<i>True_Rank</i>	-0.674 (0.756)	0.115 (0.559)	-0.789** (0.322)
<i>Treated_Within</i> × <i>Rank_Manipulation</i>	3.031*** (0.51)	0.591* (0.304)	2.44*** (0.345)
<i>Treated_Within</i> × <i>Rank_Manipulation</i> × <i>Top_25_IMDb_Votes</i>	-2.547** (1.133)	-1.001* (0.552)	-1.546** (0.678)
<i>Promoted_to_Line</i>	36.439*** (6.031)	9.416*** (2.087)	27.023*** (4.532)
<i>Demoted_from_Line</i>	-23.461*** (6.736)	-5.014* (3.025)	-18.447*** (4.439)
Week dummies	Yes	Yes	Yes
Observations	817	817	817
R-squared	0.452	0.267	0.482
R-squared adj.	0.435	0.257	0.463
F-stat (<i>p</i> -value)	0	0	0

Note. Robust standard errors are in parentheses; first differences (FD) estimator.

p* < 0.1; *p* < 0.05; ****p* < 0.01.

6.7. Convergence to True Ranks and Effect on Sales

The last column in Table 8 shows that promoted movies obtain fewer likes than the movies they displace and demoted movies obtain more likes than the

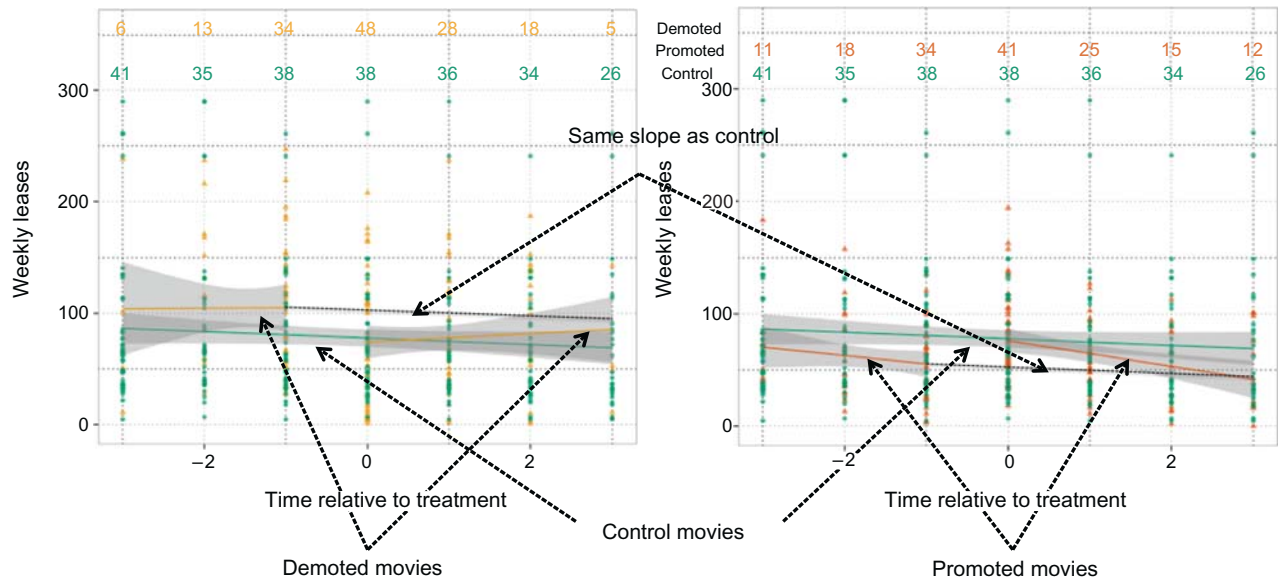
Table 10 The Mediating Effect of Price on the Effect of Rank Manipulations

Subscribers = Model = Dependent variable =	Standard FD <i>Leases_{it}</i>	Standard FD <i>Leases_{it}</i>	Premium FD <i>Leases_{it}</i>	Premium FD <i>Leases_{it}</i>
<i>Rank_Manipulation</i> × (<i>Price</i> > US\$3.89)	0.614* (0.357)		2.195*** (0.581)	
<i>Rank_Manipulation</i> × (<i>Price</i> = US\$5.19)		0.506 (0.356)		1.907*** (0.585)
<i>Rank_Manipulation</i>	0.070 (0.259)	0.154 (0.257)	0.658 (0.403)	0.887** (0.406)
<i>Promoted_to_Line</i>	13.480*** (1.930)	13.480*** (1.931)	31.630*** (3.003)	31.620*** (3.002)
<i>Demoted_from_Line</i>	-8.444*** (2.424)	-8.430*** (2.422)	-19.990*** (3.328)	-19.950*** (3.326)
Week dummies	Yes	Yes	Yes	Yes
Observations	817	817	817	817
R-squared	0.215	0.214	0.466	0.461
R-squared adj.	0.208	0.207	0.450	0.446
F-stat (<i>p</i> -value)	0	0	0	0

Note. Robust standard errors are in parentheses; first differences (FD) estimator.

p* < 0.1; *p* < 0.05; ****p* < 0.01.

Figure 12 (Color online) Convergence of Sales to Pretreatment Levels for Demoted Movies (on the Left) and for Promoted Movies (on the Right)



movies they displace. Unfortunately, we are unable to observe long-term effects in our experiment because swaps were reverted at the end of every false week. Yet these results provide suggestive evidence that manipulated movies are likely to return to their true ranks as long as movies under the new menu are periodically ordered according to the number of likes received.

The panels in Figure 12 illustrate how the sales of manipulated movies converge to their pretreatment levels over time. The horizontal axes represent time relative to the moment of treatment. The vertical axes represent, for a particular time t in the horizontal axis, the average number of weekly leases across all movies in our sample that were t weeks away from their treatment date. On the top of each panel we indicate over how many movies each average is computed.³ All movies tend to sell less over time before treatment mostly because of aging.

The panel on the left shows that promoted movies sell significantly more immediately after treatment. However, their sales reduce significantly with time, matching the level of sales they might have had had they not been promoted in roughly four weeks. Counterfactual sales are obtained from the sales trends exhibited by control movies. The panel on the right shows that demoted movies sell significantly less immediately after treatment, but their sales increase significantly with time to roughly match the counterfactual level of sales also in four weeks.

This suggests that the self-fulfilling prophecies reported in the literature do not seem to hold on in our setting. Although promoted (demoted) movies initially sell (more) less, these biases seem to correct themselves over time and do not lead to the long-term herding effects observed in other papers in the literature.

As discussed before, there are several differences between our study and the studies in the prior literature that may be driving this difference in results. One notable difference is that the consumers in our study likely have more outside information about the products they are purchasing (i.e., widely promoted movies) than did consumers in some of the other settings exhibiting “herding effects” reported in the literature (e.g., obscure music, wedding vendors, breaking news stories). The increased availability of outside information in our context may cause our consumers to rely less heavily on the information about the products available in this specific marketplace (i.e., the number of likes in the VoD system) than other studies in the literature where outside information about products may have been less available to consumers. However, it is also possible that the differences in results could be driven by other differences between our setting and the settings studied in the prior literature (e.g., the nature of the user interface, the cultural or product context, the number of products under review). As we note below, these differences deserve further study.

6.8. Economic Impact of Within Swaps

We run an analysis at the swap level to estimate their economic impact. Each pair of ranks X and Y becomes an observation (X and Y vary between 1 and 15). In

³ Note that some movies were treated more than once. To avoid confounding subsequent treatments on the same movie, in this analysis we only include the first treatment of a movie and its data up to a second treatment, or up to the end of the panel if the movie was only treated once.

Table 11 Effect of Swaps Within the New Menu on Sales

Subscribers = Dependent variable =	All <i>Leases_{it}</i>	Standard <i>Leases_{it}</i>	Premium <i>Leases_{it}</i>
<i>Treated_Movie_Pair</i>	23.284** (9.950)	9.896** (4.817)	13.387** (6.610)
<i>Constant</i>	233.374*** (16.230)	92.099*** (7.857)	141.275*** (10.782)
Week dummies	Yes	Yes	Yes
Swap dummies	Yes	Yes	Yes
Observations	348	348	348
<i>R</i> -squared	0.706	0.589	0.706
<i>R</i> -squared adj.	0.659	0.525	0.660
<i>F</i> -stat (<i>p</i> -value)	0	0	0

Note. Includes only swaps within the new menu.

p* < 0.1; *p* < 0.05; ****p* < 0.01.

some weeks, at random, the movies in these ranks were swapped. This constitutes a treated pair of movies at these ranks. In the remaining weeks, the pair of movies at these ranks is used as control. We add the sales of the movies in ranks X and Y and compare them between treated and control weeks. We add both week and swap dummies to our regressions. Tables 11 and 12 show the results obtained for sales and revenues, respectively. We observe that swaps within the new menu increase both sales and revenues for both standard and premium consumers. According to the first column of Table 12, on average, swapping two movies increases their revenues by roughly 22.6%.

In addition, we also look at the effect of swaps on how much consumers like movies. Similar to the approach above, in this analysis we compare the number of likes per lease obtained by movies in ranks X and Y when the movies in these ranks were and were not swapped. Table 13 shows that swaps reduce the number of likes per lease. The second column of this table shows that a swap within the new menu reduces this ratio by roughly 15.7%. Note that the analysis of likes per lease refers only to premium consumers, which are the ones that can issue likes and see the

Table 12 Effect of Swaps Within the New Menu on Revenues

Subscribers = Dependent variable =	All $\text{Log}(\text{Revenue}_{it})$	Standard $\text{Log}(\text{Revenue}_{it})$	Premium $\text{Log}(\text{Revenue}_{it})$
<i>Treated_Movie_Pair</i>	0.226*** (0.081)	0.244*** (0.091)	0.205** (0.084)
<i>Constant</i>	7.102*** (0.133)	6.124*** (0.149)	6.563*** (0.136)
Week dummies	Yes	Yes	Yes
Swap dummies	Yes	Yes	Yes
Observations	348	348	348
<i>R</i> -squared	0.668	0.615	0.671
<i>R</i> -squared adj.	0.617	0.555	0.619
<i>F</i> -stat (<i>p</i> -value)	0	0	0

Note. Includes only swaps within the new menu.

p* < 0.1; *p* < 0.05; ****p* < 0.01.

Table 13 Effect of Swaps Within the New Menu on Likes

Subscribers = Dependent variable =	Premium <i>Week_likes_leases_{it}</i>	Premium $\text{Log}(\text{Week_likes_leases}_{it})$
<i>Treated_Movie_Pair</i>	-0.087* (0.045)	-0.157** (0.067)
<i>Constant</i>	0.773*** (0.073)	-0.275** (0.110)
Week dummies	Yes	Yes
Swap dummies	Yes	Yes
Observations	348	348
<i>R</i> -squared	0.496	0.551
<i>R</i> -squared adj.	0.417	0.481
<i>F</i> -stat (<i>p</i> -value)	0	0

Note. Includes only swaps within the new menu.

p* < 0.1; *p* < 0.05; ****p* < 0.01.

number of likes. These results provide suggestive evidence that, in the short run, OurTelco is better off in the presence of movie swaps but consumers seem to be worse off. Therefore, and in the long run, fewer likes for the movies leased in this VoD system may turn into fewer sales as consumers lose trust in the VoD recommendations. Hence, OurTelco is unlikely to be able to use within swaps to increased revenues.

7. Conclusions

Although user-generated product information has become increasingly prevalent in online markets, there are relatively few empirical studies that analyze the impact of user-generated signals of product quality in real-world settings. We attempt to fill this gap in the literature by partnering with a major telecommunications provider who implemented an online experiment to determine the role that likes play in VoD movie sales. The VoD system of this provider was used during 24 weeks in 2012 as an experimental setting. As part of this experiment, a new menu titled “the most popular movies during the past weeks” was introduced in the highlights section of this provider’s VoD system. Movies with more likes were shown farthest to the left on the TV screen. During this experiment, movies were primarily placed in their true rank and shown along with their true number of likes. However, the position of some movies was manipulated such that a random set of movies were swapped and displayed out of order and with a fake number of likes. This randomization allows us to disentangle likes from unobserved perceived quality to identify the effect of the former on sales.

Our main finding is that sales and ratings of movies in our sample seem to be robust to artificial manipulations and do not exhibit strong herding effects seen in the prior literature. Although, on average, promoted (demoted) movies still sell more (less) 3.5%, we find that a movie artificially promoted to a fake slot sells 15.9% less and receives 33.1% fewer

likes than a “true” movie in that slot, on average. Likewise, a movie artificially demoted to a fake slot sells 27.7% more and receives 30.1% more likes than a true movie in that slot, on average. Together, these results suggest that, at least in our setting, manipulated movies will move back to their true location relatively quickly (in our setting, within one month). We also show that better-known movies are less sensitive to manipulations (return to their true location more quickly) than are other movies.

One explanation for this finding is that consumers in our empirical setting have relatively more “outside information” about the quality of the products being evaluated (i.e., widely promoted movies) than did consumers in many of the other settings reported in the literature (e.g., obscure songs, breaking news stories, wedding vendors). Although tentative, and perhaps context specific, this explanation would suggest that potential bias from herding effects could be muted in many real-world marketplace settings where consumers have outside information about the true quality of the products they are evaluating. We also acknowledge that, contrary to previous studies, in our setting consumers need to make explicit decisions that involve financial risks. The price to lease movies in the VoD system used in this experiment varied between \$1.30 and \$5.20. It might be the case that when consumers have to pay for goods, their feedback attenuates social bias more accurately. In sum, our study provides some evidence that real-world organic markets for well-known costly goods do not exhibit strong herding effects and identifies novel avenues for future research.

In particular, we believe that future works that attempt to directly measure the impact of financial costs and outside information on herding behavior would be of particular relevance for firms and researchers alike. If our findings stem mostly from the involvement of financial costs, then this suggests that product markets where social bias has the potential to be more damaging are also those that will be less affected by it. On the other hand, if our findings originate mostly from outside information about products, a natural policy to prevent bias is to increase information dissemination efforts in such markets.

Acknowledgments

This work is part of M. Godinho de Matos’ thesis dissertation. Other authors are ordered alphabetically. The authors thank the senior editor, the associate editor, and two anonymous reviewers for their valuable comments and ideas throughout the review process of this paper. The authors also thank their industry partner for support and interest in running such a large-scale randomized experiment. They thank participants in the Heinz Faculty Seminar Series, the 2012 National Bureau of Economic Research (NBER) Winter Workshop in Digitization, the 2013 NBER Summer Institute on IT and Productivity, and the 2013 Statistical

Challenges of e-Commerce Research workshop for their valuable comments and suggestions to improve this paper. All remaining errors are the authors’ own. This work has been partially supported by the Carnegie Mellon Portugal Program–Portugal Program [Ph.D. Fellowship SFRH/BD/33772/2009], by Portuguese Foundation for Science and Technology [Fellowship SFRH/BPD/94212/2013], by the iLab at Carnegie Mellon University, and by the Living Analytics Research Center at the Heinz College.

References

- Aral S (2010) Identifying social influence: A comment on opinion leadership and social contagion in new product diffusion. *Marketing Sci.* 30(2):217–223.
- Aral S, Walker D (2011) Creating social contagion through viral product design: A randomized trial of peer influence in networks. *Management Sci.* 57(9):1623–1639.
- Aral S, Muchnik L, Sundararajan A (2009) Distinguishing influence-based contagion from homophily-driven diffusion in dynamic networks. *Proc. Natl. Acad. Sci. USA* 106(51):21544–21549.
- Bapna R, Umyarov A (2015) Do your online friends make you pay? A randomized field experiment on peer influence in an online music social network. *Management Sci.* 61(8):1902–1920.
- Brynjolfsson E, Hu Y, Smith MD (2003) Consumer surplus in the digital economy: Estimating the value of increased product variety at online booksellers. *Management Sci.* 49(11):1580–1596.
- Dellarocas C, Zhang XM, Awad NF (2007) Exploring the value of online product reviews in forecasting sales: The case of motion pictures. *J. Interactive Marketing* 21(4):23–45.
- Duan W, Gu B, Whinston AB (2008) Do online reviews matter? An empirical investigation of panel data. *Decision Support Systems* 45(4):1007–1016.
- Elberse A, Oberholzer-Gee F (2007) Superstars and underdogs: An examination of the long tail phenomenon in video sales. MSI Reports: Working Paper Series 4 (2007): 49–72. (Featured in HBS Working Knowledge.)
- Eliashberg J, Shugan SM (1997) Film critics: Influencers or predictors? *J. Marketing* 61(2):68–78.
- Godes D, Mayzlin D (2004) Using online conversations to study word-of-mouth communication. *Marketing Sci.* 23(4):545–560.
- Litman BR (1983) Predicting success of theatrical movies: An empirical study. *J. Popular Culture* 16(4):159–175.
- Liu Y (2006) Word of mouth for movies: Its dynamics and impact on box office revenue. *J. Marketing* 70(3):74–89.
- Manski CF (1993) Identification of endogenous social effects: The reflection problem. *Rev. Econom. Stud.* 60(3):531–542.
- Muchnik L, Aral S, Taylor SJ (2013) Social influence bias: A randomized experiment. *Science* 341(6146):647–651.
- Nelson P (1970) Information and consumer behavior. *J. Political Econom.* 78(2):311–329.
- Reinstein DA, Snyder CM (2005) The influence of expert reviews on consumer demand for experience goods: A case study of movie critics. *J. Indust. Econom.* 53(1):27–51.
- Salganik MJ, Watts DJ (2008) Leading the herd astray: An experimental study of self-fulfilling prophecies in an artificial cultural market. *Soc. Psych. Quart.* 71(4):338–355.
- Salganik MJ, Dodds PS, Watts DJ (2006) Experimental study of inequality and unpredictability in an artificial cultural market. *Science* 311(5762):854–856.
- Shalizi C, Thomas A (2011) Homophily and contagion are generically confounded in observational social network studies. *Sociol. Methods Res.* 40(2):211–239.
- Tucker C, Zhang J (2011) How does popularity information affect choices? A field experiment. *Management Sci.* 57(5):828–842.
- Wallace WT, Seigerman A, Holbrook MB (1993) The role of actors and actresses in the success of films: How much is a movie star worth? *J. Cultural Econom.* 17(1):1–27.
- Zhang X, Dellarocas C (2006) The lord of the ratings: Is a movie’s fate influenced by reviews? *Proc. 27th Internat. Conf. Inform. Systems (ICIS), Milwaukee, 1959–1978.*