WHEN YOU CAN'T TUBE … IMPACT OF A MAJOR YOUTUBE OUTAGE ON RAPES

M. AMELIA GIBBONS and MARTÍN A. ROSSI*

On Tuesday, October 16, 2018, YouTube experienced a major and rare global service outage. Using high-frequency crime data from the United States, we document an important increase in rapes in the 24-hour period following the outage. We investigate various potential underlying channels that may link the YouTube outage to the subsequent observed increase in rapes. The overall evidence only supports the hypothesis that the increase in rapes was driven by an increase in pornography viewing. (JEL D91, K42, L82)

I. INTRODUCTION

Social media is an important part of many people's lives. According to a 2017 survey, an average adult spends approximately 54 minutes a day consuming social media.[1] Among the many social media sites available, YouTube is the most widely used site by adults in the United States.

According to a nationally representative survey conducted in January 2019, 73% of American adults use YouTube regularly, and 51% of YouTube users say they visit the site daily.[2]

The increase in the use of social media raised an important debate in the public sphere on the potential effects of social media exposure on economic and social outcomes. Our paper contributes to this debate by studying the short-run effects of deprivation of consumption of social media. In particular, we study the impact of a major YouTube outage on subsequent rapes. On Tuesday, October 16, 2018, between 9 and 11 p.m. Eastern time, YouTube experienced a major and rare global service outage. Using high-frequency data on reported criminal incidents from the United States for the period January 1, 2017 to April 1, 2019, we document an important increase in rapes in the 24-hour period following the outage. Our results are robust to controlling for day of the week dummies, day of the month dummies, month dummies, and a time trend.

We also investigate potential underlying channels or mechanisms that may link the YouTube outage to the subsequent observed increase in rapes. We find that other crimes and offenses (including drug, alcohol, and traffic) were not affected by the outage. We also report that the observed increase in rapes did not occur in the

*M. Amelia Gibbons (agibbons@udesa.edu.ar), PhD candidate at Department of Agricultural and Applied Economics, University of Wisconsin-Madison and Fulltime Lecturer at Department of Economics, Universidad de San Andrés, Vito Dumas 284, B1644BID Victoria, Buenos Aires, Argentina; Martín A. Rossi (mrossi@udesa.edu.ar), Associate Professor at Department of Economics, Universidad de San Andrés, Vito Dumas 284, B1644BID Victoria, Buenos Aires, Argentina.

Gibbons: PhD candidate and Fulltime Lecturer, Department of Agricultural and Applied Economics, University of Wisconsin-Madison, Madison, WI, 53706; Department of Economics, Universidad de San Andrés, B1644BID, Victoria, Buenos Aires Argentina. E-mail agibbons@udesa.edu.ar
Rossi: Associate Professor, Department of Economics, Universidad de San Andrés, B1644BID, Victoria, Buenos Aires Argentina. E-mail mrossi@udesa.edu.ar

1. Millennials spend approximately 114 minutes a day. Retrieved from http://www.thevab.com/wp-content/uploads/2017/, on May 7, 2019.

2. Retrieved on April 10, 2019, from https://www.pewresearch.org/fact-tank/2019/04/10/.

ABBREVIATION

OLS: Ordinary Least Squares

2-hour period during the outage, but in the 22-hour period after YouTube service had been restored. Finally, we document that in the 2-hour period during YouTube's disruption there was an important increase in traffic on the online adult video site Pornhub (the world's biggest pornography site), which implied millions of additional viewers during Pornhub's peak hours. Overall, these findings suggest that the observed link between YouTube outage and rapes may be operating through the increase in pornography viewing.

There is some important literature on the drivers of sexual aggression, as well as on the characteristics of sexual crime perpetrators and their modus operandi.[3] According to this literature, most rapes are committed by relatives or acquaintances of the victim (Gavey 2013; Koss et al. 1988; National Research Council 1996; Russell 1984).[4] We do not have information on the perpetrator, so we are unable to contribute to this particular point. Though being related to this general literature, our paper does not focus on the causes of rapes, but on the causal effect of deprivation of a social media on rapes. As such, our research only explains a relatively small fraction of rapes.

Our paper is related to the literature on the impact of media on different outcomes, such as education, family choices, labor and migration decisions, environmental choices, health, crime, attitudes, consumption and savings, and financial choices (for a review of this literature -mainly radio and television-, see DellaVigna and La Ferrara 2015). There is also small literature on the effects of social media (Enikolopov, Makarin, and Petrova 2017; Enikolopov, Petrova, and Sonin 2018) and a recent experimental research that focuses on how people react to deprivations of the consumption of social media (Allcott et al. 2019; Mosquera et al. 2019).[5]

Our finding that pornography viewing may lead to an increase in rapes adds to a long-standing debate in the United States regarding the effects of pornography. As far back as 1968, President Lyndon B. Johnson sets up the President's Commission on Obscenity and Pornography to study the effects of pornography on crime and on other antisocial conducts. The Commission concluded there was insufficient evidence to link the exposure to pornography to subsequent aggression, particularly in sexual crime. The report triggered an important amount of research (mainly in the fields of criminology, experimental psychology, and sociology) on the effects of pornography on sexual aggression. Ferguson and Hartley (2009) provide a review of this research and, in line with the report, conclude that pornography is not associated with increased sexual assault behavior. However, some authors have challenged these findings, providing evidence that pornography is associated with an increase in violent sexual behavior. Malamuth, Addison, and Koss (2000) and Foubert (2017) provide a review of this literature and conclude that the evidence supports the existence of a positive association between frequent use of pornography and sexually coercive behavior, particularly for men at high risk for sexual aggression. Additionally, the literature that analyzes sexual offenders' modus operandi documents that most sexual offenders use pornography to feed their violent fantasies (Johnson 2006).

Given that most of the evidence available on the relationship between pornography and rapes come from correlational studies, it is difficult to interpret this evidence causally. The experimental research available focuses on hypothetical behavior in the lab, and the experimental subjects are mainly college students (Fisher and Grenier 1994; Hald and Malamuth 2015; Linz, Donnerstein, and Penrod 1988; Malamuth and Ceniti 1986; Yang and Youn 2012).[6] Thus, the question of whether pornography actually increases or reduces rapes is still open. Our paper provides evidence that supports the hypothesis that an increase in pornography viewing may lead to an increase in rapes.

Finally, our paper contributes to the literature on criminal decision-making. The rational choice theory postulates that rational agents decide whether to engage in criminal activities by comparing the benefits and costs of

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3. Groth (1979) identified a least four types of rapists: opportunist rapists (30%) who exhibit no anger toward the women they assault and usually use little or no force; anger rapists (40%) who batter the survivor and use more physical force than is necessary to overpower her; power rapists (25%) who do not intend to physically harm their victim but rather to possess or control her to gain sexual gratification; and sadistic rapists (5%) who become sexually excited by inflicting pain on their victim.

4. According to RAINN, 8 out of 10 rapes are committed by someone known to the victim (https://rainn.org/statistics/perpetrators-sexual-violence).

5. There is also some research in economics that studies the impact of internet availability and sexual crime (Bhuller et al. 2013; Nolte 2019).

6. There is also literature discussing the limitations of this type of studies (Jensen 1995; Mould 1988).

committing a crime (Becker 1968). A recent literature shows that emotional cues or visceral factors (i.e., frustration and euphoria) also affect crime decisions, such as the decisions to engage in domestic violence (Card and Dahl 2011), violent crime (Munyo and Rossi 2013), and sexual crime (Lindo, Siminski, and Swensen 2018). In line with this literature, our results suggest that a fraction of sexual crime can be better characterized as a breakdown of control rather than a behavior driven by rational choice.

The organization of the paper is as follows. Section II presents the natural experiment and describes the data. Section III presents the empirical strategy and reports the results. Section IV explores mechanisms. Section V concludes.

II. NATURAL EXPERIMENT AND DATA

YouTube experienced a major and rare global service outage on October 16, 2018, between 9 and 11 p.m. Eastern time. Users who tried to access the website during this period were greeted with a blank page that showed no videos. On the app, they saw an error message saying "There was a problem with the network [503]." According to Downdetector, the first massive reports (13,650) were found at 9.01 to 11 p.m., Eastern time.

The outage received extensive coverage in the media.[7] Figure 1 displays the evolution of daily reported problems in the YouTube site for the period May 2017 to February 2019. We obtain YouTube reports data from Downdetector, which collects status reports from a series of sources (such as Twitter). Through a real-time analysis of this data, Downdetector automatically detects outages and service interruptions at a very early stage. An outage exists when the number of reports shows a significant jump relative to the baseline. As observed in Figure 1, there is a clear and unusual spike in reported problems on October 16, 2018.[8]

We use high-frequency (hourly) data on reported criminal incidents in the United States for the period January 1, 2017, to April 1, 2019. These data were collected by Socrata.[9] The Socrata data set aggregates all reported incidents at 295 police departments and sheriffs' offices (from a total of 17,784 police departments and sheriffs' offices in the United States), and represents 6.4% of the U.S. population. The data is on reported offenses and the time of the incident is the one reported by the victim.[10] There is no information on arrests.

From the original hourly data, we generate a "daily" data set that uses the date and time of the reported incident, so that all "days" start at the time of the outage (9 p.m. Eastern time). For example, in our built data set October 1 corresponds to the 24-hour period that starts at 9 p.m. Eastern time on October 1 and ends up at 8.59 p.m. Eastern time on October 2. In this way, we end up with 820 "daily" observations.

We define an incident as a rape if the record has the word "rape" or the corresponding police code in the primary incident type column or in the incident description.[11] In our sample, there is an average of 6.5 rapes per day.[12]

The data set also includes other criminal and noncriminal offenses. There are traffic offenses, community policing, disorder, theft (includes theft from vehicle, theft of a vehicle, robberies, property crime, and breaking & entering), and assault. All of these together account for approximately 80% of the total number of reports. Among these categories, we group theft and assault as criminal offenses, and traffic offenses, community policing, and disorder as noncriminal offenses. Additionally, we create variables on drug and alcohol-related offenses by aggregating all offenses that include the word "drug" and "liquor" in the incident description, respectively. Table 1 reports the summary statistics of the data.
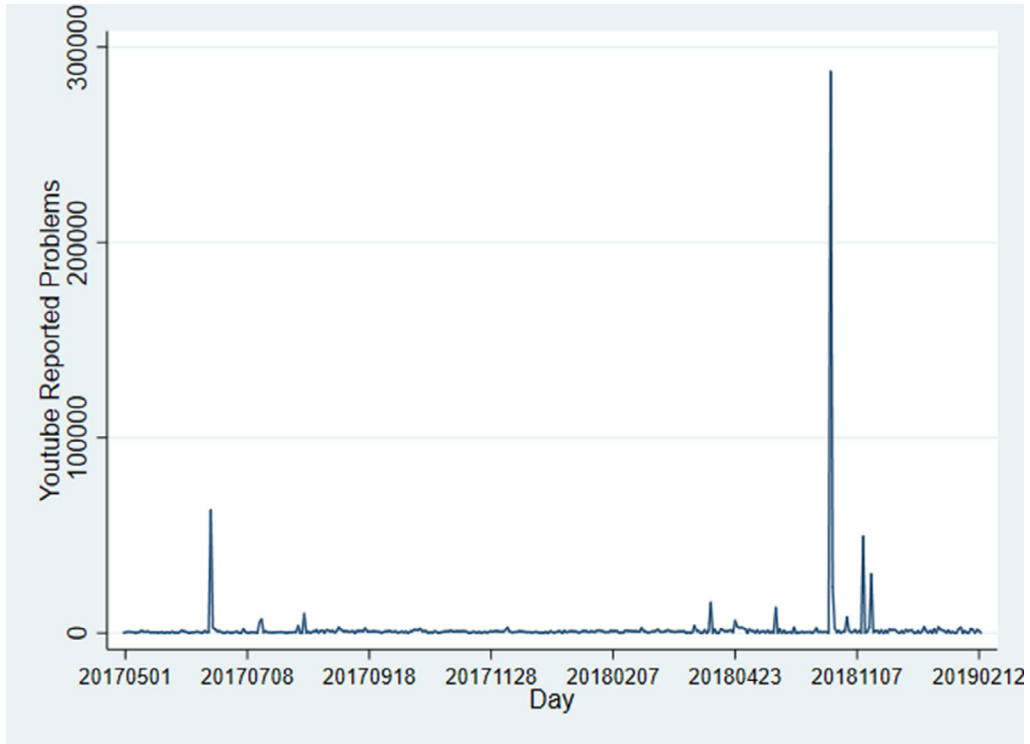
FIGURE 1
YouTube Outages, by Day.

Source: Own elaboration, based upon data obtained from Downdetector. Downloaded on April 21, 2019.

TABLE 1
Summary Statistics of Crime Data

	Mean	Standard Deviation	Minimum	Maximum
Rapes	6.54	3.21	0	21
Criminal offenses	1,976.49	211.78	1,089	2,523
Noncriminal offenses	4,281.58	477.96	2,232	6,088
Alcohol offenses	53.04	21.09	17	140
Drug offenses	187.49	25.72	66	260
Traffic offenses	1,690.13	217.64	653	2,274
Observations	820			

Notes: Table 1 reports summary statistics of "daily" data. Data were constructed using the date and time of the incident, and normalized so that all "days" start at the time of the outage (9 p.m. Eastern time). Criminal offenses include theft (a category that includes theft from vehicle, theft of vehicle, property crime, robberies, and breaking & entering) and assaults. Noncriminal offenses include traffic offenses, community policing, and disorder.

III. EMPIRICAL STRATEGY AND RESULTS

We are interested in estimating the impact of YouTube outage on rapes during the 24 hours following the outage. Figure 2 anticipates the main finding. The figure plots the distribution of rapes in all "Tuesdays" in our sample, and it shows that only 3.42% of Tuesdays have more reported rapes than October 16, 2018.[13]

13. These Tuesdays are August 22, 2017, May 15, 2018, June 12, 2018, and July 10, 2018. Note that all of these Tuesdays are either in spring or in summer.

FIGURE 2
Distribution of Rapes: All "Tuesdays" in the Sample.
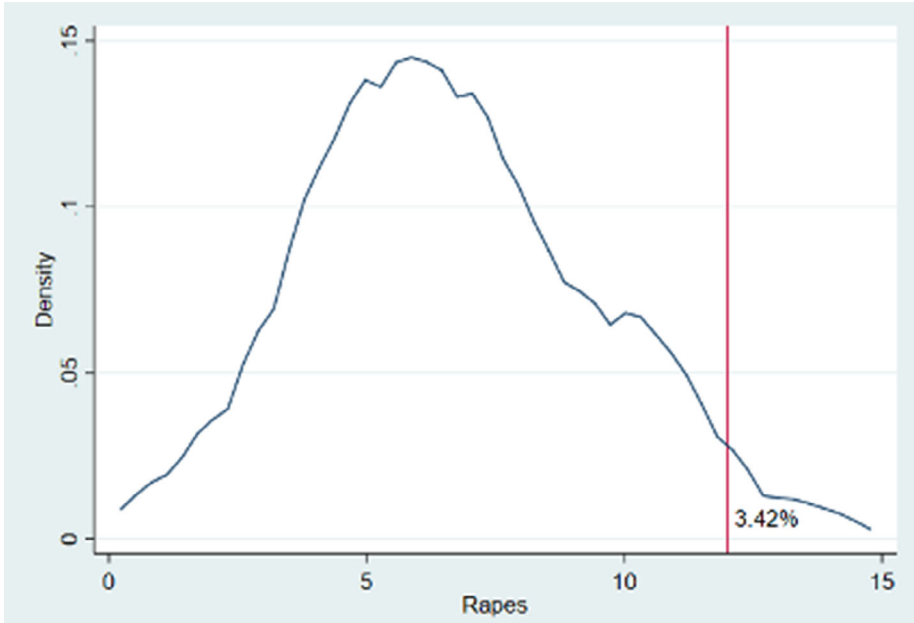
Source: Own elaboration. *Notes:* 3.42% is the percentage of Tuesdays with more rapes than October 16, 2018.

We first compare October 16, 2018, to the average Tuesday in our sample. We analyze it on three different periods: January 1, 2017 to April 1, 2019 (117 Tuesdays), January 1 to December 31, 2018 (52 Tuesdays), and September 1 to December 31, 2018 (17 Tuesdays). Formally, we estimate the following equation:

$$(1) \qquad Rapes_t = \alpha + \beta \ YouTube \ outage_t + \varepsilon_t$$

where $Rapes_t$ is the total number of rapes on day t, $YouTube \ outage_t$ is a dummy variable that takes the value 1 from October 16, 2018, 9 p.m. to October 17, 2018, 8.59 p.m. Eastern time, and zero otherwise, β is the parameter of interest, and ε_t is the error term.

Table 2 reports ordinary least squares (OLS) estimates of Equation (1). In column 1, we report estimates of Equation (1) for the 117 Tuesday in the sample period. The coefficient on YouTube outage is positive and statistically significant. The value of the coefficient implies a 1.6 standard deviation increase in rapes in the 24-hour period following the outage (the standard deviation of rapes on Tuesdays is 2.75). Columns 2 and 3 report estimates of Equation (1) for alternative time periods (January to December 2018 and

TABLE 2
Impact of YouTube Outage on Rapes: Sample of "Tuesdays"

	Dependent Variable: Rapes		
	(1)	(2)	(3)
YouTube outage	4.41***	3.63***	3.75***
	(0.25)	(0.36)	(0.50)
Permutation analysis			
500 replications	[0.018]	[0.014]	[0.006]
1,000 replications	[0.025]	[0.011]	[0.003]
5,000 replications	[0.023]	[0.013]	[0.003]
10,000 replications	[0.025]	[0.011]	[0.003]
Observations	117	52	17

Notes: Table 2 reports coefficients obtained from ordinary least squares regressions of Rapes on YouTube outage. In all cases, the samples are restricted to "Tuesdays" (the 24-hour period starting on Tuesdays at 9 p.m. Eastern time). Column 1 uses the period January 1, 2017 to April 1, 2019. Column 2 uses the period January 1, 2018 to December 31, 2018. Column 3 uses the period September 1, 2018 to December 31, 2018. White-Huber robust standard errors are in parentheses. p values (two-tailed) obtained from randomized inference using the *ritest* command in Stata are in brackets.
*Significant at 10%; **significant at 5%; ***significant at 1%.

TABLE 3
Impact of YouTube Outage on Rapes

	Dependent Variable: Rapes				
	(1)	(2)	(3)	(4)	(5)
YouTube outage	4.47	4.41	4.16	4.36	3.62
	(0.11)***	(0.25)***	(0.40)***	(0.81)***	(0.77)***
	{0.16}***	{0.25}***	{0.61}***	{0.95}***	{0.84}***
R-squared	0.002	0.094	0.105	0.187	0.260
Day of the week	No	Yes	Yes	Yes	Yes
Month	No	No	Yes	Yes	Yes
Day of month	No	No	No	Yes	Yes
Daily time trend	No	No	No	No	Yes
Observations	820	820	820	820	820

Notes: Table 3 uses daily data for the period January 1, 2017 to March 31, 2019. White-Huber robust standard errors are in parentheses. Newey-West heteroskedasticity- and autocorrelation-consistent standard errors are in braces.
*Significant at 10%; **significant at 5%; ***significant at 1%.

September to December 2018, respectively). Again, the coefficient on YouTube outage is positive and statistically significant.

Given that in these regressions the number of observations is relatively small, we conduct randomized inference and report p values obtained from permutation tests (over time) based on Monte Carlo simulations. We use the *ritest* command in Stata (Heß 2017), and we compute two-sided p values. We perform 500, 1,000, 5,000, and 10,000 replications. In all cases, the coefficients are statistically significant.

Then, we analyze the entire sample (820 daily observations). Table 3 reports OLS estimates of the following equation:

(2)
$$Rapes_t = \alpha + \beta \ YouTube \ outage_t + \varphi \ X_t + \varepsilon_t$$

Depending on the particular specification, the set of controls (X_t) includes day of the week dummies (7), day of the month dummies (31), month dummies (12), and a quadratic daily time trend. We report White-Huber robust standard errors and Newey-West heteroscedasticity- and autocorrelation-consistent standard errors.[14]

In column 1 of Table 3, we report estimates of Equation (2) without controls. The coefficient on *YouTube outage* is positive and statistically significant at the usual levels of confidence. The value of the coefficient implies a 1.4 standard deviation increase in rapes in the 24-hour period following the outage. In columns) to 5 in Table 3

we show that results are robust to controlling for day of the week dummies, month dummies, day of the month dummies, and a daily time trend.[15] Given that the average number of rapes is 6.54, the estimated coefficient indicates an approximately 55% increase in rapes in the 24-hour period following the outage.

Given the time-series nature of the exercises at hand, however, inference is always a concern. To deal with potential deviations of standard homogeneity assumptions, we implement a variant of Fisher's (1935) randomization test (see also Buchmueller, DiNardo, and Valletta 2011). We compare our estimate to the 819 "placebo" estimates obtained by running 819 additional regressions for each day and recomputing. In each case, we replace *YouTube outage_t* with an indicator that takes the value one for each of the other 819 days in the sample period. That is, we treat the 819 placebo estimates as the sampling distribution for the parameter of interest. The significance level is determined by the rank of the October 16 effect in the distribution of placebo effects. The rank of October 16, 2018 in the model in column 1 in Table 3 is 760, this means that 7% of placebo estimates are above the estimate for October 16, 2018. In the models in columns 2 to 5, the rank of the estimated coefficient corresponding to October 16, 2018 is 749, 749, 749, and 727 out of 820, respectively.

14. In all cases, the heuristic applied to obtain the number of lags is taken from the first step of Newey and West's (1994) plug-in procedure that sets the number of lags as *floor*[4(T/100)$^{2/9}$], where T is the number of observations.

15. Results are robust to using a quadratic time trend. In addition, to alleviate potential concerns arising from the use of a linear probability model when the outcome is discrete, as further robustness check we reproduce previous results using a regression model for discrete count outcomes. Conclusions are robust to using count models. All results mentioned and not shown are available upon request.

FIGURE 3
Placebo Analysis: 2 Weeks before and 2 Weeks after.
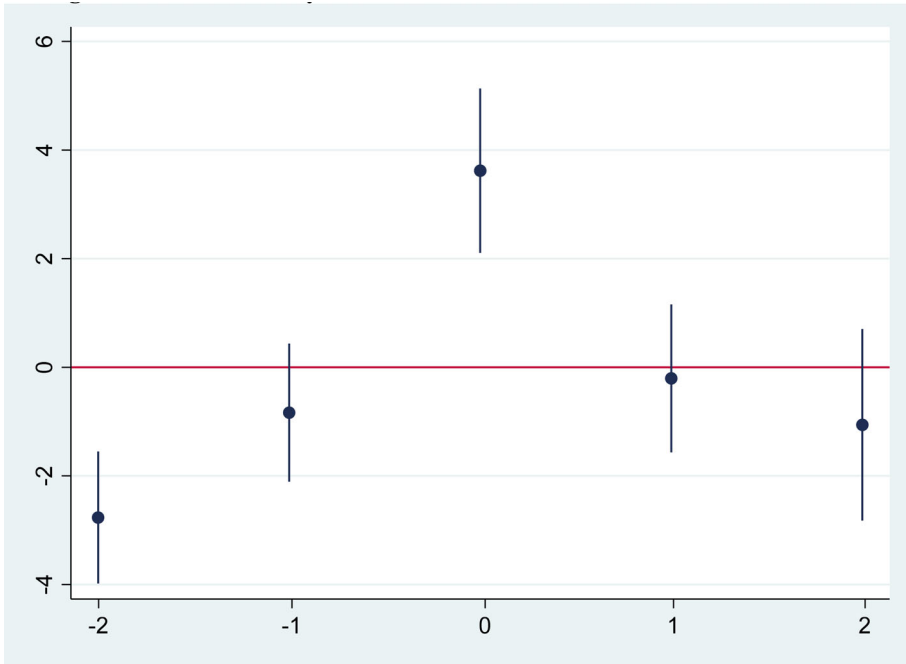
Source: Own elaboration. *Notes:* Figure 3 displays estimates of Equation (2) using the four Tuesdays around October 16 as placebo treatments. In all cases, we estimate the model in column 5 in Table 3. In the horizontal axis, 0 corresponds to October 16, 2018, whereas −1, −2, 1, and 2, are placebo treatments obtained by rolling the treatment artificially back and forward 1 week and 2 weeks, respectively.

In a similar fashion, and in order to further address the causal interpretation of our finding, we conduct a series of placebo analyses around the treatment window. First, we use the four Tuesdays around October 16 as placebos. That is, we generate four placebo treatments by rolling the treatment artificially back and forward 1 week and 2 weeks, respectively. Second, we use the 12 days around October 16 as additional placebos. That is, we generate 12 placebo treatments by rolling the treatment artificially back and forward 1, 2, 3, 4, 5, and 6 days, respectively. In all cases, we estimate the model in column 5 in Table 3. We report these placebo exercises in Figures 3 and 4. Our findings indicate that, out of the 17 estimated coefficients (16 placebos plus the real treatment), the coefficient for October 16 is the largest one.

As an additional analysis, we conduct a kind of triple-difference approach, using total crime as a within-day counterfactual. We estimate a variation of Equation (2) in which the dependent variable is the share of rapes on total criminal offenses. As observed in Table 4, the coefficients on YouTube outage are, in all cases, positive and significant, indicating that rapes are increasing on October 16, 2018, relative to total crime.

Overall, results in Tables 2 and 3 indicate that rapes spiked on October 16, 2018, whereas results in Table 4 suggest that this spike in the number of rapes does not appear to be representing general crime spikes.

IV. FURTHER RESULTS

We now investigate various potential underlying mechanisms that may link the YouTube outage to the subsequent observed increase in rapes. We explore: (1) a direct effect of the outage on other crimes and offenses, (2) an effect on drug and alcohol-related offenses, (3) an effect on more people going out after the outage for alternative entertainment, (4) an effect on time substitution, and (5) pornography viewing.

FIGURE 4

Placebo Analysis: 6 Days before and 6 Days after.
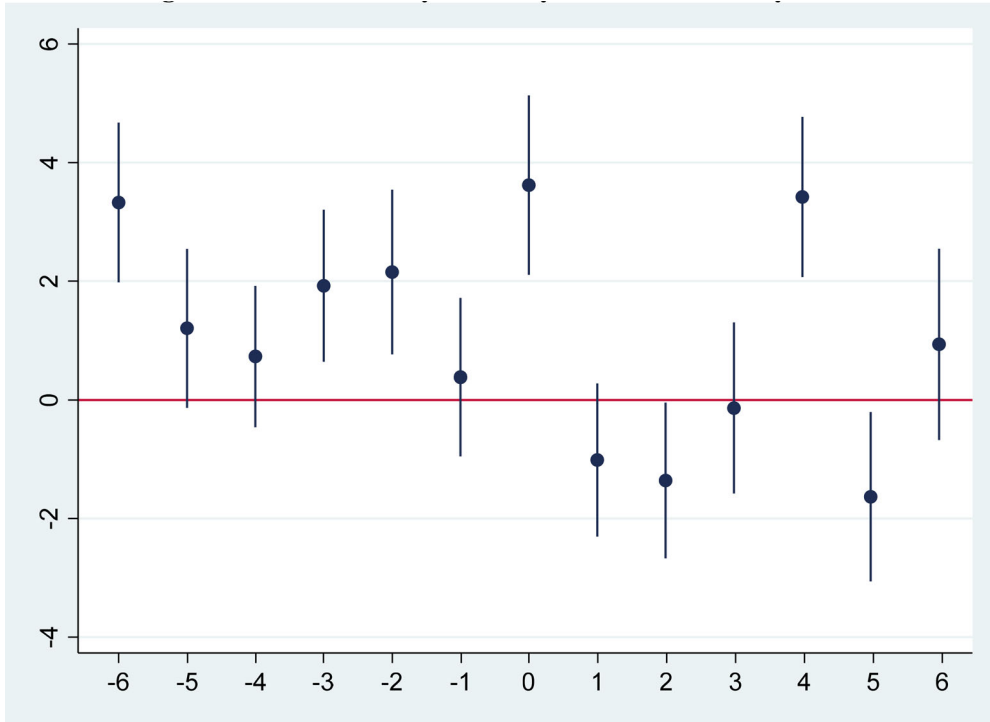
Source: Own elaboration. *Notes:* Figure 4 displays estimates of Equation (2) using the 12 days around October 16 as placebo treatments. In all cases, we estimate the model in column 5 in Table 3. In the horizontal axis, 0 corresponds to October 16, 2018, whereas −1 to −6 and 1 to 6 are placebo treatments obtained by rolling the treatment artificially back and forward 1 to 6 days, respectively.

TABLE 4

Impact of YouTube Outage on the Participation of Rapes on Total Crime

	Dependent Variable: (Rapes/Criminal offenses)*1,000				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
YouTube outage	1.89	1.96	1.97	2.05	1.73
	(0.05)***	(0.12)***	(0.19)***	(0.41)***	(0.40)***
	{0.07}***	{0.12}***	{0.27}***	{0.46}***	{0.43}***
R-squared	0.002	0.011	0.095	0.167	0.228
Day of the week	No	Yes	Yes	Yes	Yes
Month	No	No	Yes	Yes	Yes
Day of month	No	No	No	Yes	Yes
Daily time trend	No	No	No	No	Yes
Observations	820	820	820	820	820

Notes: Table 4 uses daily data for the period January 1, 2017 to March 31, 2019. White-Huber robust standard errors are in parentheses. Newey-West heteroskedasticity- and autocorrelation-consistent standard errors are in braces.
*Significant at 10%; **significant at 5%; ***significant at 1%.

TABLE 5
Mechanisms: Other Crimes and Offenses

	(1) Criminal Offenses	(2) Noncriminal Offenses	(3) Drug Offenses	(4) Alcohol Offenses	(5) Traffic Offenses
YouTube outage	−45.21	−83.70	−3.16	3.21	−43.35
	(35.11)	(75.87)	(3.15)	(5.48)	(27.97)
	{35.60}	{73.06}	{4.06}	{2.42}	{30.29}
Day of the week	Yes	Yes	Yes	Yes	Yes
Month	Yes	Yes	Yes	Yes	Yes
Day of month	Yes	Yes	Yes	Yes	Yes
Daily time trend	Yes	Yes	Yes	Yes	Yes
Observations	820	820	820	820	820

Notes: Criminal offenses include theft (a category that includes theft from vehicle, theft of vehicle, property crime, robberies, and breaking & entering) and assaults. Noncriminal offenses include traffic offenses, community policing, and disorder. White-Huber robust standard errors are in parentheses. Newey-West heteroskedasticity- and autocorrelation-consistent standard errors are in braces.
*Significant at 10%; **significant at 5%; ***significant at 1%.

We first analyze the effect of the outage on criminal offenses (theft, assault, property crime, theft from vehicle, breaking & entering, and theft of vehicle) and noncriminal offenses (traffic offenses, disorder, community policing, and vehicle stop). As mentioned before, frustration, for instance, could be an emotional cue expressing from the unexpected outage, and this could have led to an increase in crime. As shown in columns 1 and 2 in Table 5, however, there is no significant association between the outage and criminal and noncriminal offenses.

We then investigate the effect of the outage on drug and alcohol-related offenses. This is potentially important since approximately half of sexual assaults involve alcohol consumption by the perpetrator, victim, or both (Abbey et al. 2001). Columns 3 and 4 in Table 5 show the outage is not significantly related to an increase in drug-related offenses nor to an increase in alcohol-related offenses.

Finally, we also explore if the lack of online entertainment led people to go out. In principle, more people going out after the outage may be correlated with the increase in rapes. We indirectly check this potential path by looking at the effect of the outage on traffic offenses. As shown in column 5 in Table 5, the estimated coefficient is statistically not significant.

Overall, results reported in Table 5 suggest there is no positive effect of the outage on other crimes and offenses.

A plausible hypothesis is that watching YouTube and committing rape are substitutes. This may arise, for example, if some individuals that were not able to access YouTube react by committing rape.[16] We name this hypothesis as the time-substitution channel. An observational implication of the time-substitution channel is that we should observe an increase in rapes during the outage (that is, in the 2-hour period starting at 9 p.m. Eastern time on Tuesday October 16, 2018). To explore this potential channel we constructed an hourly data set for the period January 1, 2017 to March 31, 2019 (19,680 hours). An anticipation of time-substitution results is reported in Figure 5, which shows there is no increase in rapes during the outage, and all the observed increase occurs after the service was restored.

To formally test the time-substitution channel, we generate two new variables. *During outage* is a dummy variable that is equal to 1 in the 2-hour period from 9 to 10.59 p.m. Eastern time on Tuesday October 16, 2018. *After outage* is a dummy variable that is equal to 1 in the 22-hour period starting at 11 p.m. Eastern time on Tuesday October 16, 2018. As reported in Table 6, all the observed effect comes from rapes in the 22-hour period after the outage. Indeed, rapes fell during the outage. These findings do not support the time-substitution channel.

Finally, we explore the pornography-viewing channel. During YouTube's disruption, there was an important increase in traffic on the online adult

16. The literature on sexual offender's modus operandi discusses about several offender's typologies. For example, an offender who is trolling for victims may choose to acquire an opportunistic victim at a location with increased victim availability and vulnerability. Thus, the opportunistic offenders may rape the first person they see (Johnson 2006; Turvey 2013).

FIGURE 5
Hourly Distribution of Rapes during and after the Outage.
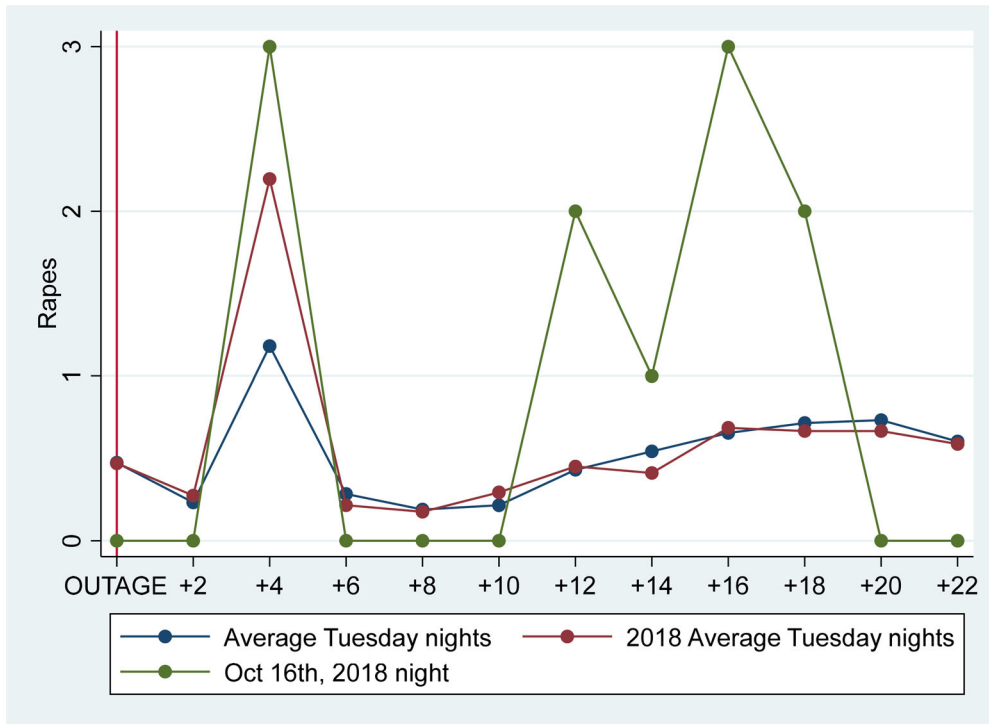
Source: Own elaboration.

TABLE 6
Mechanisms: Time Substitution

	Dependent Variable: Rapes					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
During outage	−0.27	−0.27	−0.27	−0.28	−0.29	−0.32
	(0.00)***	(0.01)***	(0.02)***	(0.02)***	(0.03)***	(0.03)***
	{0.00}***	{0.01}***	{0.02}***	{0.02}***	{0.03}***	{0.03}***
After outage	0.23	0.23	0.23	0.21	0.22	0.19
	(0.18)	(0.15)	(0.15)	(0.16)	(0.16)	(0.16)
	{0.10}**	{0.10}**	{0.10}**	{0.10}**	{0.10}**	{0.10}*
Hour of the day	No	Yes	Yes	Yes	Yes	Yes
Day of the week	No	No	Yes	Yes	Yes	Yes
Month	No	No	No	Yes	Yes	Yes
Day of the month	No	No	No	No	Yes	Yes
Time trend	No	No	No	No	No	Yes
Observations	19,680	19,680	19,680	19,680	19,680	19,680

Notes: Table 6 uses hourly data data set for the period January 1, 2017 to March 31, 2019. *During outage* is a dummy variable that takes value 1 in the 2-hour period 9 to 10.59 p.m. Eastern time on Tuesday October 16, 2018. *After outage* is a dummy variable that equals 1 in the 22-hour period starting at 11 p.m. Eastern time on Tuesday October 16, 2018. The variable *Rapes* has an hourly average equal to 0.27. White-Huber robust standard errors are in parentheses. Newey-West heteroskedasticity- and autocorrelation-consistent standard errors are in braces.
*Significant at 10%; **significant at 5%; ***significant at 1%.

video site Pornhub, the world's largest pornography site. The top panel of Figure 6 displays hourly data on YouTube reported problems. The bottom panel of Figure 6 displays hourly data on Pornhub's traffic from noon Eastern time October 16, 2018, until 2 a.m. Eastern time October 17, 2018. The Pornhub site detected a spike in traffic during YouTube's outage: traffic increased 12% above average at around 9 p.m. Eastern time, when the outage was reported, climbing to 21% increase over average traffic 1 hour later. According to information provided by Pornhub, this increase in traffic implies millions of additional viewers during Pornhub's peak hours. Traffic dropped rapidly once YouTube's service was restored, dropping to slightly below average numbers around midnight Eastern time.[17]

If YouTube viewers switched to Pornhub during the outage, there must be some substitutability between these two sites. Their traffic peak hours are late at night in comparison to other entertainment platforms.[18] Youtube's higher traffic is from 7 to 10 p.m., and Pornhub's higher traffic is from 9 to 1 a.m.[19] Thus, they are both video platforms that are mostly consumed at night.

What were YouTube users viewing before the outage? What happened to Pornhub searches during the outage? According to information provided by Pornhub, ASMR (Autonomous Sensory Meridian Response) was the word with the highest search growth during YouTube outage[20]: ASMR searches in Pornhub increased by 201% compared to the October 16, 2018, hourly average. In Pornhub, searching for ASMR leads to

hardcore material that combines the sound effects of ASMR with explicit sexual content. Even though we do not have information on YouTube searches around the outage, there is evidence that ASMR searches are very popular on YouTube,[21] and therefore it is likely that YouTube users that were watching ASMR at that site switched and searched for ASMR at Pornhub.

According to specialized literature (Both et al. 2004; Schmidt 1975), sexual arousal (and the increase in sexual activity) after pornography viewing last for up to 24 hours, so our findings are compatible with pornography viewing being the channel behind the observed increase in rapes in the 22-hour period after the outage. Additionally, the results are in line with the observed fact that one-third of sex offenders consume pornography before committing a sexual assault (Marshall 1988).

Overall, we conclude that evidence only supports the mechanism of pornography viewing. In the appendix, we develop a simple model to rationalize our interpretation that pornography viewing increases rapes.

V. FINAL REMARKS

YouTube experienced a major global interruption on Tuesday October 16, 2018. Using high-frequency crime data from the United States, we document an increase in the number of rapes in the 24-hour period following the outage. We explore various potential mechanisms, and we find evidence that the increase in rapes might be driven by an increase in pornography viewing.

The association between the increase in pornography viewing and the increase in rapes can be rationalized by combining previous research in psychology and behavioral economics. Research in psychology indicates that an important fraction of male students in the United States (25% to 30%) admit to some likelihood of raping or forcing sex acts on a woman if they could get away with it (Edwards, Bradshaw, and Hinsz 2014; Malamuth 1984). The behavioral economics literature indicates that under the influence of visceral factors (such as being sexually aroused), individuals decide without fully taking into account the consequences of their acts. In a nutshell, our results suggest that pornography consumption and rapes could be strategic

17. Using hourly data on YouTube reported problems and Pornhub traffic for the 15-hour window around the outage (from noon October 16 until 2 a.m. October 17, Eastern time), we run a regression of Pornhub's traffic on YouTube reported problems. As expected, the estimated coefficient is positive and highly significant (the estimated coefficient is 0.11, with a standard error of 0.01), indicating that the outage is highly correlated with pornography viewing.
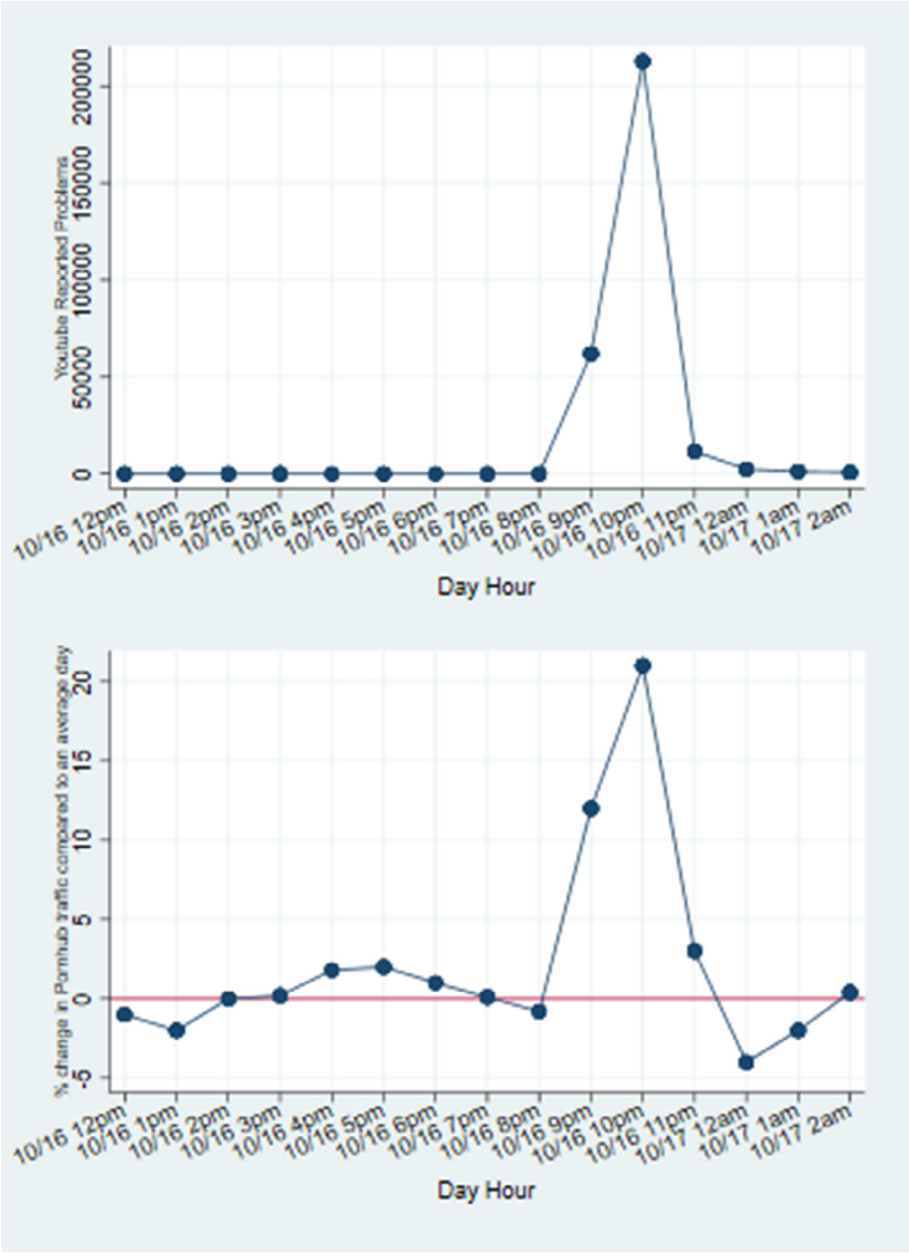
18. Social media platforms have different peak hours than the ones we are analyzing. Facebook's higher engagement is every day around 8–10 a.m. and 5 p.m., and it drops before 5 a.m. and after 6 p.m. Instagram's higher engagement on Monday through Friday, is from 9 a.m. to 4 p.m. and it is lower every day before 6 a.m. and after 9 p.m. Twitter has similar patterns, however, engagement drops off later in the day, after 10 p.m. (see https://sproutsocial.com/insights/best-times-to-post-on-social-media/).

19. See https://edgy.app/best-time-to-post-on-youtube-live-youtube-subscriber-count and https://www.pornhub.com/insights/pornhubs-fappyhour.

20. ASMR is an experience or feeling triggered by specific auditory or visual stimuli, such as quiet and whispery noises, usually accompanied by feelings of relaxation and well-being.

21. According to BBC news, there are over 13 million videos of people trying to trigger ASMR feeling on YouTube (https://www.bbc.com/news/av/newsbeat-45957504/asmr-i-can-make-your-brain-tingle).

FIGURE 6
YouTube Outage and the Increase in Pornhub's Traffic.

complements: the consumption of pornography increases sexual arousal, which in turn increases the utility from raping and decreases the perceived cost of being caught, thus increasing the probability of rape. Thus, our interpretation proposes that a small fraction of rapes could be better characterized as a failure of control rather than a behavior driven by rational choice.

APPENDIX

THEORETICAL FRAMEWORK: PORNOGRAPHY VIEWING AND RAPES

We focus on the behavior of potential male sexual offenders.[22] Our model has two stages. In the first stage, the agent decides how much pornography to consume subject to his time constraint. In the second stage, the agent decides whether or not to rape taking into account the costs and benefits associated with raping. Important to our setting is that in the first stage, the agent is unable to predict his future behavior perfectly if he were sexually aroused in the second stage. The behavioral economics literature names this as the hot-cold empathy gap, a cognitive bias in which individuals underestimate the influences of visceral factors (such as sexual arousal) on their own future behavior (Loewenstein 2000).

Formally, sexual arousal of individual i (v_i) depends on the consumption of pornography by individual i, X_{iP}. We assume that sexual arousal increases with the consumption of pornography, $v_i'(X_{iP}) > 0$. An agent is in "hot" or "cold" mode depending on whether sexual arousal is above or below a personal threshold, $\overline{v_i}$. An agent is in hot mode if $v_i(X_{iP}) \geq \overline{v_i}$, and he is in cold mode if $v_i(X_{iP}) < \overline{v_i}$.

We assume that in the first stage, being in cold mode, the agent naively predicts that in the second stage his sexual arousal will always be below his personal threshold (i.e., that in the second stage, he will always be in cold mode). Under this assumption, in the first stage, the agent solves the following maximization problem, where X_{iY} is YouTube consumption, X_{iO} is the consumption of all other leisure activities, and L_i is leisure endowment (X_{iP}, X_{iY}, X_{i0}, and L_i are measured in hours):

$$max\ U(X_{iP}; X_{iY}; X_{iO}), \text{s.t. } X_{iP} + X_{iY} + X_{i0} \leq L_i,$$

$$\text{for } i = 1, \ldots, N.$$

The agent solves this problem and chooses the optimal bundle of leisure consumption, including the optimal consumption of pornography (X_{iP}^*).[23]

In the second stage, the agent decides whether or not to rape conditional on the amount of pornography viewing chosen in the previous stage. According to the rational crime model (Becker 1968), the agent decides whether or not to rape by comparing the costs and benefits of raping. In our model, we follow the behavioral economics literature and we assume that being in hot mode affects both perceived costs and benefits of raping: it decreases the perceived cost of being

caught (see Nagin 1998; Van Winden and Ash 2012) and increases the utility from raping (Loewenstein 2000).[24]

For simplicity, we normalize the utility of not raping at zero. Thus, the agent rapes if the utility from raping is greater than zero. Formally, the agent rapes if

$$U(Rape) = \alpha + \beta\mathbf{1}(v_i(X_{iP}^*) \geq \overline{v_i})$$
$$- (c - \delta\mathbf{1}(v_i(X_{iP}^*) \geq \overline{v_i})) > 0,$$

where $\mathbf{1}(v_i(X_{iP}^*) \geq \overline{v_i})$ is an indicator that takes the value one if the agent is in hot mode, α, β, and δ are parameters greater than zero, c is the agent's expected cost of being caught (includes the probability of being caught and the length of the sentence), and $(c - \delta\mathbf{1}(v_i(X_{iP}^*) \geq \overline{v_i}))$ is the agent's perceived cost of being caught. We assume $\alpha < c$ and $\alpha + \beta + \delta > c$.

In the cold mode, $v_i(X_{iP}^*) < \overline{v_i}$, and $U(Rape) = \alpha - c$. Since $\alpha < c$, in the cold mode the agent decides not to rape. In the hot mode the agent rapes since $v_i(X_{iP}^*) \geq \overline{v_i}$, and $U(Rape) = \alpha + \beta - c + \delta > 0$.

In terms of our model, YouTube outage implies an additional restriction to the optimization problem: $X_{iY} = 0$. This implies that, in equilibrium, some agents end up consuming more pornography, thus increasing the probability of being in hot mode.

In sum, YouTube outage decreases the opportunity cost of pornography viewing relative to alternative activities, thus potentially increasing the equilibrium level of pornography viewing. The increase in pornography viewing leads to some agents crossing their sexual arousal threshold. Those agents that cross the threshold end up raping.

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22. Since males are by far the predominant perpetrators of rapes as well as the biggest consumers of pornography (see, for example, Russell 1984), we are calling the offender a "he."

23. We assume local nonsatiation so that the time constraint will hold with equality.

24. In general, visceral factors determine the trade-off between different goods and activities; thirst, for example, increases one's preference for water, and sexual arousal increases one's preference for having sex (Loewenstein 2000).

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