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The Impact of Time Shifting on TV Consumption and Ad Viewership

Rodrigo Belo,[a] Pedro Ferreira,[b] Miguel Godinho de Matos,[c] Filipa Reis[c]

[a] Rotterdam School of Management, Erasmus University, 3062 PA Rotterdam, Netherlands; [b] Heinz College and Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213; [c] Católica Lisbon School of Business and Economics, Universidade Católica Portuguesa, 1200-781 Lisbon, Portugal

Contact: rbelo@rsm.nl, http://orcid.org/0000-0001-6839-5086 (RB); pedrof@cmu.edu (PF); miguel.godinhomatos@clsbe.lisboa.ucp.pt, http://orcid.org/0000-0002-6333-2753 (MGdM); filipareis@clsbe.lisboa.ucp.pt, http://orcid.org/0000-0001-8180-1042 (FR)

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Abstract. In this paper we study the impact of time shifting on TV consumption and ad viewership. We analyze the results of a field experiment in which a random sample of "triple-play" households were given a set of premium TV channels broadcasting popular movies and TV shows without commercial breaks. A random subset of these households were given access to these channels with time shifting (automated cloud recording for later viewing or rewinding of broadcasted programs), while the remainder were not. This design allowed us to identify the effects of time shifting on TV consumption. On average, we found that receiving access to the channels with time shifting increased total TV consumption because it increased time-shifted viewership while leaving live viewership unchanged. The increase in the live viewership of these channels was similar to the reduction in the live viewership of the originally available channels, resulting in a net zero effect on live viewership. It appears that time shifting does not change the concentration of live viewership, but it does increase the concentration of total TV viewership, because it is used disproportionately to watch the most popular programs. Finally, we found that time shifting does not change the likelihood of skipping ads during live viewership, suggesting that households do not use time shifting to strategically avoid ads.

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Keywords: time shifting • television • advertising • randomized experiment

1. Introduction

Watching TV is the leisure activity to which people devote the most time in the developed world. However, the traditional model of linear TV imposed a number of restrictions on users. Those interested in specific programs needed to adjust their viewing habits to match existing programming schedules, which could be inconvenient, while those who were only able to watch TV at specific times were restricted to the content broadcast at those times, which restricted their choice of programs. Technological change removed many of these restrictions. Video cassette recorders (VCRs), digital video disc (DVD) recorders, digital video recording (DVR), and more recently time-shift TV allow viewers to have much more control over the programs they watch and greater flexibility (they can watch them whenever they want). However, historically, media firms, TV networks, and advertisers have feared the introduction of these technologies because they disrupt existing business models. For example, in the 1970s, Universal Studios and Walt Disney sued Sony over the Betamax VCR, which they claimed facilitated copyright violation. More recently, a number of large media companies, including Disney, NBC, Viacom, Time Warner, News Corporation, MGM, and Vivendi Universal sued ReplayTV—a DVR-based technology that included automated ad skipping and facilitated program sharing among consumers (Carlson 2006). ReplayTV filed for Chapter 7 bankruptcy in 2015.

The main difference between time shifting and DVR is that the former records the content broadcast live in the cloud without any intervention by the user. This means that users do not need to set their devices in advance to record content and that they can watch

programs that aired live at the same time on different channels. They can also use time shifting to restart live content at a more suitable time. Thus, time shifting significantly increases the content available to users at any point in time, granting them an unprecedented level of freedom and flexibility. The Abreu et al. (2016) global survey on the availability of nonlinear TV services shows that time shifting is currently available in most countries in North America, South America, Europe, and Asia. In most implementations, time shifting allows users to rewind up to seven days and skip commercials. The way in which users take advantage of this technology will determine whether the industry's long-standing fears of disruption are justified. It may be that time shifting will change the valuation of programs, channels, and ad slots, and this may impact the TV supply chain in complex ways.

Our goal in writing this paper was to study the impact of time shifting on TV consumption and ad viewership. We partnered with a large telecommunications provider, which we shall refer to as TELCO, to explore the outcomes of a randomized experiment. The experiment involved giving 3P/4P residential premium households access to a pack of 10 premium channels that broadcast popular movies and TV shows 24/7 without commercial breaks, which we will refer to as the *entertainment bundle*, for a period of six consecutive weeks. These channels were offered in addition to the 100 TV channels already included in TELCO's basic TV service. A random subset of these households were given access to these channels with time shifting, while the others were not. Comparing these two groups of households allowed us to readily identify the impact of time shifting on TV consumption, both live and time shifted, and to examine possible impacts per type of channel. We also used this setup to identify the effect of time shifting on the consumption of live ads placed by TELCO (for its own services and products, such as video-on-demand content) in the original TV channels, thus determining whether households use time shifting to strategically avoid these ads.

We found that TV consumption increased in the households that were given access to the entertainment bundle with time shifting compared to households given access to these channels without time shifting. Perhaps more importantly, people did not reduce their overall consumption of live TV. They reduced their consumption of live TV on the original channels, in particular on channels devoted to entertainment, but increased live consumption of the channels in the entertainment bundle by a similar amount. In other words, offering access to the entertainment bundle with time shifting triggers a spillover effect to its live consumption. In addition, the introduction of time shifting does not change the concentration of live viewership but rather increases the concentration of overall TV consumption because it is disproportionately used to watch the most popular content. Finally, we found that live consumption of TELCO's ads in the original channels decreased in proportion to the reduction in live viewership of these channels. Thus, we found no evidence that households use time shifting to strategically watch fewer of these ads. We confirmed this result by showing that the likelihood of abandoning a live ad placed by TELCO in the original channels is no different for households given access to the entertainment bundle, whether time shifting is available or not.

Our work informs researchers, media firms, TV networks, and advertisers about the impact of time shifting on TV consumption and ad viewership. Presenting outcomes from a randomized field experiment allows us to control for unobserved factors that may influence TV consumption, thus providing identification by design. In this paper, we report both intention-to-treat (ITT) and local average treatment effects (LATE), which allows us to conclude that it is indeed the use of time shifting when watching the entertainment bundle that drives our findings. We use several measures to determine compliance with treatment as a way to check the robustness of our findings. All of them deliver similar results, namely, that the consumption of live TV is not reduced with the introduction of time shifting, even for those households that use time shifting to watch the entertainment bundle more often. The remainder of this paper is organized as follows. Section 2 reviews relevant related work. Section 3 describes the empirical context of our study, the randomized experiment, the data used in our analyses, and our empirical strategies. Section 4 presents preliminary descriptive statistics and Section 5 presents our main results. Finally, Section 6 summarizes our findings and concludes the paper.

2. Related Work

Networks compete to attract viewers' attention and sell "eyeballs" to advertisers (Wilbur 2008a, b). This is why most of the literature on the impact of VCR/DVR/TiVo focuses on how these technologies affect ad viewership and how changes in the latter affect industry players and consumers. Early theoretical studies claim that ad skipping could hurt welfare. For example, Ghosh and Stock (2010) showed that consumers who use a DVR to skip ads benefit from reduced exposure to commercials, but that this behavior makes advertising less effective because it results in consumers who are less well informed. Anderson and Gans (2011) suggest that the adoption of technologies that allow consumers to skip ads increases advertising clutter, potentially reducing welfare and the quality of the content produced. A few empirical works on the topic presented mixed results. Downey (2007) showed that viewers with a DVR watch only 59% of the ads that they would watch with live TV. Pearson and Barwise (2007) found that households fast-forwarded through ads two-thirds of the time when

time shifting, although their study focused on only 22 households, whose behavior was filmed for a period of less than three weeks. Bronnenberg et al. (2010) provide contrary evidence. The authors analyzed data from a three-year field study carried out in partnership with five firms, in which a sample of 14,000 households were offered TiVo free of charge. Using propensity score matching, the authors found that skipping ads occurred relatively infrequently. Unfortunately, these studies were either observational or field studies, without randomized controls, which reduces their ability to claim causal effects.

Changes in TV viewership such as engaging in time shifting are likely to come at the expense of other similar activities (Rubin 2002, Ferguson and Perse 2000), such as consuming live TV. Yet, time shifting may also complement live TV by allowing users to restart live programs or catch-up on recent content that they intended to watch live but may have missed. In conclusion, it is not straightforward to predict whether the introduction of time shifting increases or reduces TV consumption and, in particular, how it affects the consumption of live TV. In addition, shifts in TV consumption may change viewership concentration. The increased volume and variety of content made available by time shifting may help users discover products that they would otherwise be unable to find. This is likely to reduce viewership concentration. For instance, Brynjolfsson et al. (2011a) compare the distribution of sales between advertising on online and offline channels using data from a multichannel retailer. They found that, even when the products advertised on the two channels were exactly the same, the introduction of search engines and recommendation tools in the online channel increased the share of sales of niche products. Time shifting can be seen as equivalent to such tools, because it allows users to find and access content that they would otherwise not watch. Alternatively, a "super-star" effect may arise, whereby viewers watch even more of the most popular programs. This can certainly happen with time shifting because this technology allows consumers to watch popular programs that aired at the same time on different channels. Evidence of such an effect was reported by Elberse and Oberholzer-Gee (2006) in a study on the distribution of home video products between 2000 and 2005. The authors found evidence of both a super-star effect—among top performers, most sales were concentrated around fewer titles—and of a long-tail effect: there was a significant increase in the number of titles selling only a few copies.

3. Context, Data, and Empirical Methods

3.1. Empirical Context

Our work was developed in collaboration with a multinational telecommunications provider (TELCO), the market leader in pay-TV services in the country, it operates serving more than one million households. In addition to pay-TV, TELCO offers video-on-demand, DVR, time shifting, broadband internet, mobile internet, fixed telephony, and mobile telephony. TELCO's households can opt for either standard or premium service, which differ in the number of TV channels and on the set of complementary features. One such feature is time shifting, which is offered to premium households on most of their TV channels. Time shifting allows these households to watch content broadcasted live for up to seven days. Time shifting allows them to pause, rewind, and fast-forward through content, including ads. Popular streaming services such as Netflix, Hulu, or Amazon Video were not available in this country at the time of our study. Over-the-top applications from content providers, such as those from ABC, CBS, NBC, or HBO were also unavailable. Therefore, live and time-shifted TV were the primary sources of movies and TV shows for premium households.

Our study focuses on 3P/4P residential premium households. They accounted for 86% of TELCO's households in 2015. Premium households have at least one set-top box (STB) with at least 100 TV channels, a high-speed Internet connection, and unlimited fixed telephony. Premium households can complement their basic TV service with additional bundles of thematic channels such as children, music, sports, documentaries, movies, and TV shows, which can be purchased a la carte for a fixed monthly fee. In this paper, we study the effect of offering time shifting to watch the entertainment bundle—a set of 10 premium channels broadcasting popular movies and TV shows 24/7 without commercial breaks. The TV shows broadcasted in these channels aired only a couple of days earlier in the United States. Access to the entertainment bundle can be purchased for 13 USD/month. In April 2015, the month before our study, 19% of TELCO's premium households subscribed to the entertainment bundle.

3.2. Randomized Experiment

We study the outcomes of a randomized field experiment ran by TELCO in May and June 2015. A random sample of 40,500 3P/4P residential premium households that had not purchased the entertainment bundle in April 2015 were randomly split into three experimental conditions. Households in the first experimental condition—*treated no time shifting*—were gifted access to the entertainment bundle without time shifting for free for a period of six consecutive weeks. Households in the second experimental group—*treated time shifting*—were gifted access to the entertainment bundle with time shifting for the same period of time. Finally, households in the third experimental condition—*control*—were left untouched. Households were notified about these temporary offers by both SMS and email. No setup action was needed on their part.

Our randomized setting readily allows for identifying the effect of time shifting to watch the entertainment bundle on TV consumption and ad avoidance by comparing households in the treated no time shifting and in the treated time shifting conditions. Comparing households in the control condition and households in the treated no time shifting condition allows for identifying the effect of offering access to the entertainment bundle. We note that households in the control condition were not locked out from subscribing the entertainment bundle during the treatment period and thus some of them may have subscribed and then watched these channels. Similarly, some households in the treated no time shifting condition may have not watched the channels in the entertainment bundle. Likewise, some households in the treated time shifting condition may have also not watched these channels, either live or using time shifting. Therefore, our setting is prone to noncompliance, which is commonly observed in randomized experiments based on incentive designs (e.g., Acland and Levy 2015, Bulte et al. 2017, Mochon et al. 2017). We explain how we address it empirically in Section 3.4.

3.3. Data

TELCO granted us access to the anonymized TV viewership logs of all households in our experiment between May 1, 2015, and June 30, 2015. For each household, these logs include an anonymized household identifier, the timestamp of each viewership event (every time a viewer changes TV channel a new event is generated), the unique identifier for the program and for the channel associated to each event, and the event's viewership mode—live or time shifting. We compute TV viewership time by differencing between consecutive events. We aggregate the data by computing the daily average TV view time for each household in each viewership mode and type of channel. We aggregate viewership time in a panel with two time periods, one before the experiment started, between May 1 and May 12, and another one during the experiment, between May 19 and June 30.[1] As a robustness check, we created a second data set where we aggregate the data weekly. Results using the weekly panel are similar to the ones discussed in Section 5 and are presented in Appendix A.

Additionally, TELCO granted us access to a data set including all TV ad spots in the original TV channels that it purchased for its own products (such as video-on-demand content) and that were broadcasted between June 1 and June 30, 2015 (recall that the entertainment bundle does not feature ads). For each ad, this data set includes all live viewership instances by households in our experiment. Each entry in this data set includes the anonymized household identifier, the identifier of the ad watched, timestamp of transmission, the channel in which it was broadcasted, and the duration in seconds of both the ad and of the viewership event (thus allowing us to compute whether households watch the full ad). We aggregate these data in a cross section by computing the total time that each household spends watching ads during June 2015. We note that this data set contains only ads sponsored by TELCO and thus it may not be representative of the general distribution of TV ads in terms of the channels and times at which they air. Also, the characteristics of these ads for TELCO products may be different from those of ads for other products. Finally, TELCO shared with us additional household level covariates, specifically, service tenure, subscriber's date of birth (age), whether the subscriber opted for electronic receipt (updated monthly), and the monthly billing total (in USD). This data covers the full period of analysis.

We dropped a number of households from our analysis, namely, those that had opted out from marketing campaigns (and thus could not be offered access to the entertainment bundle, churned or had set-top boxes that did not register any TV viewership during our experiment because of technical failures. Our final sample includes 35,107 households—11,631 in the control condition, 11,752 in the treated no time shifting condition, and 11,724 in the treated time shifting condition. Appendix B shows that attrition dropped a similar number of households in each condition. In addition, the remaining households in each condition are similar in observed covariates, as shown in Section 4, which provides strong evidence that attrition was orthogonal to treatment assignment and thus our findings have causal interpretations. As a robustness check, we ran all our analyses using the full sample of households and imputing zeros to the TV viewership of the households for which TELCO could not obtain the corresponding records. These results are in line with the ones presented in Section 5 and are available upon request. The attrition in our sample does not prevent us from measuring causal effects but introduces a limitation in terms of generalizability. Namely, our results generalize only to the subpopulation of 3P/4P residential premium households that did not subscribe the entertainment bundle in April 2015, do not churn, and do not opt out from marketing campaigns. We believe that this is still the most interesting population of households to study the effect of time shifting on TV viewership.

3.4. Empirical Strategy and Identification

We start by comparing households in the control condition and households in the treated no time shifting condition to measure the effect of offering access to entertainment bundle on TV consumption. We use differences-in-differences with household fixed effects to do so and thus estimate

$$Y_{it} = \beta_0 + \beta_1 During_t + \beta_2 EB_i + \beta_3 During_t \times EB_i + \alpha_i + \epsilon_{it}, \quad (1)$$

where i indicates a household in the two conditions and t indicates one of two time periods—before or during the experiment. The term $During_t$ indicates whether the observation pertains to the time period during the experiment or before the experiment. The term EB_i indicates whether household i was offered access to the entertainment bundle without time shifting. The coefficient of interest is this specification if β_3, which measures how the average of the dependent variable changes from households in the control condition to households with the entertainment bundle without time shifting. We use live TV consumption, time-shifting consumption, and total TV consumption as dependent variables in our analyses. In some specifications, we break down these dependent variables per type of channel, such as general purpose, entertainment, children, news, sports and the entertainment bundle. We estimate this equation using fixed effects and cluster standard errors at the household level. Estimating this equation using ordinary least squares (OLS) provides an unbiased measure for the causal effect of the ITT households with access to the entertainment bundle (Hollis and Campbell 1999).

Compliance with treatment assignment, and lack thereof, can be measured in our setting by observing whether households in the control condition and in the treated no time shifting condition watched the entertainment bundle. We define the endogenous variable $WatchEB_i$ to indicate whether household i watched the entertainment bundle for at least x minutes within one day at least once during the experiment. We instantiate x to 30, 60, and 90, thus using three different measures of compliance to study the robustness of our results. The set of compliers when $x = 60$ is a subset of the compliers when $x = 30$ that watches the entertainment bundle more intensely. Likewise for when $x = 90$ relative to $x = 60$. We estimate the effect of watching the entertainment bundle on the dependent variable of interest using the following specification:

$$Y_{it} = \beta_0 + \beta_1 During_t + \beta_2 WatchEB_i + \beta_3 During_t \times WatchEB_i + \alpha_i + \epsilon_{it}, \quad (2)$$

where we instrument $WatchEB_i$ with EB_i, as is usually the case when analyzing outcomes of randomized field experiments. This approach allows us to compute the LATE (Angrist et al. 1996), that is, the average effect of watching the entertainment bundle over the set of compliers. As discussed in detail in Angrist et al. (1996), the LATE provides the average effect of treatment on those that comply with the assigned treatment during our experiment and reveals the average effect on the population of future compliers despite possible heterogeneity in individual level effects (Angrist et al. 1996). On the contrary, the ITT averages out effects across all households included in the sample, including noncompliers, and thus provides a lower bound for the causal effect of treatment. The benefit of reporting the LATE is that it measures the causal effect of the treatment, in our case that of watching the entertainment bundle, thus allowing us to provide additional evidence of the mechanism driving our findings.

We follow a similar empirical approach to measure the causal effect of offering time shifting to watch the entertainment bundle but in this case we compare households in the treated time shifting and in the treated no time shifting conditions. Both sets of households have been gifted access to the entertainment bundle, thus comparing them directly nets out the effect of offering access to these channels, allowing us to measure only the effect of time shifting. We estimate the effect of the intention to treat households with time shifting using the following fixed effects specification:

$$Y_{it} = \gamma_0 + \gamma_1 During_t + \gamma_2 TS_i + \gamma_3 During_t \times TS_i + \delta_i + \nu_{it}, \quad (3)$$

where now i indicates a household gifted access to the entertainment bundle. The term TS_i indicates whether household i was gifted access to this bundle of channels with or without time shifting. As before, the coefficient of interest is γ_3, which measures how the average of the dependent variable changes from households without time shifting to households with time shifting (on the entertainment bundle). Again, we use OLS to estimate this regression and cluster the standard errors at the household level. We measure the causal effect of using time shifting to watch the entertainment bundle over the subpopulation of compliers (the LATE) using the following fixed effects specification:

$$Y_{it} = \gamma_0 + \gamma_1 During_t + \gamma_2 WatchEBTS_i + \gamma_3 During_t \times WatchEBTS_i + \delta_i + \nu_{it}, \quad (4)$$

where $WatchEBTS_i$ is an indicator of whether household i used time shifting to watch the entertainment bundle at least x minutes within one day at least once during the experiment. As before, we instantiate x to 30, 60, and 90 and use these different definitions of compliance to study the robustness of our findings. We estimate this equation using $time\text{-}shifting_i$ as an instrument for $WatchEBTS_i$.

Next, we follow the approach in Brynjolfsson et al. (2011b) and use the Pareto distribution to study the effect of time shifting on the concentration of TV viewership. We run the following specification:

$$\mathrm{Log}(Time_{kv}) = \theta_0 + \theta_1 TS_v + \theta_2 \mathrm{Log}(Rank_{kv}) + \theta_3 TS_v * \mathrm{Log}(Rank_{kv}) + \epsilon_k, \quad (5)$$

where k indexes a program offered as part of the entertainment bundle and v a treatment condition—either treated time shifting or treated no time shifting. The term $Time_{kv}$ represents the time devoted to program k during the experiment by households in condition v. The term TS_v indicates whether condition v includes

time shifting. As before, identification is obtained by design given the random assignment of households to conditions treated time shifting and treated no time shifting. We expect θ_2 to be negative given that higher ranks have less viewership time. We are interested in the sign of coefficient θ_3, which measures how the distribution of viewership time across program ranks differs for households that were offered access to the entertainment bundle with and without time shifting. A negative θ_3 indicates that viewership is more concentrated with time shifting. The dependent variables that we consider in our analysis are total and live viewership time.

In another analysis we measure the effect of time shifting on ad viewership by comparing the total live ad view time of ads placed by TELCO in the original TV channels during June 2015 by households who received the entertainment bundle with and without time shifting. We do not have data on ad viewership before the experiment. Therefore, we aggregate our data in a cross section of households and estimate the following specification:

$$Y_i = \eta_0 + \eta_1 TS_i + \epsilon_i, \tag{6}$$

where the dependent variables of interest in this case are the consumption of live ads placed by TELCO in the original channels and its ratio to the live consumption of these channels. We estimate this equation using OLS and cluster the standard errors at the household level. This provides the effect of the intention to treat households with time shifting on the consumption of live ads placed by TELCO in the original channels. As discussed previously, we can also compute the LATE over the compliers with treatment assignment by regressing our dependent variables of interest on $WatchEBTS_i$ and instrumenting the latter with TS_i.

Finally, we measure how offering time shifting to watch the entertainment bundle affected the probability of exiting TELCO's ads that aired live in the original TV channels. We estimate the following specification to do so:

$$Exit_{li} = \zeta_0 + \zeta_1 TS_i + \epsilon_{li}, \tag{7}$$

where l represents an instance in which household i offered access to the entertainment bundle started watching a live ad placed by TELCO in the original channels. The term $Exit_{li}$ indicates whether this household abandoned the ad in instance l before it ended. Households abandon an ad when they switch channels or turn off the TV before the ad ends. Note that our results are conditional on entering the ad in the first place and thus apply only to the subpopulation of households that do so. As before, identification is obtained by design and thus we estimate this equation using OLS and clustering standard errors at the household level. As before, we estimate the LATE by regressing $Exit_{li}$ on $WatchedEBTS_i$ and instrumenting the latter with TS_i.

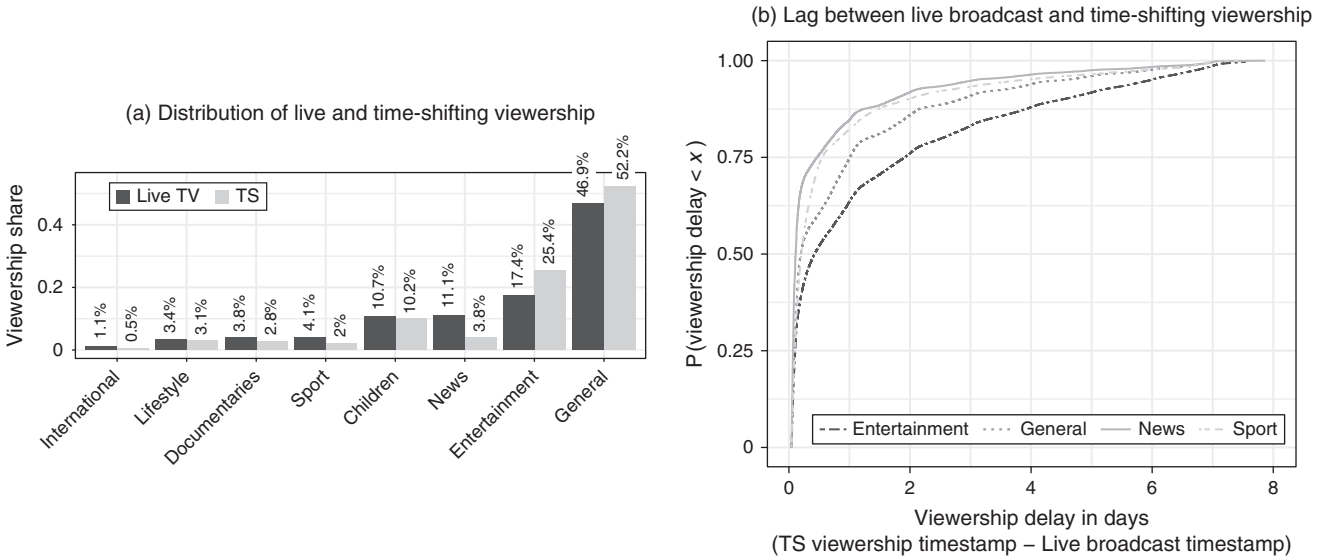
4. Preliminary Descriptive Statistics

Time shifting was first introduced to TELCO's premium households at the end of summer 2012. Within about one month after its introduction, time-shifting viewership captured about 8% of TV viewership time. This share, which remained roughly constant from 2012 to 2015, is similar to the share of time-shifting consumption in other countries. For example, and according to Nielsen's 2015 total audience report, 8% of all TV consumption in the United States in 2015 was time shifted. A similar share of time-shifting consumption was registered in the United Kingdom (BARB 2011) and in France (iSuppli Screen Digest 2011). In Section 4.1, we provide additional descriptive statistics for the consumption of TV, both live and time shifting, for households in our control condition during May 2015. This provides additional information about how households in our sample consume TV absent of experimental interventions.

4.1. TV Consumption per Type of Channel in the Control Group

Households in our control condition watched, on average, 5.0 hours of TV per day and 58% of them used time shifting at least once during our preexperimental period—May 1 to May 12, 2015. Figure 1(a) shows the breakdown of live and time-shifting viewership time per type of channel type. We observe that general purpose channels (e.g., national free to air) account for most of the viewership, both in live and in time shifting, followed by entertainment, news, and children. We also observe that general purpose and entertainment channels capture a disproportionate larger viewership share in time shifting than in live TV and conversely for news and sports channels. This is expected given that the value of the latter types of content is extremely time dependent—it is highest when consumed live and decreases quickly after the original broadcast—while movies and TV shows remain valuable to viewers for much longer after their original broadcast. Figure 1(b) shows the cumulative distribution of time-shifting viewership time by the number of days elapsed since the program was first broadcasted live per type of channel. On average, 80% of the programs watched using time shifting aired in the previous 48 hours. This short lag between original broadcast time and time-shift consumption suggests that time shifting is mostly used to catch-up on content missed recently. This statistic is larger for time-sensitive content, such as sports and news, and smaller for entertainment and general purpose content, which supports the idea that time shifting is more valuable for the latter types of content. Therefore, gifting time shifting to watch the entertainment bundle is likely to be quite useful to households and thus may significantly displace TV viewership. Consequently, our results would

Figure 1. Live and Time-Shifting (TS) Viewership and Lag Between Them per Type of Channel (Control Group, May 2015, Only Channel Types with More Than 1% of Total Viewership Are Represented)



likely be different, and most likely smaller in magnitude, had we have given time shifting over other types of channels during our experiment.

4.2. Balance Across Conditions, TV Consumption, and Compliance Levels

Table 1 shows that our randomization schedule achieved good balance in key observed covariates computed between May 1 and May 12. This table compares these covariates for households in the control group against households gifted access to the entertainment bundle with and without time shifting. All p-values for the corresponding tests of means are above the 5% threshold.

Figures 2 and 3 show the total and the time-shifting daily viewership time of the entertainment bundle before and during the experiment. We observe that households that were offered access to these channels

Table 1. Balance Across Treatment Conditions During the Pretreatment Period (May 1 to May 12)

	Treatment group	Avg. treated	Avg. control	Std. dev. control	Std. effect	p-value
Total TV time (min per day)	No TS	296.551	296.563	160.515	−0.0001	0.996
Total TV time general (min per day)	No TS	113.112	112.258	85.803	0.010	0.449
Total TV time entertainment (min per day)	No TS	41.932	42.329	52.232	−0.008	0.557
Total TV time news (min per day)	No TS	20.990	21.443	33.193	−0.014	0.290
Total TV time sports (min per day)	No TS	14.207	14.481	33.999	−0.008	0.534
Total TV time children (min per day)	No TS	22.067	22.185	43.808	−0.003	0.835
Total TV time other (min per day)	No TS	83.535	83.161	75.949	0.005	0.707
Live TV time (min per day)	No TS	269.960	270.151	151.945	−0.001	0.923
Time shifting TV time (min per day)	No TS	23.334	23.216	38.409	0.003	0.817
Month bill (USD)	No TS	51.364	51.352	13.883	0.001	0.946
Tenure (months)	No TS	79.065	78.897	61.354	0.003	0.834
Electronic receipt	No TS	0.404	0.414	0.492	−0.019	0.145
Total TV time (min per day)	TS	297.750	296.563	160.515	0.007	0.570
Total TV time general (min per day)	TS	113.324	112.258	85.803	0.012	0.345
Total TV time entertainment (min per day)	TS	42.028	42.329	52.232	−0.006	0.657
Total TV time news (min per day)	TS	21.280	21.443	33.193	−0.005	0.701
Total TV time sports (min per day)	TS	14.611	14.481	33.999	0.004	0.770
Total TV time children (min per day)	TS	22.361	22.185	43.808	0.004	0.758
Total TV time other (min per day)	TS	83.463	83.161	75.949	0.004	0.761
Live TV time (min per day)	TS	270.435	270.151	151.945	0.002	0.885
Time shifting TV time (min per day)	TS	23.703	23.216	38.409	0.012	0.337
Month bill (USD)	TS	51.171	51.352	13.883	−0.013	0.318
Tenure (months)	TS	78.612	78.897	61.354	−0.005	0.722
Electronic receipt	TS	0.418	0.414	0.492	0.010	0.455

Figure 2. (Color online) Average Daily Total TV Viewership in the Entertainment Bundle *(Minutes)*

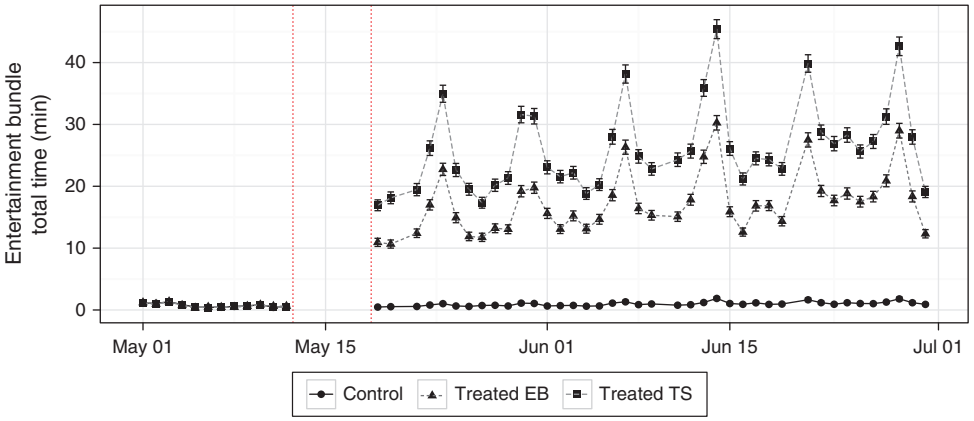
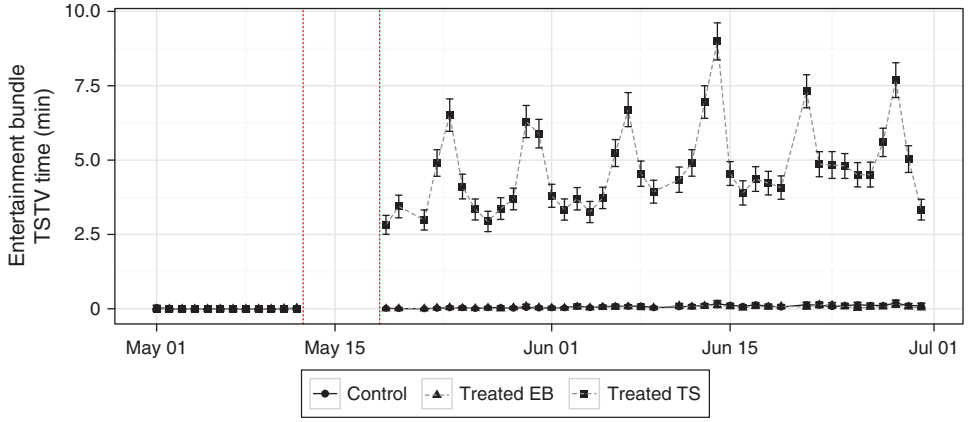


Figure 3. (Color online) Average Daily Time-Shifting Viewership in the Entertainment Bundle *(Minutes)*



started watching them right away. This is true for both live and time-shifted viewership, and thus learning effects were unlikely at play in our setting. We also observe that the viewership time of the entertainment bundle was significantly higher for households that received access to this set of channels with time shifting. The periodic peaks in viewership time in these figures correspond to weekends.

In Figures 2 and 3 we observe that some households in the control group watched the entertainment bundle, which results from organic subscriptions. During our experiment, 19.6% of households in the control group watched the entertainment bundle for at least 30 minutes within one day at least once. This statistic becomes 12.4% and 7.5% for 60 and 90 minutes, respectively. Also, not all households gifted access to the entertainment bundle without time shifting watched these channels. During our experiment, 56.1% of households in the treated no time shifting condition watched these channels for at least 30 minutes within one day at least once. This statistic becomes 50.1% and 43.3% for 60 and 90 minutes, respectively. Also, not all households offered access to the entertainment bundle with time shifting used time shifting to watch these channels. During our experiment, 26.9% of the households in the treated time shifting condition used time shifting to watch the entertainment bundle for at least 30 minutes within one day at least once. This statistic becomes 24.2% and 19.7% for 60 and 90 minutes, respectively. Finally, during our experiment, some households in the treated no time shifting condition asked TELCO to add time shifting to these channels. However, this is very uncommon. Only 0.5% of them used time shifting to watch the entertainment bundle for at least 30 minutes within one day at least once during the experiment (this statistic is 0.5% and 0.4% for 60 and 90 minutes, respectively). Therefore, with respect to the effect of time shifting, our setting is a case of noncompliance only on the treatment side and thus our estimates measure the average treatment effect on the treated (ATT) (Angrist and Imbens 1995).

5. Results

5.1. The Effect of the Entertainment Bundle on TV Consumption

Table 2 shows how offering access to the entertainment bundle changes TV consumption by comparing

Table 2. Effect of Gifting and Watching the Entertainment Bundle on TV Consumption

	Dependent variable											
	All				Live				Time shifting			
	ITT (1)	LATE (2)	LATE (3)	LATE (4)	ITT (5)	LATE (6)	LATE (7)	LATE (8)	ITT (9)	LATE (10)	LATE (11)	LATE (12)
During	−0.767	−1.066	−0.950	−0.883	−3.724***	−4.838***	−4.407***	−4.157***	2.856***	3.656***	3.346***	3.166***
	(0.787)	(1.281)	(1.078)	(0.965)	(0.751)	(1.221)	(1.027)	(0.920)	(0.194)	(0.318)	(0.267)	(0.239)
During ∗ *EB*	0.554				2.067*				−1.484***			
	(1.108)				(1.056)				(0.274)			
During ∗ *WatchEB* 30 min		1.520				5.671**				−4.071***		
		(3.038)				(2.893)				(0.754)		
During ∗ *WatchEB* 60 min			1.472				5.491**				−3.943***	
			(2.942)				(2.802)				(0.729)	
During ∗ *WatchEB* 90 min				1.548				5.773**				−4.145***
				(3.093)				(2.945)				(0.765)
Observations	46,766	46,766	46,766	46,766	46,766	46,766	46,766	46,766	46,766	46,766	46,766	46,766
R^2	0.00004				0.001				0.011			
F statistic	0.514	9.565***	9.144***	9.053***	14.850***	44.787***	46.498***	47.676***	133.403***	59.843***	98.411***	117.791***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

households in the control and in the treated no time shifting conditions. Columns (1), (5), and (9) show ITT estimates for total TV consumption, live TV consumption, and time-shifting consumption, respectively. Columns (2)–(4) show LATE estimates for the effect on total TV consumption with 30, 60, and 90 minutes compliance thresholds, respectively. Columns (6), (7), and (8) provide similar statistics for live TV consumption while columns (10)–(12) do so for time-shifting consumption. Column (1) shows that offering access to the entertainment bundle does not change the total consumption of TV. Nor does watching these channels, as reported in columns (2)–(4). However, there is a clear substitution of time shifted for live TV consumption, which is similar in magnitude for different levels of compliance. Appendix C shows, as expected, that this substitution is driven by consumption of the entertainment bundle live at the expense of consumption in the original channels, in particular in the general purpose and entertainment channels, both live and in time shifting. In short, these results show that the entertainment bundle attracts households viewership and thus offering access to them with time shifting might trigger further interesting effects.

5.2. The Effect of Time-Shift TV on TV Consumption

Table 3 shows how offering access to the entertainment bundle changes TV consumption by comparing households in the treated no time shifting and in the treated time shifting conditions. As before, columns (1), (5), and (9) provide ITT estimates for total, live and time-shifting consumption, respectively. Columns (2)–(4) show LATE estimates for the effect on total TV consumption with 30, 60, and 90 minutes compliance thresholds, respectively. Columns (6)–(8) provide similar statistics for live TV consumption while columns (10)–(12) do so for time-shifting consumption. Column (1) shows that offering time shifting on the entertainment bundle increases total TV consumption, on average 4.6 minutes per day from a baseline of 5.0 hours (1.5%, p-value < 0.01). Columns (2)–(4) show that this statistic is significantly larger for more stringent levels of compliance, that is, for households that use time shifting more heavily to watch the entertainment bundle, which provides us with additional confidence that it is in fact the use of time shifting to watch these channels that drives this result. For example, total TV consumption increases 23.5 minutes per day for households that use time shifting to watch the entertainment bundle for at least 90 minutes within one day at least once during the experiment. Columns (5)–(8) show that offering and using time shifting to watch the entertainment bundle does not change the consumption of live TV, not even for the households that use time shifting more heavily to watch these channels. Therefore, this result significantly increases our confidence that indeed offering and using time shifting to watch the entertainment bundle does not change the consumption of live TV. Finally, columns (9)–(12) show that the increase in total TV consumption is essentially driven by time-shifting consumption.

Table 4 breaks down the ITT effect on total TV consumption per type of channel. Likewise for Tables 5 and 6 with respect to live and time-shifting consumption, respectively. We observe that the increase in total

Table 3. Effect of Time Shifting on the Entertainment Bundle on TV Consumption

	Dependent variable											
	All				Live				Time shifting			
	ITT (1)	LATE (2)	LATE (3)	LATE (4)	ITT (5)	LATE (6)	LATE (7)	LATE (8)	ITT (9)	LATE (10)	LATE (11)	LATE (12)
During	−0.213	−0.261	−0.262	−0.263	−1.657**	−1.666**	−1.666**	−1.666**	1.372***	1.335***	1.335***	1.334***
	(0.780)	(0.788)	(0.788)	(0.788)	(0.743)	(0.751)	(0.751)	(0.751)	(0.193)	(0.195)	(0.195)	(0.195)
During ∗ *TS*	4.582***				0.785				3.434***			
	(1.110)				(1.055)				(0.292)			
During ∗ *WatchEBTS* 30 min		17.208***				2.947				12.896***		
		(4.160)				(3.962)				(1.079)		
During ∗ *WatchEBTS* 60 min			19.125***				3.275				14.333***	
			(4.623)				(4.403)				(1.198)	
During ∗ *WatchEBTS* 90 min				23.460***				4.018				17.582***
				(5.672)				(5.402)				(1.464)
Observations	46,952	46,952	46,952	46,952	46,952	46,952	46,952	46,952	46,952	46,952	46,952	46,952
R^2	0.001				0.0003				0.024			
F statistic	15.519***	59.526***	59.824***	55.463***	3.153**	5.452***	4.978***	2.655*	293.515***	643.423***	671.452***	770.480***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 4. Effect of Offering and Using Time Shifting to Watch the Entertainment Bundle on Overall TV Consumption per Type of Channel

	Dependent variable						
	E-Bundle (1)	General (2)	Entertainment (3)	Children (4)	News (5)	Sports (6)	Other (7)
During	15.108***	14.518***	−0.001	9.110***	4.218***	−3.777***	−39.389***
	(0.266)	(0.480)	(0.319)	(0.278)	(0.186)	(0.184)	(0.488)
During ∗ *TS*	8.273***	−0.287	−2.746***	0.090	−0.184	−0.177	−0.386
	(0.452)	(0.678)	(0.450)	(0.397)	(0.264)	(0.261)	(0.691)
Observations	46,952	46,952	46,952	46,952	46,952	46,952	46,952
R^2	0.245	0.071	0.003	0.083	0.040	0.036	0.359
F statistic	3,800.244***	899.240***	37.215***	1,062.770***	489.230***	438.207***	6,569.444***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 5. Effect of Offering and Using Time Shifting to Watch the Entertainment Bundle on Live TV Consumption per Type of Channel

	Dependent variable						
	E-Bundle (1)	General (2)	Entertainment (3)	Children (4)	News (5)	Sports (6)	Other (7)
During	14.875***	15.380***	0.398	8.706***	4.345***	−3.712***	−39.737***
	(0.262)	(0.465)	(0.300)	(0.264)	(0.184)	(0.181)	(0.476)
During ∗ *TS*	3.425***	−0.234	−2.243***	0.153	−0.146	−0.199	−0.150
	(0.392)	(0.658)	(0.423)	(0.379)	(0.261)	(0.258)	(0.672)
Observations	46,952	46,952	46,952	46,952	46,952	46,952	46,952
R^2	0.236	0.084	0.002	0.084	0.044	0.036	0.374
F statistic	3,621.002***	1,075.778***	19.928***	1,074.985***	536.764***	436.515***	7,013.208***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 6. Effect of Offering and Using Time Shifting to Watch the Entertainment Bundle on Time-Shifting Consumption per Type of Channel

	Dependent variable						
	E-Bundle (1)	General (2)	Entertainment (3)	Children (4)	News (5)	Sports (6)	Other (7)
During	0.050***	−0.757***	−0.352***	0.334***	−0.126***	−0.061***	2.291***
	(0.012)	(0.094)	(0.064)	(0.038)	(0.024)	(0.016)	(0.127)
During ∗ *TS*	4.242***	0.023	−0.425***	−0.010	−0.042	0.025	−0.379**
	(0.120)	(0.134)	(0.093)	(0.055)	(0.035)	(0.021)	(0.184)
Observations	46,952	46,952	46,952	46,952	46,952	46,952	46,952
R^2	0.098	0.005	0.007	0.006	0.003	0.001	0.022
F statistic	1,280.457***	61.756***	84.540***	71.072***	35.364***	11.426***	263.695***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

TV consumption is essentially driven by watching the entertainment bundle both live and in time shifting, that is, offering time shifting to watch the entertainment bundle also increases its live consumption. Offering access to the entertainment bundle with time shifting increases its consumption by 4.3 minutes per day in time shifting and by 3.4 minutes per day in live. This spillover effect that time shifting has on the live consumption of the entertainment bundle leads to no reduction in the overall consumption of live TV. There is, however, a substitution in the live consumption of the original channels for the entertainment bundle, namely, from the original channels that broadcast entertainment content. In other words, offering time shifting to watch the entertainment bundle accentuates the substitution of viewership in the original entertainment channels for viewership (both live and in time shifting) in the entertainment bundle.

Finally, Appendix D shows evidence of heterogeneous effects with respect to how time shifting changes the consumption of TV. This appendix compares the behavior of households in the treated time shifting and treated no time shifting conditions interacting the effect of time shifting with key observables. We find evidence that proxies for better IT skills, such as lower age and the use of electronic receipt, are associated to more pronounced increases in the use of time shifting. The households interest for entertainment content and their familiarity with time shifting also discriminate their behavior. Households that spend more time watching entertainment channels and that use more time shifting before the experiment started to use more time shifting during the experiment. None of these interactions show statistically significant effects on the consumption of live TV. This provides additional evidence that time shifting does not reduce live viewership even when we look at specific types of households in our sample, namely, households that use more time shifting during the experiment to watch the entertainment bundle.

5.3. The Effect of Time-Shift TV the Concentration on TV Consumption

Table 7 shows the effect of offering time shifting to watch the entertainment bundle on the concentration of TV consumption. Column (1) shows that the shape parameter of the Pareto distribution of live viewership time as a function of rank for the programs broadcasted in the channels offered as part of the entertainment bundle is not statistically different for households that obtained access to these channels with and without time shifting. However, column (2) shows that the shape parameter of the Pareto distribution for total viewership time as a function of rank for these same programs is statistically more negative ($p < 0.01$) for the households that obtained access to these channels with time shifting. Therefore, we find no evidence that time shifting changes the concentration of live viewership

Table 7. Viewership Concentration as a Function of Offering Time Shifting to Watch the Entertainment Bundle

	Dependent variable	
	log (live viewership hours) (1)	log (total viewership hours) (2)
log(*rank*)	−1.462***	−0.960***
	(0.063)	(0.035)
TS	−0.407*	0.860***
	(0.240)	(0.130)
log(*rank*) ∗ *TS*	0.047	−0.084***
	(0.039)	(0.022)
Constant	11.695***	9.889***
	(0.385)	(0.216)
Observations	2,178	2,178
R^2	0.557	0.788
F statistic	911.584***	2,700.295***

Note. Cluster robust standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

but it increases the concentration of total TV viewership because it is disproportionately used to watch the more popular content. The increase in the concentration of TV viewership may have significant impact on the production of content through preference externalities (Anderson and Waldfogel 2015). Our results show that niche content attracts fewer households with time shifting, which may reduce the revenue that this content generates. However, producers will not be able to shoot this content if it fails to generate enough revenue to cover fixed costs, which are usually high in entertainment. At the same time, the more popular content attracts more households and will be increasingly more available. In other words, the content that will be available to one household will more strongly depend on the preferences of other households.

5.4. The Effect of Time-Shift TV on Ad Avoidance

The displacement of live viewership in the original channels triggered by offering time shifting to watch the entertainment bundle might affect the consumption of live ads in these channels. We study this issue in more detail by looking at the live consumption of ads placed by TELCO in these channels during June 2015. Figure 4 shows how TELCO split its budget for ads across the different types of TV channels. A total of 110 thousand seconds of ad slots were purchased by TELCO during this month. This amounts to roughly one hour of ads per day, of which 44% were associated to primetime. Figure 4(b) shows the live consumption of these ads by households included in the control group. On aggregate, these households watched 4.5 million seconds of these ads. A disproportionately larger amount of ads were viewed in general purpose channels and in primetime.

Table 8 shows the impact of time shifting on the time that households in our experiment spent watching these ads. Column (1) shows that households gifted access to the entertainment bundle with time shifting consumed 13 seconds less of these ads compared to households gifted access to the entertainment bundle without time shifting (a decline of roughly 2.0%). Column (5) shows that this reduction is proportional to the reduction in the live consumption of the original channels. Therefore, we find no evidence that households strategically use time shifting to watch fewer live ads in these channels relative to the time they spend watching them.

Columns (2)–(4) and (6)–(8) show our LATE estimates using 30, 60, and 90 minutes as thresholds for compliance with treatment, respectively. These results confirm that even the households that use time shifting more heavily to watch the entertainment bundle, and thus consume less live TV in the original channels and consequently fewer ads on these channels, do not use time shifting to strategically watch fewer live ads placed by TELCO in the original channels relative to how much they consume these channels live. This provides us with increased confidence that indeed time shifting on the entertainment bundle is not used as a tool to strategically avoid these ads.

We complement this analysis by looking at how offering and using time shifting to watch the entertainment bundle changes the probability of exiting TELCO's live ads in the original channels. Table 9 shows the results obtained. Column (1) shows that offering access to the entertainment bundle with or without time shifting does not change the probability of abandoning these ads. This is true not only on average across all households gifted access to the entertainment bundle but also across compliers as reported in columns (3), (5), and (7), which increases our confidence that indeed time shifting does not lead households to disproportionately abandon live ads placed by TELCO in the original channels. Columns (2), (4), (6), and (8) show results for ads in primetime and nonprimetime, a breakdown that is interesting given that the former slots are usually more expensive. Also

Figure 4. Ad Investment by TELCO and Consumption by Households in the Control Group

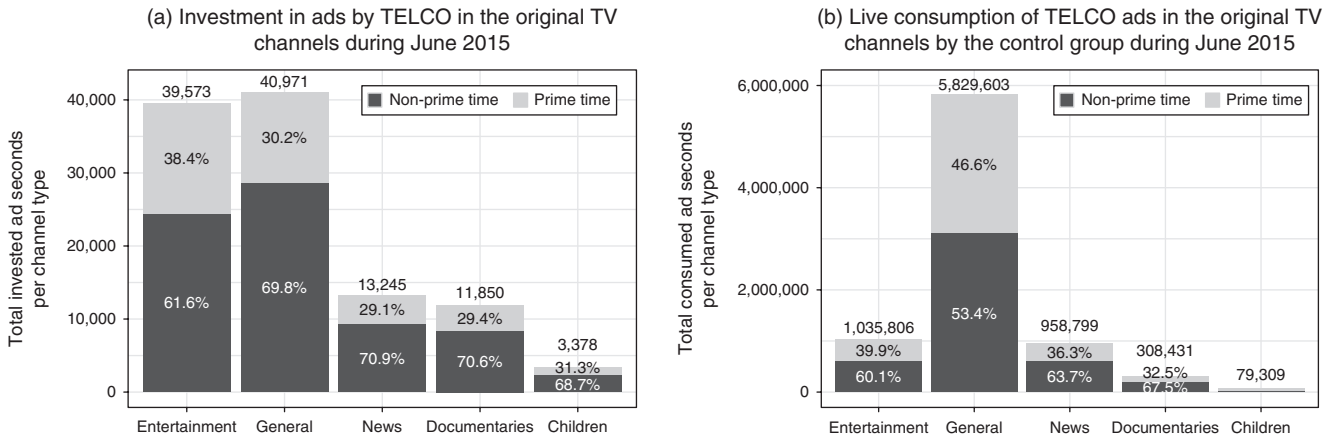


Table 8. Impact of Time Shifting on the Live Consumption of Ads in the Original Channels (June 2015) for Households Gifted Access to the Entertainment Bundle

	Dependent variable							
	Commercial view seconds/Month				Commercial view time/TV view time			
	ITT (1)	LATE (2)	LATE (3)	LATE (4)	ITT (5)	LATE (6)	LATE (7)	LATE (8)
TS	−13.458**				−0.00002			
	(6.763)				(0.00005)			
WatchEBTS 30 min		−50.451**				−0.0001		
		(25.396)				(0.0002)		
WatchEBTS 60 min			−56.058**				−0.0001	
			(28.222)				(0.0002)	
WatchEBTS 90 min				−68.774**				−0.0001
				(34.633)				(0.0003)
Constant	679.563***	679.705***	679.706***	679.709***	0.002***	0.002***	0.002***	0.002***
	(4.852)	(4.904)	(4.904)	(4.906)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
Observations	23,414	23,414	23,414	23,414	23,414	23,414	23,414	23,414
R^2	0.0002				0.00001			
Residual std. error	517.411	518.281	518.339	518.480	0.004	0.004	0.004	0.004
F statistic	3.960**				0.129			

Note. Cluster robust standard errors in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

here, we find no evidence that time shifting introduces significant changes to the likelihood of abandoning these ads.

6. Conclusions

We partnered with TELCO, a large telecommunications provider, to explore the outcomes of a randomized field experiment designed to study the effect of time shifting on TV consumption and ad viewership. TELCO gave a set of 10 TV channels that broadcast popular movies and TV shows 24/7 without commercial breaks—referred to here as the entertainment bundle—to a random sample of 3P/4P residential premium households that did not subscribe to these channels when the experiment started. A random subset of these viewers received access to the channels without time shifting. Another random subset received access to the channels with time shifting. For the remainder of the households nothing changed, so these functioned as a control group. This experimental setup made it possible to identify the effects of watching the entertainment bundle on TV consumption as well as the impact of using time shifting to watch these channels on the consumption of TV, in particular on the consumption of live TV. In this way we aimed to address the industry's concern that time shifting may displace live TV consumption and thus affect exposure to ads. We also measured whether time shifting affects the likelihood of skipping live ads, thus providing even more direct evidence of its impact on advertising.

We start by showing that the entertainment bundle captures the attention of households by comparing households in the control group with households given access to these channels without time shifting. Households with access to these channels without time shifting substitute live and time-shifting consumption in the original channels, namely, in the general purpose and entertainment ones, for live consumption of the entertainment bundle in a way that does not change overall TV consumption. Next, we compare households given access to the entertainment bundle with and without time shifting. We found that, for households with time shifting, total TV consumption increased. This result is driven by the fact that time shifting significantly increases the consumption of the entertainment bundle, even though it also accentuates the displacement from consumption of programs on the original entertainment channels. The increase in the consumption of the entertainment bundle occurs in both viewership modes: live and time shifting. A spillover effect from time shifting to the consumption of the entertainment bundle live means that the overall consumption of live TV is unchanged, which may alleviate some of the industry's fears associated with the potential disruption that time shifting was expected to cause the media sector. This spillover effect is also consistent with using time shifting to catch up on content that was missed a few days earlier, and thus households are likely to combine live and time shifting once the latter is available. In fact, in our sample we observe that 80% of the time-shifting consumption

Table 9. Impact of Time Shifting on the Probability of Exiting Ads Placed by TELCO When Watching the Original Channels Live (June 2015) for Households Gifted Access to the Entertainment Bundle

	Dependent variable							
	Add exit							
	Probit (1)	Probit (2)	LATE (3)	LATE (4)	LATE (5)	LATE (6)	LATE (7)	LATE (8)
Prime Time		0.023***		0.003***		0.003***		0.003***
		(0.008)		(0.001)		(0.001)		(0.001)
TS	−0.006	−0.012						
	(0.007)	(0.008)						
Prime Time ∗ *TS*		0.013						
		(0.011)						
WatchEBTS 30 min			−0.003	−0.006				
			(0.003)	(0.004)				
WatchEBTS 60 min					−0.003	−0.006		
					(0.004)	(0.004)		
WatchEBTS 90 min							−0.004	−0.008
							(0.005)	(0.005)
Prime Time ∗ *WatchEBTS* 30 min				0.007				
				(0.006)				
Prime Time ∗ *WatchEBTS* 60 min						0.007		
						(0.006)		
Prime Time ∗ *WatchEBTS* 90 min								0.009
								(0.007)
Constant	−1.406***	−1.416***	0.080***	0.078***	0.080***	0.078***	0.080***	0.078***
	(0.005)	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	602,633	602,633	602,633	602,633	602,633	602,633	602,633	602,633
Log likelihood	−167,281.700	−167,261.100						
Akaike inf. crit.	334,567.300	334,530.200						
Residual std. error			0.271	0.271	0.271	0.271	0.271	0.271

Notes. Cluster robust standard errors in parentheses. Errors clustered at household level. Add view time is not available in the period prior to the experiment.

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

relates to content that aired live in the last 48 hours. We also show that time shifting does not increase the concentration of live TV consumption, but it is disproportionately used to watch the more popular programs, which increases the concentration of overall TV consumption. This change in the distribution of total TV consumption may have implications for the valuation of ad slots, depending on whether households skip ads with time shifting. If households do not skip ads when using time shifting then the ad slots associated with the more popular content will acquire a disproportionate share of attention.

We found no evidence that households use time shifting strategically to watch fewer live ads placed by TELCO in the original channels during the last month of our experiment. The reduction in the consumption of these ads is proportional to the reduction in the live consumption of these channels. Furthermore, the likelihood of skipping one of these ads live is the same for households given access to the entertainment bundle with and without time shifting. This result also holds both for ads aired during prime time and those shown at other times. In conclusion, we found robust evidence that time shifting does not disproportionately reduce the consumption of TELCO's live ads. We report both ITT and LATE estimates for all of our results, which increases our confidence that our findings are indeed driven by the use of time shifting when watching the entertainment bundle. For example, time shifting increases total TV consumption, especially for those households that use time shifting more heavily to watch the entertainment bundle. However, even these households maintain their viewership of live TV. So there is robust evidence that using time shifting to watch the entertainment bundle does not reduce the consumption of live TV.

Finally, we note that our paper has some limitations. First, our experiment involved a random sample of residential 3P/4P premium households linked to TELCO that did not subscribe to the entertainment

bundle when the experiment started. While they represent 70% of TELCO's clients and TELCO is the leading provider of pay-TV services in the country we studied, we acknowledge that it may not be possible to extrapolate our results to other countries or to the media industry in general. In this respect, we note that the aggregate share of time-shifting viewership time at TELCO is similar to that registered in other countries, such as France, the United Kingdom, and the United States. Second, we note that our experiment was carried out during May and June and thus our results might have been different had the experiment been run at a different time of the year. Also, we are unable to separate the short- and long-term effects on TV consumption that may arise from using time shifting because our experiment only ran for six consecutive weeks in 2015. In any case, we observe that TELCO introduced time shifting for the first time at the end of the summer of 2012 and that the use of time shifting stabilized after a month at a level that was on aggregate similar to that observed in 2015 during our experiment. Third, our experiment allows us to measure the causal effect of using time shifting to watch the entertainment bundle and thus the results might have been different had time shifting been offered over a different set of channels. In fact, we provide evidence that time shifting is mostly used to catch up on entertainment content and thus, for the duration of our experiment, TELCO offered time shifting over the set of channels for which they thought this technology would be more valuable to households. Most likely, offering time shifting for other types of channels would produce smaller effects. Finally, we measured the effect of time shifting on the live consumption of ads placed by TELCO for its own products (such as video-on-demand movies and TV shows) in the original TV channels. TELCO's ads are not representative of the wide spectrum of TV ads and thus the results might have been different for other types of ads, for example, for other products or for ads placed at different times.

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Appendix A. Robustness Checks Using the Weakly Panel A

For robustness, we run the analyses presented in Tables 2–4, using the weekly panel. These analyses are presented in Tables A.1–A.3, respectively. All results are qualitatively similar to those presented in the main text.

Table A.1. Effect of Gifting and Watching the Entertainment Bundle on TV Consumption Using Weekly Panel Data

	Dependent variable											
	All				Live				Time shifting			
	ITT (1)	LATE (2)	LATE (3)	LATE (4)	ITT (5)	LATE (6)	LATE (7)	LATE (8)	ITT (9)	LATE (10)	LATE (11)	LATE (12)
*During * EB*	0.004 (1.266)				1.343 (1.195)				−1.212*** (0.257)			
*During * WatchEB* 30 min		0.011 (3.521)				3.734 (3.322)				−3.370*** (0.715)		
*During * WatchEB* 60 min			0.011 (3.402)				3.608 (3.209)				−3.256*** (0.690)	
*During * WatchEB* 90 min				0.011 (3.572)				3.788 (3.369)				−3.418*** (0.724)
Week dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	187,064	187,064	187,064	187,064	187,064	187,064	187,064	187,064	187,064	187,064	187,064	187,064
R^2	0.050				0.053				0.005			
F statistic	1,081.465***	1,081.503***	1,081.499***	1,081.496***	1,155.099***	1,167.135***	1,166.427***	1,165.562***	96.008***	63.299***	78.057***	84.218***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A.2. Effect of Offering and Using Time Shifting to Watch the Entertainment Bundle on TV Consumption Using Weekly Panel Data

	Dependent variable											
	All				Live				Time shifting			
	ITT (1)	LATE (2)	LATE (3)	LATE (4)	ITT (5)	LATE (6)	LATE (7)	LATE (8)	ITT (9)	LATE (10)	LATE (11)	LATE (12)
During ∗ *TS*	4.581*** (1.258)				1.275 (1.184)				2.906*** (0.271)			
During ∗ *WatchEBTS* 30 min		47.155*** (13.187)				13.120 (12.191)				29.916*** (3.340)		
During ∗ *WatchEBTS* 60 min			50.597*** (14.186)				14.078 (13.076)				32.099*** (3.696)	
During ∗ *WatchEBTS* 90 min				49.686*** (13.898)				13.824 (12.834)				31.521*** (3.612)
Week dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	187,808	187,808	187,808	187,808	187,808	187,808	187,808	187,808	187,808	187,808	187,808	187,808
R^2	0.049				0.053				0.006			
F statistic	1,053.867***	1,000.904***	955.985***	961.198***	1,153.409***	1,198.371***	1,196.861***	1,195.817***	127.069***	−1,745.639	−2,096.359	−2,033.400

Notes. Robust standard errors in parentheses. Fixed effects estimator.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A.3. Effect of Offering Time Shifting to Watch the Entertainment Bundle on Overall TV Consumption per Type of Channel Using Weekly Panel Data

	Dependent variable						
	E-Bundle (1)	General (2)	Entertainment (3)	Children (4)	News (5)	Sports (6)	Other (7)
During ∗ *TS*	6.980*** (0.397)	−0.156 (0.856)	−1.360*** (0.485)	−0.146 (0.364)	−0.244 (0.265)	0.061 (0.342)	−0.554 (1.079)
Week dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	187,808	187,808	187,808	187,808	187,808	187,808	187,808
R^2	0.108	0.289	0.162	0.093	0.139	0.071	0.295
F statistic	2,479.721***	8,357.422***	3,984.365***	2,100.470***	3,302.926***	1,562.476***	8,595.648***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Appendix B. Analysis of the Sample Attrition Rate per Treatment Condition

Table B.1 presents the attrition rate in the three experimental conditions. Tables B.2 to B.3 show the ANOVA and Tukey test statistics comparing the attrition rate across the three experimental groups caused by missing data. In all cases we show estimates that are not statistically significant at the 5% level and thus missing data dropped a similar number of households from each treatment condition, which provides strong evidence that attrition was orthogonal to treatment.

Table B.1. Attrition Rate in the Three Experimental Conditions

Control	Treated no time shifting (EB)	Treated time shifting (TS)
0.1398	0.1309	0.1330

Table B.2. ANOVA Analysis for the Attrition Rate in the Three Experimental Conditions

	Df	Sum sq	Mean sq	*F* value	Pr(>*F*)
Treatment group	2	0.59	0.30	2.55	0.0783
Residuals	40,563	4,723.78	0.12		

Table B.3. Tukey Multiple Comparison Test for the Difference in the Attrition Rate Across Experimental Conditions

	Diff	Lwr	Upr	*p* adj
TS – EB	0.0021	−0.0077	0.0118	0.8718
Control – EB	0.0089	−0.0008	0.0187	0.0789
Control – TS	0.0069	−0.0028	0.0166	0.2219

Figure B.1. Tukey Multiple Comparison Test for the Difference in the Attrition Rate Across Experimental Conditions

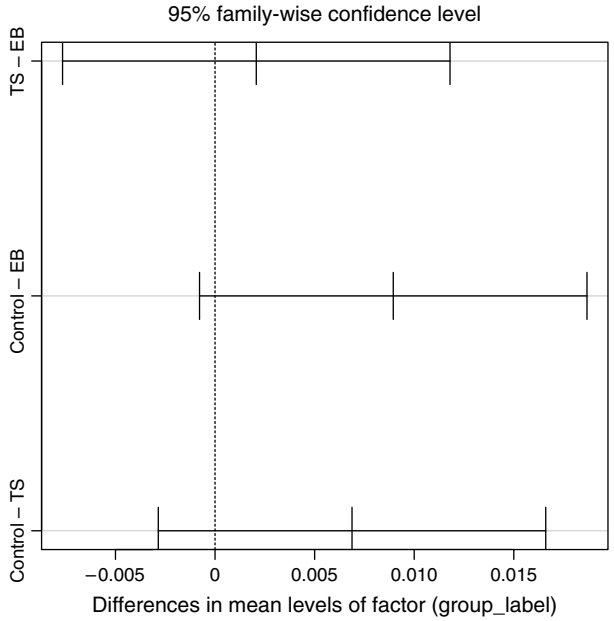

Table C.1. Effect of Offering Access to the Entertainment Bundle on Total TV Consumption per Type of Channel

	Dependent variable						
	E-Bundle (1)	General (2)	Entertainment (3)	Children (4)	News (5)	Sports (6)	Other (7)
During	0.210***	18.719***	5.776***	9.648***	4.796***	−3.299***	−36.616***
	(0.059)	(0.483)	(0.315)	(0.296)	(0.193)	(0.192)	(0.486)
During * *EB*	14.898***	−4.201***	−5.777***	−0.538	−0.578**	−0.477*	−2.773***
	(0.273)	(0.681)	(0.448)	(0.406)	(0.268)	(0.266)	(0.689)
Observations	46,766	46,766	46,766	46,766	46,766	46,766	46,766
R^2	0.207	0.094	0.014	0.084	0.046	0.030	0.343
F statistic	3,057.269***	1,208.635***	165.200***	1,067.845***	566.386***	356.325***	6,094.358***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table C.2. Effect of Offering Access to the Entertainment Bundle on Live TV Consumption per Type of Channel

	Dependent variable						
	E-Bundle (1)	General (2)	Entertainment (3)	Children (4)	News (5)	Sports (6)	Other (7)
During	0.118**	13.677***	3.628***	7.596***	3.759***	−3.743***	−27.471***
	(0.049)	(0.444)	(0.284)	(0.265)	(0.181)	(0.186)	(0.459)
During ∗ *EB*	14.757***	−3.719***	−4.903***	−0.495	−0.580**	−0.351	−2.668***
	(0.267)	(0.627)	(0.406)	(0.362)	(0.250)	(0.258)	(0.647)
Observations	46,766	46,766	46,766	46,766	46,766	46,766	46,766
R^2	0.209	0.059	0.008	0.066	0.032	0.038	0.254
F statistic	3,095.186***	727.779***	89.387***	827.500***	387.747***	463.146***	3,977.667***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table C.3. Effect of Offering Access to the Entertainment Bundle on TSTV Consumption per Type of Channel

	Dependent variable						
	E-Bundle (1)	General (2)	Entertainment (3)	Children (4)	News (5)	Sports (6)	Other (7)
During	0.067***	−0.661***	−0.125*	0.281***	−0.158***	−0.032**	3.527***
	(0.014)	(0.091)	(0.065)	(0.037)	(0.025)	(0.014)	(0.133)
During ∗ *EB*	−0.016	−0.291**	−0.296***	−0.012	0.024	−0.033	−0.868***
	(0.019)	(0.129)	(0.091)	(0.052)	(0.034)	(0.021)	(0.187)
Observations	46,766	46,766	46,766	46,766	46,766	46,766	46,766
R^2	0.002	0.007	0.002	0.005	0.003	0.001	0.046
F statistic	20.094***	80.660***	23.736***	56.505***	36.555***	11.625***	559.605***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Appendix C. Additional Results on the Effect the Entertainment Bundle

Tables C.1–C.3 are analogous to Tables 4–6 in Section 5.2 but contrast the total, live, and time shift view time of households who received the entertainment bundle without time shift to households in the control condition.

Appendix D. Heterogenous Treatment Effects Associated to TSTV

Tables D.1–D.4 present the results of our analyses of the heterogeneity in households' response to the treatment. The household characteristics considered are the age of the contract holder, an indicator of whether the household opted for an electronic receipt, the average time spent by the household using time shifting before the experiment, and the average time spent watching entertainment content before the experiment (Tables D.1–D.4, respectively).

Table D.1. The Moderating Effect of the Household Contract Holders Age

	Dependent variable		
	All (1)	Live (2)	Time shifting (3)
During	−4.087	−3.321	−0.609
	(3.082)	(2.902)	(0.786)
During ∗ *Age*	0.079	0.031	0.042***
	(0.063)	(0.060)	(0.016)
During ∗ *TS*	11.265**	2.574	7.427***
	(4.439)	(4.181)	(1.177)
During ∗ *TS* ∗ *Age*	−0.146	−0.042	−0.085***
	(0.091)	(0.086)	(0.024)
Observations	45,316	45,316	45,316
R^2	0.001	0.0004	0.025
F statistic	7.215***	2.256*	148.080***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table D.2. The Moderating Effect of the Households' Use of Electronic Receipts

	Dependent variable		
	All (1)	Live (2)	Time shifting (3)
During	1.846*	0.028	1.695***
	(1.009)	(0.962)	(0.252)
During ∗ *Electronic Receipt*	−5.094***	−4.170***	−0.801**
	(1.588)	(1.513)	(0.391)
During ∗ *TS*	3.145**	−0.041	2.858***
	(1.454)	(1.385)	(0.385)
During ∗ *TS* ∗ *Electronic Receipt*	3.609	2.115	1.404**
	(2.251)	(2.138)	(0.589)
Observations	46,952	46,952	46,952
R^2	0.002	0.001	0.025
F statistic	10.521***	3.921***	148.210***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table D.3. The Moderating Effect of the Households Previous Use of TSTV

	Dependent variable		
	All (1)	Live (2)	Time shifting (3)
During	6.708***	2.021**	4.743***
	(0.903)	(0.873)	(0.203)
During ∗ *TS Time Before*	−0.297***	−0.158***	−0.144***
	(0.022)	(0.019)	(0.011)
During ∗ *TS*	3.358***	1.413	1.679***
	(1.286)	(1.246)	(0.310)
During ∗ *TS*	0.056*	−0.024	0.076***
∗ *TS Time Before*	(0.031)	(0.027)	(0.016)
Observations	46,952	46,952	46,952
R^2	0.017	0.007	0.063
F statistic	99.879***	41.632***	392.050***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table D.4. The Moderating Effect of the Households Previous Use of Entertainment Content

	Dependent variable		
	All (1)	Live (2)	Time shifting (3)
During	10.515***	7.164***	2.975***
	(1.002)	(0.959)	(0.261)
During ∗ *Entertainment Time Before*	−0.256***	−0.210***	−0.038***
	(0.018)	(0.017)	(0.005)
During ∗ *TS*	2.898**	1.279	1.467***
	(1.435)	(1.360)	(0.417)
During ∗ *TS*	0.041	−0.011	0.047***
∗ *Entertainment Time Before*	(0.025)	(0.024)	(0.009)
Observations	46,952	46,952	46,952
R^2	0.022	0.019	0.028
F statistic	130.467***	114.827***	171.270***

Notes. Robust standard errors in parentheses. Fixed effects estimator.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Endnote

[1] The activation of the entertainment bundle for the experimental households was a gradual process that started on May 13 and was completed on May 18. We thus drop this period from our data.

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