

Online Surveillance and Privacy-Enhancing Technologies*

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Abstract

The revelations of the NSA online surveillance program made by Edward Snowden in 2013 are thought to have had a large impact on the propensity of people to access information online. Studies analyzing this phenomenon have usually framed their analysis in terms of the suppression of access to information. In our work, we approach the event from a different perspective. We utilize an interrupted time-series study design and analyze pageview data on Wikipedia in order to determine whether the event had an impact on the propensity of people to access information related to privacy-enhancing technologies. We conclude that previously established models in the literature are unable to answer this question and that further work in the area should use a different model over a longer time span than has been used in the past.

1 Introduction

”Chilling effects theory” - the theory that government actions might affect the way in which people access information, has been a challenging topic among courts, legal scholars, and empirical researchers. The skepticism about the existence, nature, and extent of the chilling effects is particularly due to the lack of empirical evidence. However, in June 2013, Edward Snowden leaked classified information about the online surveillance program (PRISM) by the United States’ National Security Agency (NSA). This event provides a suitable opportunity to investigate the existence of

a ”Chilling effect” and the impact of government surveillance on people’s behavior. In this project, we consider the case of the NSA/PRISM revelations in June 2013 and study the effect of the event on the propensity to seek information related to privacy-enhancing technologies (PET) by analyzing the pageview data of related Wikipedia articles. This is of interest since it has previously been observed, as can be seen in Kokolakis (2015), that people’s expressed privacy concerns do not necessarily match their behavior online. We study both the immediate and long-term effects and test whether there were any notable changes following the event. In addition, we consider both the English and German language editions of the PET-related articles and compare their pageview data.

2 Related Works

In Penney (2016), the author considered the case of NSA/PRISM revelations in June 2013 and explored the potential chilling effect of such news by analyzing Wikipedia article views on privacy-sensitive topics. The author used 48 articles from the English language edition of Wikipedia that were related to a list of ”Terrorism-related” keywords for online surveillance issued by the US Department of Homeland Security (DHS). After excluding outliers, Penney observed a significant immediate and long-term impact on the pageviews of these articles. Similarly, in Marthews and Tucker (2017), the authors analyzed data from 11 countries on Google Trends to find whether users’ search behavior changed after June 2013. Their results show the change in activity was not limited to the US as there was also a drop in traffic observed globally for keywords that were rated as personally sensitive. In Rosso et al. (2020), authors used data from *DuckDuckGo*, a search engine that claims to protect users’ privacy and observed a significant increase in search volume after the PRISM surveillance revelations. However,

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analyzing the largest cyber-security companies' stock prices did not show any significant change, but rather a muted response. Similarly, in Patsakis et al. (2018), the authors did not observe any significant impact on the stock prices of the companies that shared their customers' information with the NSA.

3 Data Collection

For selecting articles to include in our analysis, we decided to use the Wikipedia Category "[Internet Privacy Software](#)" as our list of articles. Given the crowdsourced nature of Wikipedia categories, we were assured that they would be related to our signal. We thus created a dataset made of all articles that are contained within this root category, along with all articles which are contained within all direct sub-categories, namely: "Anonymous Social Media", "I2P" and "Tor (anonymity network)". In addition to English articles, we considered German language editions of the same articles.

As the source of pageview data on Wikipedia, we decided to use [WikiShark](#) by Vardi and Muchnik (2017). We asked and were granted permission by the developers of the service to access their data for the sake of this report under the condition that we waited 1 second between requests and only accessed data related to the subset of articles relevant to our analysis.

4 Methodology

Once pageview data for all articles indexed by WikiShark ($n = 84$) had been collected, an exploratory data analysis revealed that the majority of the cumulative pageviews were coming from a very small subsample of articles (the top 5 articles in pageviews account for 75% of the total pageviews). Then, pre-processing was done to remove all articles that would not have a significant impact on the outcome of our study. To this end, we simply removed all articles that never obtained more than 100 views in a single month. This brought the total amount of articles to a more manageable number of 52 articles. In order to assure that the articles used were representative of the signal we are interested in, outlier removal was done on a per-article basis. For each article, we used the Interquartile Range (IQR) to detect outliers in the monthly pageview data.¹ However, not every article that has a high level of variance

¹IQR was chosen as it places no assumption on the underlying distribution of the given observations.

in pageviews should be considered an outlier. To avoid this issue we performed manual inspection using Google News on each article observed to determine whether the high variance obtained is a result of the PRISM reveal or another unrelated event. Finally, 44 articles remained after removing outlier articles.

To determine both the direct and long term impact of the event, we used an interrupted time series (ITS) study design with segmented regression, in a similar fashion to Penney (2016). That is, we performed a linear regression analysis on the pageviews for our selected articles before and after the PRISM reveal, and compared the coefficients and their confidence intervals to determine if there were statistically significant changes in immediate and long-term trends. The model is defined using

$$Y_t = \beta_0 + \beta_1 \text{time} + \beta_2 \text{intervention} + \beta_3 \text{postslope} + \epsilon,$$

where β_0 is the total pageviews at the start of the study, β_1 is the linear trend in pageviews independent of the PRISM reveal, β_2 is the exogenous impact of the event, β_3 is the change in trend following the reveal and Y_t is the outcome variable, i.e., the pageviews of our subset of articles at a given point in time t .

We then performed the same regression analysis on the global Wikipedia pageviews, in order to see if the results we get are simply due to a general trend in the Wikipedia pageviews, or if it is in fact as a result from an increased propensity to seek information about PET.

Lastly, we applied this analysis on the German language editions of the articles.

5 Results

The results of fitting our segmented regression model to the English language articles can be seen in Figure 1. The coefficient of determination (R^2) for the model was 0.696, meaning that our model explains a good proportion of the variance in pageviews during the period. Analyzing the coefficients of the model, we found that the 95% confidence interval (CI) for the immediate increase in pageviews (β_2) was [-29500, 37000] following the revelations - meaning that we cannot conclusively deduce whether there truly was an immediate impact on pageviews following the event. The 95% CI for the impact of the event on viewing trends (β_3) was [-3380, 1425]. We observe that even though the fit of the model was quite good, we cannot determine any immediate

or long-term changes in pageviews following the event.

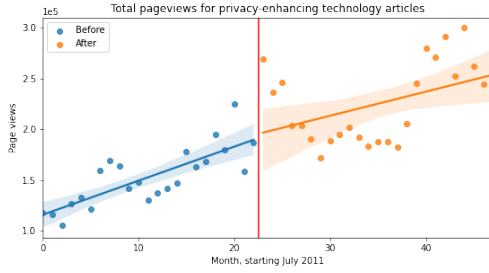


Figure 1: Fitting the regression model to the pageviews of articles selected in our study.

Doing the above analysis on the pageview data of all articles on the English language edition of Wikipedia and plotting the resulting model is illustrated in Figure 2. We observed a bad fit to the data overall ($R^2 = 0.282$), meaning it would be difficult to make quantitative statements in relation to the previous model. Nevertheless, the 95% CI of the immediate impact on pageviews following the revelation (β_2) was $[-1.8e+09, 5.42e+08]$, and $[-1.57e+08, 1.25e+07]$ for the change in viewing trends following the event (β_3).

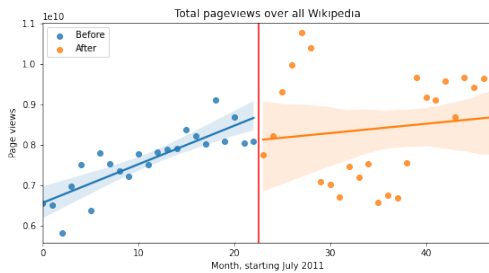


Figure 2: Fitting the regression model to the pageviews of all English language articles.

The model fitted to the pageviews of the German articles didn't lead to better results: while the P-values for the β_2 and β_3 coefficients were < 0.05 , the P-value for the β_1 coefficient was 0.562, with an overall R^2 score of 0.519.

6 Discussion

Though we were not able to perform a statistical test on the difference in direct and long-term viewing trends between our sample and the population, it is clear that the two signals are not identical. The former can be explained reasonably well using our model, whereas the latter cannot. We were surprised to see such a bad fit to the cumulative pageview data on the English language Wikipedia

given the reasonable fit achieved in previous studies. As a result we verified our data by fitting the same model to the same time span used in Penney (2016), where we observed a comparable model to the one reported in that paper. We therefore conclude that future studies on pageview data relating pageviews on articles from the English language edition of Wikipedia must take this longer period of time into account.

Despite this it is still clear that the model we used to analyze the pageviews of the PET-related articles was insufficient - we simply cannot determine neither the immediate nor long-term effects the reveal had on the pageviews of these articles. In order to do so, and to answer questions related to all the articles on the English language edition of Wikipedia, another model must be discovered which can both explain the variance in pageviews, and provides confident estimates of the model parameters.

During our study we encountered many issues with the reliability of our data. The WikiShark API had issues with disambiguating different language editions of articles, keeping the pageviews of identically named articles separate and also had gaps in time where there was no data available for some articles. The last of these issues was also encountered early on in the study when attempting to use an API which is part of the `wikipediatrend` R package by Meissner (2020). The source used by Penney (2016) (stats.grok.se) has also been inoperational since March 1st 2017. We conclude that there seems to be a lack of reliable legacy pageview data for individual Wikipedia articles available. The alternative to using these services would have been to process the `pagecounts raw` dataset provided by the Wikimedia foundation, but this presents challenges because of the sheer size of the dataset.

7 Conclusion

We conclude that in order to study the effects on long-term viewing trends for articles related to PET following the June 2013 PRISM revelations another model than the one used in our study must be discovered. As a result, we are unable to answer any questions related to the propensity to search for information related to PETs.

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