How Valuable are Consumers' Digital Footprints?

Yican Liu Fangzhou Lu *

February 9, 2025

Abstract

We measure firms' value of consumer data, or digital footprints, and consumers' privacy preferences by using a combination of option and stock data on various regulatory policies. Standard methods such as CARs underestimate the negative stock returns on consumer-app-intensive firms during the passage of GDPR, CCPA, or DSLC. Option-based methodologies estimate the average negative stock returns around −7%, amounting to a market cap loss of $0.20 billion for big tech firms during the GDPR passage, $0.32 billion during the CCPA passage, or $0.40 billion during the DSLC passage. Standard methods estimate the effect to be less than 1.5% for the passage of GDPR and CCPA and less than 4% for the passage of DSLC. Complementary to this methodology, we also estimate changes in firm app privacy settings at the mobile-app permission level, which allows us to estimate the value of data tracking back to different digital footprints. Permissions related to fintech payments are worth 1.3% of a firm's stock price. Additionally, we find that the passage of data protection regulations is associated with a decrease in the downloads and the active users of apps. Our findings are more significant among firms or apps with fewer active app users, suggesting that the passage of data privacy regulations has a more negative impact on firms with smaller capabilities for collecting data from existing app users. Together, these results suggest that the value of consumer data is a major component of tech firm value.

Keywords: Consumer Digital Footprints, Technology Firms, Data Privacy Regulations, Fintech, Mobile Applications, Stock Returns, App Permissions, Data Value.
JEL Classification: D82, G12, G32, K24, M15.

*Liu: HKU Business School, University of Hong Kong; yicanliu@connect.hku.hk. Lu: HKU Business School, University of Hong Kong; lufz@hku.hk. Helpful comments were provided by Peidi Chen, Xiangyu Ding, and Freddy Xuming Gong, as well as seminar and conference participants from Tsinghua PBC School of Finance and HKU Finance.

1 Introduction

In recent years, the rapid proliferation of mobile applications and the increasing digital footprint of consumers have led to a wealth of data, commonly referred to as "big data". This rich source of information, encompassing a wide array of consumer preferences and behaviors, has become particularly accessible to large technology firms such as Meta and Google. These firms, due to their extensive user base and data collection capabilities, are in a unique position to gather and analyze this information. In this paper, we estimate the value of big data derived from consumers' digital footprints on mobile applications as well as other sources in general, while also considering the privacy implications and the impact of regulations such as the General Data Protection Regulation (GDPR), the California Consumer Privacy Act (CCPA), and the Data Security Law of the People's Republic of China (DSLC).

The consumer's digital footprint or privacy data is valuable for two main reasons. First, it allows firms to extract consumer behavior and is thus valuable for marketing purposes. Second, certain private data enables firms to streamline payment processes while protecting the security of consumers using fintech technology. While the previous literature mostly discusses the optimal privacy policies given consumer's preferences[1], we take an alternative approach and accept those policies or changes in privacy settings as given, while estimating the value of consumer data using the stock and option prices of technology firms. Digital footprints can be a valuable data asset to firms (Berg et al., 2020), but their exact value is yet to be known. We first estimate the value of digital footprints or consumer data at the firm level and then break down the exact consumer privacy data at a permission level, such as facial recognition or contact data of the consumers.

Empirically, the standard approach to studying these questions is to use stock price reactions as direct measures of value change during important regulatory changes. The problem with this approach, however, is that stock price reactions do not cleanly identify any of the research questions posed above (Subramanian, 2004), as those events typically are highly anticipated so the event study estimated of the passage of these law that tighten consumer data collection is usually small. For example, the average negative return before GDPR is 0.05%, suggesting that tightening the consumer data collection do not affect technology firms in an economically meaningful way.

In this paper, we follow the approach of Borochin and Golec (2016) and show how

[1]See Goldfarb and Tucker (2012), Abowd and Schmutte (2019), Jones and Tonetti (2020), Fainmesser et al. (2023), and Ali et al. (2023).

call options written on technology firms can be used to identify the market's beliefs about the likelihood of the passage of these consumer data protection acts. marginal investors set call option prices based on their assessments of the same sources of value change. Like observed stock prices, observed call option prices can be written as a weighted average of call option prices if the consumer protection acts were passed. As Barraclough et al. (2013) show, because option prices on the technology firms are nonlinear functions of the underlying stock prices, each call option provides an additional unique piece of information about the passage of the consumer data protection act. With multiple call option series on different technology firms, we can identify the market's beliefs about all of the sources of data value.

We first apply our technique to a sample of 21 stocks during the GDPR passage in 2016, in which the firms had exchange-traded stock options. These stocks also have apps that have at least 5 million downloads or have apps in the top 100 downloads in the Eurozone, with more than 10 million market capital on the U.S. major stock exchange. We estimate the GDPR passage probability at 97% one day before the EU passage, which implies a very large adjustment in terms of affected stocks' return. Before adjusting for the probability of the GDPR happening, we estimate that technology firms with consumer apps gain 0.05% of their stock price, but they lose 7.31%, amounting $0.20 billion total market capital after adjustment.

Then, we estimate a similar outcome using the CCPA event. Different from GDPR, this is a local event applying to firms operating in California. Similarly, as for GDPR, we apply our technique to a sample of 21 stocks that have adequate apps users in the U.S. as well as large market size during the CCPA passage in 2018. We estimate the CCPA passage probability at 83% one day before the CCPA passage, which implies a very large adjustment in terms of affected stocks' return. Before adjusting for the probability of the CCPA passage, we estimate that firms with consumer apps gain 1.49% of their stock price, but the loss is 6.26%, amounting $0.32 billion total market capital after adjustment.

Next, we perform our event study methodology on the DSLC event, which is also about a regional regulation that applies to firms operating in mainland China. Similar to our analysis of GDPR and CCPA, we apply our technique to a sample of 19 stocks that have significant app users in China's app market and large market sizes on the U.S. stock market during the DSLC passage in 2021. We estimate the CCPA passage probability at 90% one day before the DSLC passage. From our estimation, we observe that the market began to anticipate the DSLC passage only one day before the event, indicating that the

passage of DSLC was not highly anticipated by stock market participants compared to GDPR or CCPA. Before adjusting for investors' anticipation, we estimate that firms with consumer apps lose 3.89% of their stock price. This loss increases to 7.06%, amounting to $0.32 billion in total market capital after adjustment using our option-based methodology.

We also estimate the heterogeneous impact of the passage of privacy protection laws. In general, we find that firms with less active app users are more likely to be influenced by the data privacy regulation passage. Our finding exists when market equity is controlled by including market equity as control variable or using value-weighted least regression with market equity as weight. This might be because the firms have more app users who persistently use their digital products. These users provide useful data for innovation, which may mitigate the negative impact of data privacy regulations on these firms.

Eventually, we use Google Play store to complement our study for the value of consumer data. we are able to tease out each permission add/drop using staggered policy rollout by the technology firms. Because the unexpected nature of these events, our option-based estimation yields a very similar result as the usual CARs. For this analysis, we are able to break down the app-based study to a permission level, which includes 13 different important permissions. Specifically, permission related to streamlined payment and fintech, such as the right to use fingerprint and the other to use use biometric in general, on average cost 0.5% to 1% of the firm's value, which is close to 0.07 billion dollar. Others that are more deeply related to app users' privacy and can be used to analyze user's behaviour, wealth, and, patterns, such as "Write External Storage"[2] or "Receive Boot Completed" [3], also are worth 1% of firm's value which is close to 0.07 billions dollar. Together with the results on consumer act passage, these results suggest that consumer digital print worth a significant amount of value.[4]

What might be the possible explanation or channel for how changes in privacy regulations influence firms' values? We extend our analysis by investigating how data

[2]The "WriteExternalStorage" permission in Android allows an app to write and modify files on external storage, such as SD cards or USB drives. With this permission, an app can create, update, or delete files and directories on external storage, which can be used for various purposes such as saving user-generated content, storing app-related data, or sharing files with other apps. This permission is important for apps that need to manage data outside of their internal storage to avoid filling up the device's limited internal memory. Note that granting this permission also indirectly grants read access to external storage.

[3]This is useful for apps that need to perform specific tasks or start certain services when the device boots, such as scheduling alarms, starting background services, or re-initializing app-related data.

[4]There are other permissions such as vibrate or call phone, or install shortcut that also matter for firm value. But these permission are more for the rights as interactive purposes rather than the value of consumer data. They are more for the value of privacy.

privacy regulations impact app activities. We find that the adoption of data protection regulations, such as GDPR and CCPA, is associated with a decrease in the number of active users of apps, especially those with higher data collection intensity. These results are more significant for apps with fewer active users. Our findings indicate that data privacy regulations might harm the quality of data-intensive innovations in apps, particularly for apps with smaller groups of existing users. This is consistent with our discussion on the heterogeneous effects of data privacy regulation passage on the capital market.

Our paper is related to the literature on consumer data privacy and firm's rent. Ichihashi (2020) show that while firms that collect more consumer data may serve their consumers better, they are also likely to price discriminate against consumers which lower consumers' surplus. Liu et al. (2020, 2023) show that large technology firms exploits the consumer privacy data through temptation goods and negative externality. Our research takes these policies as given as estimate the value of consumer digital footprints to firms and show that laws that favors the privacy of consumers are extremely costly to firms and perhaps consumers alike.

More generally, our research is related to the value of information, innovation and other potential tangible and intangible assets. Kadan and Manela (2019) show that investors are welling to pay 3% to 5% of their wealth for information such as economic indicators. Chen et al. (2019) estimate the value of fintech innovation. Our research shows that consumer's digital footprints are extremely valuable. Permissions that are related to fintech payments worth 2% of a firm's stock price. The average negative stock returns range from -10% to -20% when law enactment limits technology firms' collection of digital footprints.

2 Institutional background

2.1 The data protection laws: GDPR, CCPA, and DSLC

The collection and use of private data raise significant concerns regarding consumer privacy. As technology firms and businesses increasingly rely on big data to drive innovation, ensuring the protection of personal information and maintaining user trust has become paramount. In response to these concerns, regulations such as the General Data Protection Regulation (GDPR) in the European Union and the California Consumer

Privacy Act (CCPA) in the United States have been enacted to safeguard consumer privacy and grant individuals greater control over their personal data. In this section, we provide a brief introduction to the passage of these two regulations.

In the European Union, GDPR is one of the earliest and toughest data privacy regulations around the world, which is adopted by 28 countries that have active mobile app markets in the European Union. Since October 24, 1995 when 95/46/EC was adopted, GDPR has had a long-term discussion before this law was officially passed by European Union on April 14, 2016 and came into force on May 25, 2018. A salient feature of GDPR is that it requires obtaining clear and explicit consent from individuals before collecting and processing their personal data. For example, in Art. 12 of Chapter 3, GDPR documents the transparent information, communication, and modalities for the exercise of the rights of the data subject as:

> *"... The controller shall take appropriate measures to provide any information referred to in Articles 13 and 14 and any communication under Articles 15 to 22 and 34 relating to processing to the data subject in a concise, transparent, intelligible and easily accessible form, using clear and plain language, in particular for any information addressed specifically to a child. The information shall be provided in writing, or by other means, including, where appropriate, by electronic means. When requested by the data subject, the information may be provided orally, provided that the identity of the data subject is proven by other means..."*

Compared to GDPR, the passage of CCPA has a relatively shorter period of discussion. CCPA was applied to customers in California on June 28, 2018, protecting their rights and cybersecurity by giving the State of California a capable framework for enforcing data privacy regulations. Similar to GDPR, the CCPA emphasizes individuals' "rights to know" of the data collection procedure. Consumers in California have the legitimacy to know how their personal data is collected by companies. To be specific, in the section of "*General Information About the CCPA*," this law documents that:

> *"You can request that a business disclose to you: (1) the categories and/or specific pieces of personal information they have collected about you, (2) the categories of sources for that personal information, (3) the purposes for which the business uses that information, (4) the categories of third parties with whom the business discloses the information, and (5) the categories of information that the business sells or discloses to third parties. You can make a request to know up to twice a year, free of charge."*

Similar to GDPR and CCPA, DSLC requires digital firms to protect consumers' data privacies. This is one of the earliest data protection laws in China. Signed on June 11, 2021 by China's president, Xi Jinping, this law documents that:

> *"Article 8: When carrying out data processing activities, one must abide by laws and regulations, respect social morality and ethics, abide by business ethics and professional ethics, be honest and trustworthy, fulfill data security protection obligations, assume social responsibilities, and shall not endanger national security or public interests, or damage the legitimate rights and interests of individuals and organizations."*

In general, GDPR and CCPA require consumers' right to know that their personal data is collected by these digital firms, and DSLC restricts firms' invasions in consumers' privacy. Although this helps protect customers' rights, these three laws also limit the data collection capabilities of digital firms. This is because data protection regulations may limit the quantity and quality of personal information that a firm may collect from its consumers and, thus, reduce the quality of the digital services provided by this firm. In our paper, we use option-based event study methodology to estimate the potential negative impact of data privacy regulations on digital firms' values. We focus on the passage of each data privacy regulation, as before their passage, the market has expectations on the forthcoming events which may lead to biases in the standard estimations by cumulative abnormal returns.

2.2 Important permissions

In this section, we document the important privacy permissions that are requested by the mobile apps for data collection. We present some of the most important ones that are related to financial technology and privacy data collection on Android which we later use for event-study.

First we present fintech technology that is specifically used for payment: 1. Use-Biometric: This permission allows the app to access and use the device's biometric features, such as facial recognition or fingerprint scanning, to authenticate the user. This is typically used for secure logins or to authorize transactions. 2. UseFingerprint: This permission allows the app to access and use the device's fingerprint scanner for authentication purposes. Similar to UseBiometric, it is used for secure logins and authorizing transactions.

Second, we present important permissions that allow app firms to collect valuable data regarding their consumers: 1. ActivityRecognition: This permission enables the app to recognize and monitor the user's physical activities, such as walking, running, or cycling. It is commonly used by fitness and health-related apps to track users' activities and provide insights. 2. BadgeCountRead: This permission allows the app to read the badge count on the app's icon. Badge counts are typically used to show the number of unread notifications or pending tasks in the app. 3. BluetoothAdmin: This permission grants the app administrative control over the device's Bluetooth settings. This includes the ability to enable or disable Bluetooth, connect or disconnect devices, and manage paired devices. 4. PackageUsageStats: This permission allows the app to access the usage statistics of other apps installed on the device. This data includes information on how often and for how long each app is used, allowing the app to analyze and optimize the user's app usage. 5. ReceiveBootCompleted: This permission allows the app to receive a broadcast once the device has finished booting. This is often used by apps that need to start running in the background as soon as the device is ready, such as alarm clock apps or system utilities. 6. WriteExternalStorage: This permission enables the app to write data to the device's external storage, such as an SD card. This is commonly used by apps that need to save large amounts of data, like media files or documents. 7. CallPhone: This permission enables the app to initiate phone calls without requiring the user to confirm through the dialer interface. This is typically used by apps that offer call-related features, such as contact management or voice assistants.

Finally, we document some other permissions that may also be related for firms: 1. InstallShortcut: This permission allows the app to create and add shortcuts to the device's home screen. This is useful for apps that want to provide quick access to specific features or content within the app. 2. Vibrate: This permission enables the app to control the device's vibration function. It is typically used by apps that provide notifications, alerts, or haptic feedback during user interactions.

We also list some of the most important permission in Apple's iTune store: 1. AppTracking: This permission allows the app to track user data across apps and websites owned by other companies for advertising purposes. 2. BackgroundLocation: This permission allows the app to access the user's location even when the app is not in use. 3. Bluetooth: This permission allows the app to connect to Bluetooth devices. 4. Calendar: This permission allows the app to access and manage the user's calendar events. 5. Camera: This permission allows the app to access the device's camera to take photos

or record videos. 6. Contacts: This permission allows the app to access the user's contact list. 7. FaceID: This permission allows the app to use Face ID for authentication purposes. 8. ForegroundLocation: This permission allows the app to access the user's location only when the app is in use. 9. GameKit: This permission allows the app to use Game Center, Apple's social gaming network. 10. Health: This permission allows the app to access and write data to the Health app. 11. HomeKit: This permission allows the app to connect and communicate with devices that are compatible with Apple's home automation platform, HomeKit. 12. InAppPurchase: This permission allows the app to offer in-app purchases. 13. LocalNetwork: This permission allows the app to discover and interact with devices on the user's local network. 14. Microphone: This permission allows the app to access the device's microphone to record audio. 15. MotionActivity: This permission allows the app to access the device's motion and fitness activity. 16. NFC: This permission allows the app to communicate with NFC (Near Field Communication) devices. 17. Notifications: This permission allows the app to send notifications to the user's device. 18. Photos: This permission allows the app to access and manage the user's photos and videos. 19. Reminders: This permission allows the app to access and manage the user's reminders. 20. Siri: This permission allows the app to integrate with Siri, Apple's voice assistant. 21. SpeechRecognition: This permission allows the app to use Apple's speech recognition technology. 22. TurnOnBluetooth: This permission allows the app to turn on the device's Bluetooth. 23. TurnOnLocation: This permission allows the app to turn on the device's location services. 24. YourMusicAndVideoActivity: This permission allows the app to access the user's music and video activity. This can be used for recommendations and personalization.

3 The Data

The goal of our study is to understand how data collection and data privacy laws influence digital firms' value. In our study, we focus on the firms that have apps, as mobile phone activity is one of the major sources of personal data collection, and we estimate the impact of the passage of data protection laws by firms' market values. Thus, we utilize three kinds of datasets, including the stock and option dataset, apps' permission label dataset, and app activity dataset, to help our empirical analysis.

Stock trading data and option data In our study, we focus on the passage of two data protection laws: GDPR and CCPA. These two events are similar as they all focus on the data collection and protection of individual firms. However, there are two major differences between these two events. First, there has been a long-run discussion of GDPR, while CCPA has only been discussed for a relatively shorter period. In 1995, the European Data Protection Directive (Directive 95/46/EC) was adopted by European Union countries, which is considered the origin of GDPR. On April 14, 2016, GDPR was officially applied by the European Union. However, the CCPA was proposed by the California Attorney General's Office on June 28, 2018, and enforcement of the CCPA begins on July 1, 2020. The passage of DSLC was mostly unexpected by the market before the event, and it was signed by President Xi on June 10, 2021. Second, GDPR is only effective in European Union countries, CCPA is only effective in California, and DSLC is only effective in China mainland. Thus, the firms that are mostly influenced by the passage of laws are probably different in these three events. We construct different event study samples for these three events. For all of these three events, we focus on a five-trading day event study window ahead of the passage of each data privacy regulation.

We get the option trading data for these firms from OptionMetrics, and the stock prices from CRSP. When constructing the sample for our event study analysis, we only include the firms with enough app downloads before the passage of each data privacy regulation as these firms are more likely to be significantly influenced. We also exclude the firms that are with less $10 million market capital to ensure that these firms have enough active options within our sample. In Table A1 of Appendix B, we provide a full list of firms that have active apps in the EU, U.S., and China's app market before the passage of GDPR, CCPA, and DSLC. Table 1 presents a full list of the firms in our analysis, in which we document the company name, average number of daily active users (in millions), average number of daily downloads (in thousands), total revenue from App users (in millions), the number of active apps on iTunes Connect, the number of active apps on Google Play. We also include the information of firms' stocks, including exchanges where the stocks are traded, ticker, permanent number, SIC industry classification code, as well as market capital.

For the firms included in our event study analysis of GDPR passage, Alphabet has the highest number of app downloads in the European Union app market from January 2015 to December 2015 (531.44 thousand), while Expedia has the smallest number of app downloads (11.77 thousand). For CCPA, Alphabet also has the largest number of app

downloads in the U.S. app market from January 2017 to December 2017 (985.54 thousand), while Twitter has the smallest number of active users (35.01 thousand). For DSLC, Alibaba has the largest number of downloads in China's app market (380.64 thousand), while Amazon has the smallest number of app downloads (6.42 thousand).

The permission change data: Android permission time series dataset To estimate the impact of privacy permission changes on firms' market value, we also scrape the time-series data from the online page of the Android app developer tools. This website provides information about the daily changes in the permissions or types of data collected by the major apps on Google Play.

MyGlobalApp: the dataset of app activities To test the possible channel of how data protection laws influence the value of digital companies, we use daily-updated estimated mobile app data from a vendor, referred to as MyGlobalApp. At the end of each day, MyGlobalApp estimates daily downloads and active users for each app based on publicly available information such as app ranking and firm news. In our analysis, we focus on the app activities of the users from iTunes Connect in the United States, which is one of the largest and most important app markets around the globe. We also obtain the permission label data from MyGlobalApp. An example of permission labels is shown in Figure A1 of Appendix A. The records of permission labels provide useful information on which kinds of personal data are collected by the apps.

4 The anticipated impact of the passage of data protection laws

4.1 Methodology

In this section, we describe how we develop the estimator to calculate the individual effects of an anticipated event that may influence stock prices. Different from traditional event study methodology that only uses stock prices to measure the impact of an event, the idea of our methodology is to use stock prices as well as option prices to estimate the counterfactual stock prices of the firms that might be influenced by this event. Our main empirical methodology is similar to prior studies that use option prices to identify the

counterfactual stock prices of M&A (Barraclough et al., 2013), the Obamacare (Borochin and Golec, 2016), and the passage of Tax Cuts and Job Act (Borochin et al., 2021).

Our methodology starts with the model in Subramanian (2004) by defining the price process, dS. There are two possible geometric Brownian motions at the event date:

$$\frac{1}{r}dS = \begin{cases} S_u + \sigma_u S_u dz & \text{if event occurs with probability } q \\ S_d + \sigma_d S_d dz & \text{otherwise} \end{cases} \tag{1}$$

in which dz is the Brownian motion increment. S_u presents the price process with the occurrence of the event and S_d otherwise. We do not include risk-free rate in Equation 1, because the returns of risk-free rates are equal in both states. Without the loss of generality, we assume $\sigma_u \neq \sigma_d$. Additionally, because the impact of data privacy laws on digital firms is negative, we further assume that $S_u < S_d$. That is, the passage of such laws has a negative impact on the expected stock prices.

Suppose there are J options on the asset, with unique strike prices K_j and a common remaining time to maturity τ that ends after the event. In this case, for any firm i on any day before the event, the prices of $J+1$ assets can be measured as follows:

$$\begin{aligned} S_{i,t} = \;& E_t(q)E_t(S_{i,u}) + (1 - E_t(q))E_t(S_{i,d}) \\ c_{i,1,t} = \;& E_t(q)C(E_t(S_{i,u}), E_t(\sigma_{i,u}), K_1, \tau) + (1 - E_t(q))C(E_t(S_{i,d}), E_t(\sigma_{i,d}), K_1, \tau) \\ & \dots \\ c_{i,J,t} = \;& E_t(q)C(E_t(S_{i,u}), E_t(\sigma_{i,u}), K_J, \tau) + (1 - E_t(q))C(E_t(S_{i,d}), E_t(\sigma_{i,d}), K_J, \tau) \end{aligned} \tag{2}$$

in which $C(\cdot)$ is a function that gives the theoretical price of the option with a binomial pricing formula.

There are altogether five parameters to jointly estimate with the pricing functions in Equation 2 for the $J+1$ assets: $\{q, S_{i,u}, S_{i,d}, \sigma_{i,u}, \sigma_{i,d}\}$. Because we assume that $S_{i,u} < S_{i,d}$, the label switching problem as described by Borochin et al. (2021) is thus avoided in our estimation process. We define the minimization problem in our methodology as follows:

$$V_{i,t}(q, \theta) = \left| 1 - \widehat{P}_{i,t}(q, \theta_i)/P_{i,t} \right| \tag{3}$$

in which $P_{i,t}$ is a vector of prices on the left-hand side of Equation 2, and $\theta = \{S_u, S_d, \sigma_u, \sigma_d\}$. Additionally, $|\cdot|$ is the vector norm that minimizes the sum of squares.

Thus, our optimization problem can be defined as

$$\left(\widehat{q}_t, \left\{\widehat{\theta}_{i,t}\right\}_{i=1}^{M}\right) = \underset{q,\left\{\theta_{i,t}\right\}_{i=1}^{M}}{\arg\min} \left\{\sum_{i=1}^{M} V_{i,t}(q, \theta_i)\right\} \tag{4}$$

Thus, we need to determine $1 + 4 \times M$ parameters through our estimation, in which the "1" comes from q, and "$4 \times M$" is the number of parameters for option pricing of M firms.

For the accuracy of our estimation, we use a two-step strategy to solve Equation 4. First, for each probability q in $\{1\%, 2\%, ..., 99\%\}$, we estimate the best-fitted parameters of θ by Equation 3. This procedure requires $99 \times M$ times of estimations, and for each estimation, we use $J+1$ assets to estimate four parameters contained in θ. Our first step of estimation yields $99 \times M$ values of $\widehat{V}_{i,t}$. Second, for each probability q in $\{1\%, 2\%, ..., 99\%\}$, we calculate the total loss of optimization problem by Equation 4. The globally estimated probability of the passage of the event is the value of $\widehat{q}$ that minimizes Equation 4.

Following Borochin et al. (2021), in our estimation, we only use the call options with non-zero open interests, and we set J as 8 in Equation 2. That is, for each estimation of Equation 3, we include nine assets to estimate five parameters, including the parameters in θ as well as q. Compared to the number of parameters to be estimated, our estimation is over-identified and, thus, we can have a relatively accurate estimation of these parameters.

To estimate the confidence intervals for the estimation, we use bootstrapping by constructing 1,000 simulated samples for each day in our event study window. Then, we calculate the 5th or 95th percentiles of the bootstrap sample. We present our estimated $\widehat{q}$ and $\widehat{S_u/S_d} - 1$ for each event: the prior value is the estimated anticipated probability of the passage of this privacy law, while the later one is the market expected return of this event.

4.2 The estimation results

4.2.1 The option-estimated impact of the passage of data privacy regulations

We begin our analysis by performing the option-based event study methodology as described in Section 4.1 on the three major events related to the passage of data privacy protection laws, including the passage of GDPR, the passage of CCPA, and the passage of DLSC. We summarize the event study statistics for each trading day within our event

study sample, in which we present the option-estimated probability, return ($\widehat{S_u/S_d} - 1$), implied volatility when this event happens ($\widehat{\sigma_u}$), and implied volatility when this event does not happen ($\widehat{\sigma_d}$).

The option-estimated probability and impact of GDPR passage Our first set of empirical results is from the study of GDPR. The passage of GDPR is on April 14, 2016, and the event study window for this case is from April 7, 2016 to April 13, 2016. Table 2 shows such results. As one can see, the passage of GDPR is almost fully anticipated by the capital market, and the probability of its passage ranges from 83% (April 8, 2016) to 97% (April 13, 2016). The average probability of GDPR passage is 89% across the five trading days. The estimated firms' loss is also large, which ranges from a loss of 6.72% market capital (April 7, 2016) to 7.77% (April 13, 2016) with an average value of 7.31% across the five trading days. The estimated implied volatilities for two different states are consistent with our prior assumption: the average $\widehat{\sigma_u}$ is smaller than the average $\widehat{\sigma_d}$ for each trading day, indicating that the market has already anticipated the happen of the event. The states with a larger probability of happen are associated with a smaller value of implied volatilities.

We also present our option-based estimated results by figures. In Figure 2, we present the estimated probability as well as returns of the passage of GDPR on each trading day between April 7, 2016 and April 13, 2016. Starting from around 86% probability of passage of GDPR, there is an increasing trend in the estimated probability of the passage of GDPR. On the last day of our event study window, this probability is around 97%. This increasing trend in the estimated probability of the passage of GDPR is consistent with the intuition: as the time gets closer to the decision time of GDPR, the market is much more likely to anticipate the passage of this law. The estimated loss during the passage of GDPR also shows an increasing trend from 6.72% to 7.71%, but the magnitude of such increases is not large. The finding indicates that market expectations of the loss of digital firms are very persistent. We plot the boot-strapped 90% probability interval of our estimation. In our estimation, the 90% band is pretty narrow, indicating that our results are robust enough.

The option-estimated probability and impact of CCPA passage We continue our empirical analysis as described in Section 4.1 on the case of CCPA passage. In Table 3, we report our estimates on each trading day within our event study window. Similar to the case of GDPR, we find the market has already anticipated the passage of CCPA, and the

market starts to react to this event for at least three trading days before the event. Starting from 71% on June 21, 2018, the estimated probability of CCPA passage raised to 83% at the end of the event study window, June 27, 2018. The average estimated loss in the market value of CCPA passage on app firms is between 5.35% and 7.02%. To sum up, we could get some similar conclusions as the event study of GDPR passage: the market participants have already anticipated the passage of CCPA, and CCPA has a giant and negative impact on the market value of these app firms. However, the estimated probability of the passage of CCPA is much smaller than GDPR. This conclusion is consistent with the reality, as GDPR has longer discussion period for over ten years. The average $\widehat{\sigma_u}$ is still smaller than the average $\widehat{\sigma_d}$ for each trading day in this event study, which is similar to our conclusions in the event study of GDPR.

We observed an increase in the estimated probability of passage of CCPA from 45% (June 25, 2018) to 78% (June 26, 2018). This increase is consistent with the news released on these two days. On June 25, 2018, Secretary of State Alex Padilla confirms that his office received more than the required signatures for the passage of CCPA. Then, Governor Jerry Brown signs the CCPA into law. In Figure A2 of Appendix A, we show a screen shot about this news happen on that day.

Additionally, we also report the time series of the option-estimated impact of CCPA passage in Figure 3, in which we present the estimated probability of the passage of GDPR on each trading day between June 21, 2018, and June 27, 2018. Starting from around 71% probability of passage of CCPA, the estimation passage probability falls to 45% on June 25, 2018. Then, the estimated probability goes up to around 80% in the following two trading days. On the last day of our event study window, this probability is around 83%. We also show the estimated impact of CCPA passage on the market value. On average, the option estimated return of the passage of CCPA is around -6.26%.

The option-estimated probability and impact of DSLC passage In Table 4, we report our estimates on each trading day within our event study window. Similar to the previous two cases, we find the market has already anticipated the passage of DSLC. The market starts to reat to this event on at least three trading days before the passage of DSLC. The estimated probability of the passage of DSLC across the five trading days are 72%, and the return in this event is -7.09%. The average $\widehat{\sigma_u}$ is still smaller than the average $\widehat{\sigma_d}$ for each trading day in this event study, which is similar to our conclusions in the previous two event studies.

Additionally, we also report the time series of the option-estimated impact of DSLC passage in Figure 4, in which we present the estimated probability of the passage of DSLC on each trading day between June 3, 2021, and June 9, 2021. The market also anticipates the passage before the actual signature of this law, and the estimated probability ranges from 52% (June 7, 2021) to 90% (June 9, 2021). The increasing trend is also consistent with the economic intuition, in particular the last three trading days within this window. As one can see, there is a large increase from a probability of 60% to 90% on the last two trading days, which might indicate the possible information leakage during the last two trading days before the passage of DSLC. The estimated loss of each firm is also large, with 7.09% across all five trading days from 6.26% (June 9, 2021) to 8.21% (June 4, 2021).

4.2.2 Traditional event study methodology on the passage of data privacy regulations

In this section, we present the estimated cumulative abnormal returns around the passage of data privacy regulations for our event study firms. By comparing with the option-based event study results from Section 4.2.1, we discuss when the traditional event study methodology based on cumulative abnormal returns is efficient. We calculate the Fama-French 5-factor adjusted abnormal cumulative returns for each firm of trading day $t-1$ to trading day t (two-day window), trading day $t-3$ to trading day t (four-day window) or trading day $t-5$ to trading day t (six-day window).

In Panel A of Table 5, we present the cumulative abnormal return estimators for GDPR passage. Our estimated return by traditional event study methodology around the GDPR passage is positive, and the magnitude is less than 1%. As is shown in Table 2, the passage of GDPR is highly anticipated. This event study strategy does not take the market anticipation into account so that the estimator underestimates the negative impact of GDPR passage on those firms.

In Panel B of Table 5, we show the traditional event study measure for the CCPA. Similar to the conclusions we obtain from the traditional event study of GDPR, we observe significant and positive cumulative abnormal returns around CCPA passage, and the magnitude is also tiny: the coefficient is less than 1.5%. We can conjecture that the negative impact of CCPA passage is also underestmated by this methodology.

Panel C of Table 5 presents the traditional event study results for DSLC. We observe significant and negative cumulative abnormal returns around DSLC passage among our sample firms. The significant negative impact estimated by cumulative abnormal returns is consistent with our observations from Table 4, because the passage of DSLC is

not highly anticipated by the market until one trading before the signature by China's President. However, traditional event study methodology still underestimates the magnitude of the negative impact of passage of DSLC, with average cumulative abnormal returns below −4%. In Table 4, the estimated return of DSLC is −6.26%.

4.3 Additional analysis: The heterogeneous impact of data protection laws

To test which firms are more likely to be influenced by data protection laws, in Table 6, we present the impact of each event on each of the firms included in our event study sample. We report the company name, PERMNO, estimated return ($\widehat{S_u/S_d} - 1$), estimated implied volatility for two states (Ave. $\widehat{\sigma_u}$ and Ave. $\widehat{\sigma_d}$), market capital, as well as option-estimated loss in market capital in this table. We order the firms by $\widehat{S_u/S_d} - 1$ from smallest to the largest. Thus, we order the firms that are most influenced by data privacy regulations to least influenced by such regulations. From this table, we may conclude that the firms that are less dependent on digital products to make profits (e.g., Under Armour, Amazon, Adobe, Apple) are less likely to be influenced, compared to the firms whose major product is app or digital services (e.g., Unity Technologies, Bilibili, Comcast).

We extend our analysis by investigating the heterogeneity existing in the cross-section of the firms. To be specific, we run the following cross-sectional regression:

$$\text{OptRet}_i = \beta \text{FirmChar}_i + \alpha + \varepsilon_i \tag{5}$$

in which OptRet_i is the option-based estimation of the return of firm i. FirmChar_i is one of the firm characteristics for firm i, which is estimated before our event study window. For comparison, we also report the regression results by replacing OptRet_i in Equation 5 with the cumulative return or the cumulative abnormal return of firm i within the event study window. The dependent variables we choose include the log value of app daily active users, the log value of app downloads, as well as the log value of market capital.

Table 7 reports the regression results. In Panel A, we show the heterogeneous impact of the GDPR passage. The log value of app daily active users and the log value of app downloads are positively associated with option-estimated returns. This positive correlation remains when controlling for log market equity and becomes more significant when we use value-weighted least square regression with market equity as the weight.

In Panel B, we show the heterogeneous impact of the CCPA passage. In this set of regressions, we did not find a significant correlation between our explanatory variables and the option-estimated returns. In Panel C, we show the heterogeneous impact of the DSLC passage. We observe a positive correlation between the log value of app active users and the estimated returns. Additionally, Chinese firms lose more during the DSLC passage. Taken together, our findings show a positive correlation between app active users and option-estimated returns, with a stronger correlation observed during the GDPR passage and the DSLC passage. Our findings indicate that firms with more active app users are less likely to be negatively influenced by data protection regulations. These firms have more users who persistently use their apps, and these users provide useful data for innovation, which may mitigate the negative impact of data privacy regulations on these firms.

5 The impact of data collection on firms' value

In this section, we document how data privacy regulations influence firms with different data collection intensities. In Section 5.1, we show when a firm add or drop one data collection permission, how will the privacy setting change influence the firm's market value. In Section 5.2, we give a comprehensive look at how the passage of data privacy regulations influences the activities of apps with different data collection intensities.

5.1 The change of privacy permission and stock return

What is the value of data collection for app companies? One direct method to test this is by calculating how adding or removing a specific type of data collection permission influences the market value of these firms. To achieve this, we obtain the permission label time-series dataset from the Android developer website. For each app, we acquire the date when it adds or removes one particular type of data collection permission. Then, we calculate the cumulative abnormal returns, from one trading day before the permission change to the day after the permission change.

Table 8 reports the average abnormal cumulative return and the t-statistics of adding or dropping one kind of data collection permission. We also report the number of times of adding or removing this permission label from apps. Additionally, we also report the difference of t-statistics between removing and adding this permission label.

We report the 13 most important ones, including two FinTech-related permissions, including UseBiometric and UseFingerprint; seven data collection permissions, including AccessCoarsLocation, AccessBackgroundLocation, AccessFineLocation, Bluetooth, PackageUsageStats, ReadPrivilegedPhoneState, ReceiveBootCompleted, and WriteExternalStorage; and two other important permissions, including AccessWifiState, Flashlight and Vibrate.

Table 8 shows that for most of these permissions, adding them does not change the stock prices significantly. Only adding two permission labels, the AccessFineLocation permission and the Vibrate permission, makes the market value go up at 0.33% and 0.40%, respectively. However, removing these permissions harms the market value of these firms. Among all 13 permissions, dropping 6 of them, including UseBiometric, UseFingerprint, ReadPrivilegedPhoneState, ReceiveBootCompleted, WriteExternalStorage, and Flashlight, is associated with a significant loss in the stock prices. Specifically, for FinTech-related permissions concerning Financial payments, adding UseBiometric results in a −0.10% average cumulative abnormal return with a t-statistic of −0.2857. In contrast, removing this permission leads to a −1.00% average cumulative abnormal return with a t-statistic of −2.0083, causing a −1.7226 difference in t-statistic. Adding UseFingerprint yields a 0.01% average cumulative abnormal return with a t-statistic of 0.0443. On the other hand, removing this permission produces a −0.34% average cumulative abnormal return with a t-statistic of −1.6779 and a −1.7222 difference in t-statistic. For data-collection permissions and other important permissions, adding these permissions does not lead to significant changes in stock prices. However, removing them tends to result in significant losses in stock prices, as evidenced by the negative coefficients and t-statistics.

Together, these results seem to suggest that adding permissions, with the exception of the Vibrate permission, does not significantly impact stock prices. However, the removal of these permissions, particularly FinTech-related and data-collection permissions, negatively impacts the market value of the firms, indicating their importance in the operation of these firms. The removal of FinTech-related permissions like UseBiometric and UseFingerprint leads to pronounced stock price decreases, possibly due to perceived reductions in service efficiency and security. Similarly, removing data-collection permissions results in significant losses in stock prices, suggesting investors view data collection as vital to app companies' business models. Lastly, while the removal of other permissions like InstallShortcut does impact stock prices, the effect is less severe, potentially indicating these permissions are less integral to app companies'

core operations.

5.2 Privacy laws and the app activities

What might be the potential channel for how the change in privacy regulations influences firms' values? In this section, we investigate how privacy laws such as GDPR and CCPA influence the activities of different apps. We hypothesize that data privacy regulations harm the qualify of apps, especially for those apps that require a larger data intensity in developing.

To test our hypothesis, we run the following regression with a continuous difference-in-difference specification:

$$\log(\text{AppActivity}_{i,t}) = \beta \text{PermNo}_i \times \text{Post}_t + \text{AppLinearTrend} + \text{ID FE} + \text{Year-Week FE} \quad (6)$$

in which $\text{AppActivity}_{i,t}$ can be the downloads or average daily active users of app i in year-week t. In our regression, we use the natural log value of app activity as our dependent variable. The major difference in the app data collection intensity comes from PermNo_i, which is the total number of privacy permissions of app i. Post_t is a dummy variable that equals one if year-week t is after the adoption of GDPR or CCPA and zero otherwise. In this case, the adoption of GDPR is on May 25, 2018 and the adoption of CCPA is on July 1, 2020. In our basic empirical specification, we focus on the top 1,000 apps from iTunes Connect and control app-specific linear trends, app ID fixed effects, as well as year-week fixed effects in our regression. We also run this regression on the apps with PermNo_i larger than 0, or on the apps with top 500 highest daily active users or the apps with top 500-1000 highest daily active users on iTunes Connect.

In Table 9, we present the empirical results of Equation 6. In Panel A of Table 9, we show the impact of the GDPR passage on app activities. To sum up, we only find that the adoption of GDPR has a negative impact on the downloads of top 500-1000 intensive apps. For the firms with top 500 active users, we do not observe a negative impact. GDPR also has a negative impact on the active users of data-intensive apps: one more privacy permission is associated with a 2.70% decrease in the active users of apps. This negative impact might come from the decrease in the quality of app development caused by the limitation of data collection after the passage of data privacy laws. Additionally, our finding is not significant on the top 500 apps, indicating that the users of larger apps are more sticky. On the contrary, our finding is more significant with a larger effect size on

the apps with less active users. Our finding indicates that apps with a smaller group of users are more likely to be influenced by data privacy regulations.

Similar conclusions are found in the case of the CCPA passage. In Panel B of Table 9, we investigate how CCPA passage influences app activities. We do not find any significant impact of CCPA on the downloads of apps. However, we find a significant and negative impact of CCPA passage on the number of daily active users: one more privacy permission is associated with a 1.39% decrease in the users of apps. Additionally, the impact of CCPA adoption is also significant on the apps with less active users, which is consistent with our conclusions from GDPR adoption. Compared to GDPR, CCPA has a weaker impact on app activities. This is because CCPA is only adoptable within California, while GDPR is applied to all European Union countries and covers a wider range of mobile phone users.

Taken together, our analysis of app activities is consistent with our findings in the option-based event study for both the GDPR and CCPA passages. In Section 4.3, we find that firms with fewer app users are more likely to be negatively impacted by data privacy regulations. In this section, we provide further evidence to support our findings in Section 4.3. Our results indicate that the passage of data privacy regulations harms digital firms' value by reducing their app users. These effects are even stronger for firms with fewer existing app users, which might be the "fuel" for generating data essential for digital innovation and sustaining the quality of innovation.

We then extend our analysis based on Equation 6 by looking into how a specific kind of permission influences the impact of data privacy regulations. The regression we run is

as follows:

$$
\begin{aligned}
\log(\text{AppActivity}_{i,t}) = \quad & \beta_1 \text{AppTracking}_i \times \text{Post}_t + \beta_2 \text{BackgroundLocation}_i \times \text{Post}_t \\
& + \beta_3 \text{Bluetooth}_i \times \text{Post}_t + \beta_4 \text{Calendar}_i \times \text{Post}_t + \beta_5 \text{Camera}_i \times \text{Post}_t \\
& + \beta_6 \text{Contacts}_i \times \text{Post}_t + \beta_7 \text{FaceID}_i \times \text{Post}_t + \beta_8 \text{ForegroundLocation}_i \times \text{Post}_t \\
& + \beta_9 \text{GameKit}_i \times \text{Post}_t + \beta_{10} \text{Health}_i \times \text{Post}_t + \beta_{11} \text{HomeKit}_i \times \text{Post}_t \\
& + \beta_{12} \text{InAppPurchase}_i \times \text{Post}_t + \beta_{13} \text{LocalNetwork}_i \times \text{Post}_t \\
& + \beta_{14} \text{Microphone}_i \times \text{Post}_t + \beta_{15} \text{MotionActivity}_i \times \text{Post}_t + \beta_{16} \text{NFC}_i \times \text{Post}_t \\
& + \beta_{17} \text{Notifications}_i \times \text{Post}_t + \beta_{18} \text{Photos}_i \times \text{Post}_t + \beta_{19} \text{Reminders}_i \times \text{Post}_t \\
& + \beta_{20} \text{Siri}_i \times \text{Post}_t + \beta_{21} \text{SpeechRecognition}_i \times \text{Post}_t \\
& + \beta_{22} \text{TurnOnBluetooth}_i \times \text{Post}_t + \beta_{23} \text{TurnOnLocation}_i \times \text{Post}_t \\
& + \beta_{24} \text{YourMusicAndVideoActivity}_i \times \text{Post}_t + \text{AppLinearTrend} \\
& + \text{ID FE} + \text{Year-Week FE} \qquad (7)
\end{aligned}
$$

The permission labels we include in our analysis include AppTracking, BackgroundLocation, Bluetooth, Calendar, Camera, Contacts, FaceID, ForegroundLocation, GameKit, Health, HomeKit, InAppPurchase, LocalNetwork, Microphone, MotionActivity, NFC, Notifications, Photos, Reminders, Siri, SpeechRecognition, TurnOnBluetooth, TurnOnLocation, and YourMusicAndVideoActivity. The major independent variables in Equation 7 are the interaction terms of dummies for each kind of permission with the post-event dummy variable. Similar to the regression of Equation 6, we focus on the top 1,000 apps from iTunes Connect and control app-specific linear trends, app ID fixed effects, as well as year-week fixed effects in our regression.

Table 10 reports the regression coefficients of Equation 7. In Panel A of Table 10, we show the impact of GDPR passage on the app activities with different permission labels. Compared to the apps without any permission labels, we find that the downloads of apps with the permissions of BackgroundLocation, FaceID, and Reminders decreased since the passage of GDPR. Additionally, the active users of apps with BackgroundLocation, Bluetooth, Camera, FaceID, Microphone, Notifications, and Reminders permissions also decreased since the passage of GDPR.

Panel B of Table 10 shows how CCPA passage influenced the app activities with different permissions. Among all of these permission labels, the apps with GameKit and Health permissions are more likely to lose daily downloads. The daily active users of the

apps with FaceID, GameKit, InAppPurchase, as well as Reminders permissions decrease after the passage of CCPA.

These evidence suggest that privacy regulations such as GDPR and CCPA, while intending to protect data privacy, may inadvertently hamper the user experience and quality of service provided by data-intensive apps. Although these laws do not significantly impact app downloads, they lead to a noticeable decrease in active users, likely due to limitations in data collection affecting app development quality. The impact is most pronounced on apps and firms that rely on specific functions, such as BackgroundLocation, FaceID, and Reminders, to deliver superior service. This suggests that while privacy regulations are essential, they may also have unintended consequences on both consumers and service providers in the app industry.

6 Conclusions

Our research calibrates the value of consumers' digital footprints for technology firms. Digital footprints, harnessed through mobile applications and other sources, provide firms with valuable insights into consumer behaviors and preferences, which are useful for marketing efforts and optimizing fintech processes. However, the introduction of stringent data protection regulations like GDPR, CCPA, and DSLC results in a considerable decrease in firm value, with average negative stock returns around −7%. This is attributed to the restrictions imposed on data collection activities, which are crucial for these firms.

Our research also highlights the potential decrease in the number of active app users, particularly for apps with higher data collection intensity, following the enforcement of such regulations. This suggests that data privacy regulations could negatively impact data-intensive innovations of apps. Further investigation revealed that permissions related to fintech payments were particularly valuable, equating to 1.3% of a firm's stock price. Overall, while regulations intended to protect consumer privacy are vital, they come at a significant cost to technology firms and possibly consumers as well, indicating the necessity for a carefully considered approach in handling digital footprints and the associated privacy concerns.

References

Abowd, J. M. and Schmutte, I. M. (2019). An economic analysis of privacy protection and statistical accuracy as social choices. *American Economic Review*, 109(1):171–202.

Ali, S. N., Lewis, G., and Vasserman, S. (2023). Voluntary disclosure and personalized pricing. *Review of Economics Studies*, 90:538–571.

Barraclough, K., Robinson, D. T., Smith, T., and Whaley, R. E. (2013). Using option prices to infer overpayments and synergies in m&a transactions. *The Review of Financial Studies*, 26(3):695–722.

Berg, T., Burg, V., Gombović, A., and Puri, M. (2020). On the rise of fintechs: Credit scoring using digital footprints. *The Review of Financial Studies*, 33(7):2845–2897.

Borochin, P., Celik, M. A., Tian, X., and Whited, T. M. (2021). Identifying the heterogeneous impact of highly anticipated events: Evidence from the tax cuts and jobs act. *Available at SSRN 3806560*.

Borochin, P. and Golec, J. (2016). Using options to measure the full value-effect of an event: Application to obamacare. *Journal of Financial Economics*, 120(1):169–193.

Chen, M. A., Wu, Q., and Yang, B. (2019). How valuable is fintech innovation? *The Review of Financial Studies*, 32(5):2062–2106.

Fainmesser, I. P., Galeotti, A., and Momot, R. (2023). Digital privacy. *Management Science*, 69(6):3157–3173.

Goldfarb, A. and Tucker, C. (2012). Shifts in privacy concerns. *American Economic Review*, 102(3):349–353.

Ichihashi, S. (2020). Online privacy and information disclosure by consumers. *American Economic Review*, 110(2):569–595.

Jones, C. I. and Tonetti, C. (2020). Nonrivalry and the economics of data. *American Economic Review*, 110(9):2819–2858.

Kadan, O. and Manela, A. (2019). Estimating the value of information. *The Review of Financial Studies*, 32(3):951–991.

Liu, Z., Sockin, M., and Xiong, W. (2020). Data privacy and temptation. *NBER Working Paper*.

Liu, Z., Sockin, M., and Xiong, W. (2023). Data privacy and algorithmic inequality. *NBER Working Paper*.

Subramanian, A. (2004). Option pricing on stocks in mergers and acquisitions. *The Journal of Finance*, 59(2):795–829.

Figures and Tables

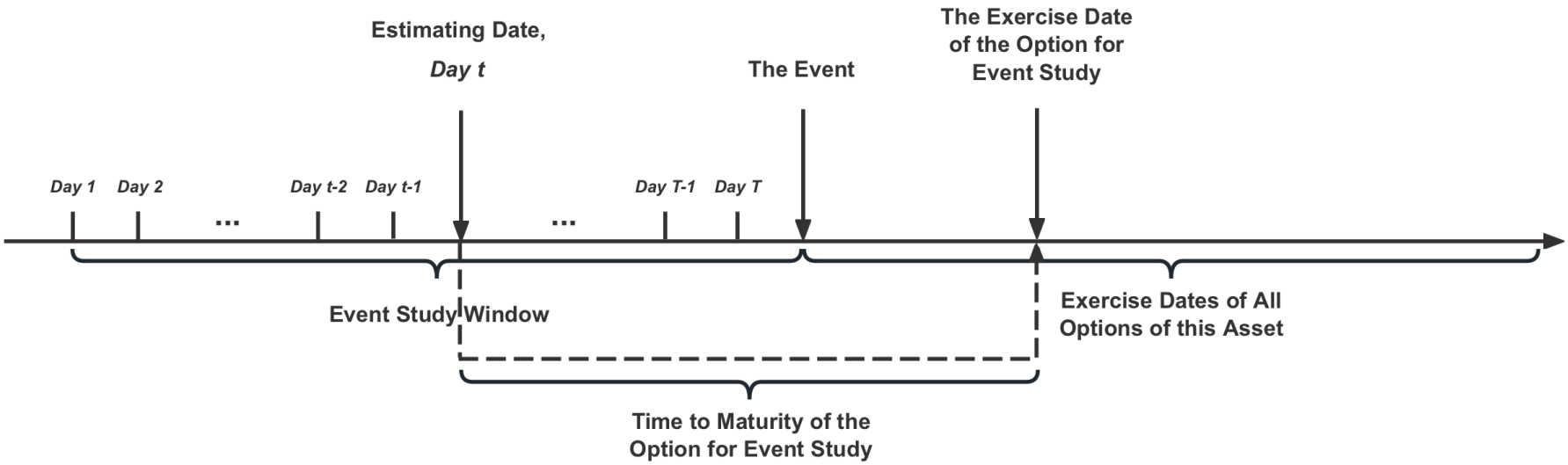


Figure 1: The Event Study Methodology

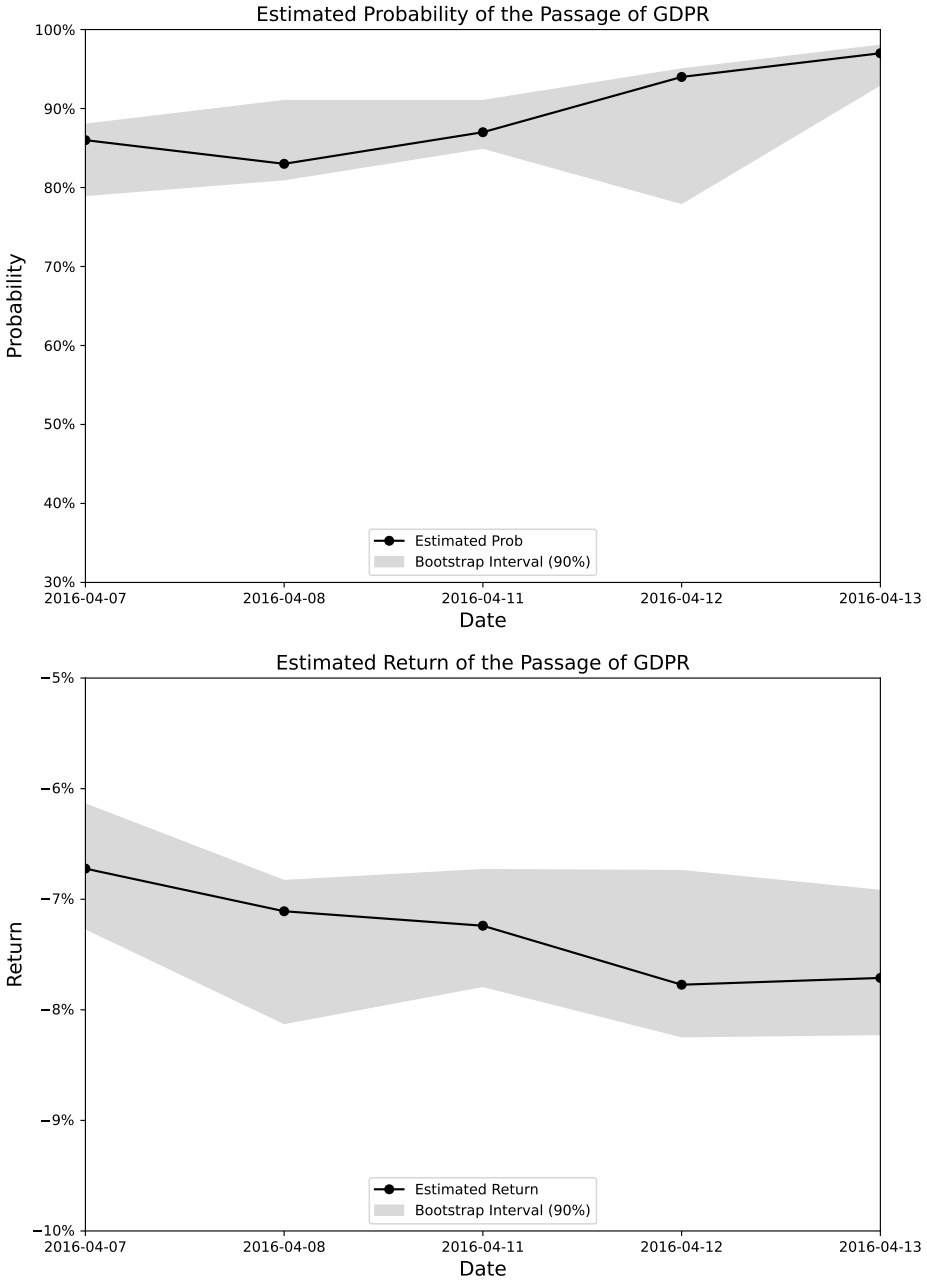


Figure 2: The Option-Estimated Probability and Return of the Passage of GDPR

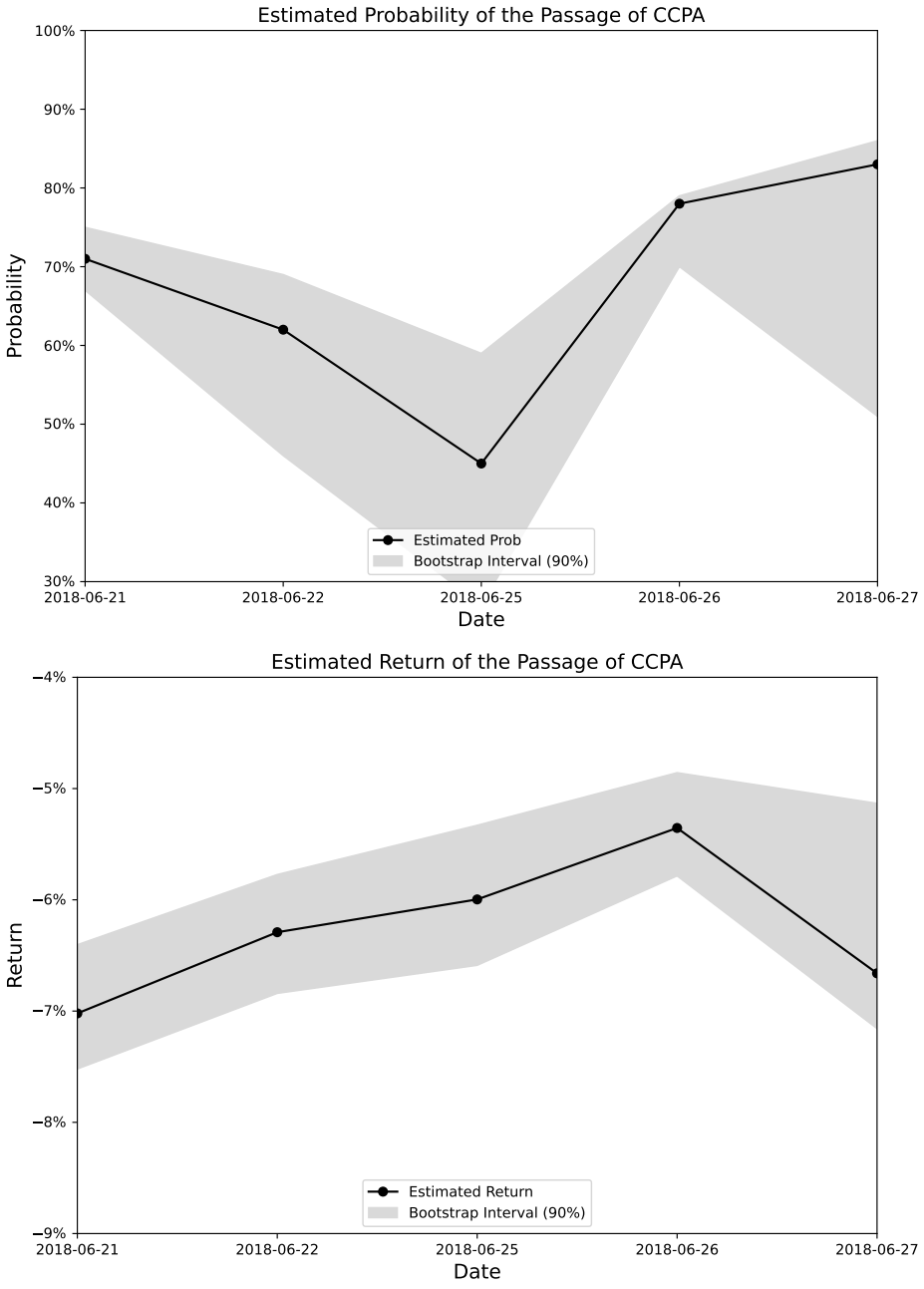


Figure 3: The Option-Estimated Probability and Return of the Passage of CCPA

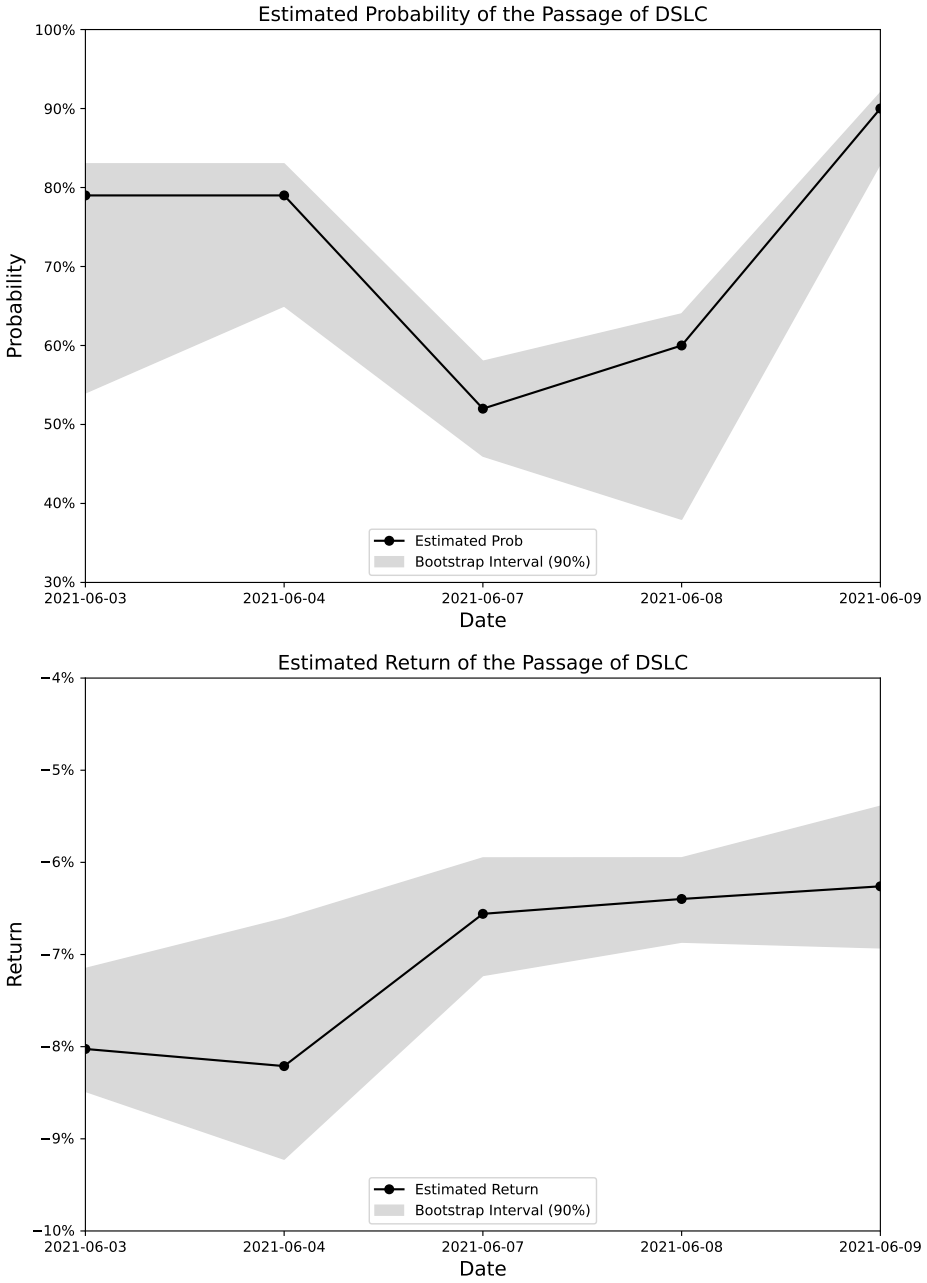


Figure 4: The Option-Estimated Probability and Return of the Passage of DSLC

Table 1: List of Firms in Our Event Study

Panel A: The EU App Market, Before the Passage of GDPR

		EU App Market, Jan. 2015 to Dec. 2015					United States Stock Market, Dec. 2015					
No.	Parent Company	DAU	Down.	Rev.	No. iTunes	No. Google	Exchange	TICKER	PERMNO	SICCD	Market Capital	Digital
1	Alphabet Cl A	178.88	531.44	2.82	82	64	NASDAQ	GOOG	14542	7375	261.63	1
2	Meta Platforms Inc (formerly Facebook)	176.48	485.97	11.49	33	14	NASDAQ	FB	13407	7375	240.19	1
3	Electronic Arts	13.31	192.83	221.39	368	65	NASDAQ	EA	75828	7372	21.30	1
4	Microsoft	13.59	185.44	44.12	95	41	NASDAQ	MSFT	10107	7370	439.68	1
5	Activision Blizzard	12.56	182.07	501.00	50	28	NASDAQ	ATVI	79678	7370	28.43	1
6	Apple	7.68	88.32	1.83	30	4	NASDAQ	AAPL	14593	3571	583.61	1
7	Comcast	5.11	62.59	10.96	68	26	NASDAQ	CMCSA	89525	4841	137.29	0
8	Amazon	3.42	55.01	0.39	39	18	NASDAQ	AMZN	84788	7370	318.34	1
9	Twitter	26.84	43.20	0.06	6	3	NYSE	TWTR	14295	7375	15.80	1
10	Baidu	1.77	39.65	0.37	32	5	NASDAQ	BIDU	90857	7370	51.23	1
11	Adobe	2.74	36.79	1.23	36	32	NASDAQ	ADBE	75510	7370	46.76	1
12	Disney	1.94	32.68	13.99	259	66	NYSE	DIS	26403	4841	173.72	0
13	Under Armour	2.43	28.57	14.81	16	8	NYSE	UA	90979	5611	14.52	0
14	Verizon	1.84	24.81	0.01	28	13	NYSE	VZ	65875	4813	188.06	0
15	Vodafone	1.49	22.64	0.00	112	39	NASDAQ	VOD	75418	4812	12.52	0
16	Liberty Global	0.92	18.10	0.35	44	13	NASDAQ	LBTYK	90866	4841	23.81	0
17	PayPal	1.86	15.40	0.00	6	1	NASDAQ	PYPL	15488	9999	44.31	0
18	TripAdvisor	0.40	13.56	0.00	12	3	NASDAQ	TRIP	13168	9999	11.29	0
19	McDonald's	0.70	12.36	0.00	29	17	NYSE	MCD	43449	5812	108.48	0
20	eBay	0.46	12.33	0.00	10	4	NASDAQ	EBAY	86356	7389	32.54	0

Continued

21	Expedia, Inc.	1.00	11.77	0.00	13	3	NASDAQ	EXPE	90808	4833	16.90	0

Panel B: The U.S. App Market, Before the Passage of CCPA

		U.S. App Market, Jan. 2017 to Dec. 2017					United States Stock Market, Dec. 2017					
No.	Parent Company	DAU	Down.	Rev.	No. iTunes	No. Google	Exchange	TICKER	PERMNO	SICCD	Market Capital	Digital
1	Alphabet Cl A	743.91	985.54	445.42	84	63	NASDAQ	GOOG	14542	7375	365.55	1
2	Meta Platforms Inc (formerly Facebook)	318.82	375.37	0.18	29	14	NASDAQ	FB	13407	7375	422.97	1
3	Take Two Interactive	15.38	191.27	533.14	101	64	NASDAQ	TTWO	84761	7370	12.55	1
4	Electronic Arts	14.84	174.97	558.47	124	64	NASDAQ	EA	75828	7372	32.25	1
5	Microsoft	15.24	162.81	95.55	79	25	NASDAQ	MSFT	10107	7370	659.09	1
6	AT&T	14.83	151.73	64.41	27	13	NYSE	T	66093	4813	238.68	0
7	Comcast	12.66	132.65	6.17	83	22	NASDAQ	CMCSA	89525	4841	185.63	0
8	Amazon	18.13	128.44	0.49	34	14	NASDAQ	AMZN	84788	7370	563.53	1
9	Disney	10.81	113.56	108.08	154	66	NYSE	DIS	26403	7313	162.05	0
10	Capital One	10.38	97.22	0.00	4	2	NYSE	COF	81055	6021	48.27	0
11	Verizon	8.43	91.11	0.78	38	20	NYSE	VZ	65875	4813	215.92	0
12	SiriusXM Holdings Inc.	138.35	86.42	325.85	2	2	NASDAQ	SIRI	80924	4832	24.27	0
13	Snap	21.82	82.33	3.49	3	0	NYSE	SNAP	16595	7372	12.61	1
14	Activision Blizzard	6.12	74.47	682.28	39	23	NASDAQ	ATVI	79678	7370	47.97	1
15	Bank of America	8.94	67.29	0.00	2	1	NYSE	BAC	59408	6021	307.91	0
16	Wells Fargo & Co	6.97	56.08	0.00	3	2	NYSE	WFC	38703	6021	298.75	0
17	Apple	5.03	49.48	2.06	25	4	NASDAQ	AAPL	14593	3571	860.88	1
18	PayPal	10.82	46.85	0.00	5	4	NASDAQ	PYPL	15488	9999	88.34	0
19	Walmart	17.90	43.36	0.00	16	7	NYSE	WMT	55976	5331	292.54	0

Continued

20	J.P. Morgan Chase &	5.99	39.19	0.00	6	1	NYSE	JPM	47896	6021	371.05	0
21	Twitter	36.52	35.01	0.51	6	3	NYSE	TWTR	14295	7375	17.83	1

Panel C: The China's App Market, Before the Passage of DSLC

		China's App Market, Jan. 2020 to Dec. 2020					United States Stock Market, Dec. 2020					
No.	Parent Company	DAU	Down.	Rev.	No. iTunes	No. Google	Exchange	TICKER	PERMNO	SICCD	Market Capital	Digital
1	Alibaba Group	47.69	380.64	608.25	66	14	NYSE	BABA	14888	7375	264.27	1
2	NetEase	20.73	214.31	1453.71	145	10	NASDAQ	NTES	88362	7379	28.69	0
3	Baidu	22.65	190.25	274.13	130	3	NASDAQ	BIDU	90857	7370	58.68	1
4	Pinduoduo Inc ADR	8.94	94.75	0.27	3	1	NASDAQ	PDD	17972	9999	61.38	0
5	JD.com	9.25	79.34	0.67	18	3	NASDAQ	JD	14655	9999	73.02	0
6	Alphabet Cl A	26.60	52.74	0	22	47	NASDAQ	GOOG	14542	7375	575.75	1
7	Apple	5.56	47.23	5.89	20	2	NASDAQ	AAPL	14593	3571	2232.28	1
8	Bilibili	3.96	39.08	89.73	23	0	NASDAQ	BILI	17346	9999	17.03	0
9	Trip.com Group	3.77	27.58	0	9	3	NASDAQ	TCOM	89927	7389	17.77	0
10	Microsoft	2.60	24.95	1.75	26	24	NASDAQ	MSFT	10107	7370	1678.38	1
11	Nike Inc	1.57	15.28	0	5	2	NYSE	NKE	57665	3021	177.52	0
12	Electronic Arts	1.46	14.55	11.36	31	2	NASDAQ	EA	75828	7372	41.36	1
13	Vipshop Holdings Ltd	1.74	13.06	0	2	0	NYSE	VIPS	13315	7372	12.84	1
14	Take Two Interactive	0.80	10.97	8.72	52	21	NASDAQ	TTWO	84761	7370	23.91	1
15	Unity Technologies	0.47	10.16	0.01	21	13	NYSE	U	19794	7371	41.56	1
16	Zoom Video Communications Cl A	0.95	8.37	0	3	1	NASDAQ	ZM	18484	9999	65.70	0
17	Adobe	1.13	8.20	0.53	4	1	NASDAQ	ADBE	75510	7372	239.56	1
18	Activision Blizzard	0.69	7.07	17.49	16	3	NASDAQ	ATVI	79678	7370	71.89	1
19	Iac/Interactive	0.69	6.43	2.42	23	5	NASDAQ	IAC	78840	4833	15.71	0

Continued

20	Amazon	0.97	6.42	0.04	8	9	NASDAQ	AMZN	84788	7370	1638.24	1

Note: In this table, we provide the list of firms that are used in our event study based on option and stock prices. In Panel A, we show the firms with the most daily active users before the event study window of GDPR, in Panel B, we show the firms for the event study of CCPA, and in Panel C, we show the firms for the event study of DSLC. For both panels, we report the company name, average daily active users of all apps on iTunes Connect and Google Play, total downloads of all apps on iTunes Connect and Google Play, total app revenue, the number of active apps on iTunes Connect, and the number of active apps on Google Play. We also report the exchange, ticker, permanent number, SIC industry classification code, market capital, as well as the indicator for the digital industry.

Table 2: The Option-Estimated Impact of the Passage of Data Privacy Regulations: The Passage of GDPR

Date	Prob.	$\widehat{S_u/S_d} - 1$	Ave. $\widehat{\sigma_u}$	Ave. $\widehat{\sigma_d}$
April 7, 2016	86%	–6.72%	0.0641	0.0664
April 8, 2016	83%	–7.11%	0.1120	0.1151
April 11, 2016	87%	–7.24%	0.1130	0.1179
April 12, 2016	94%	–7.77%	0.1015	0.1108
April 13, 2016	97%	–7.71%	0.0930	0.1000
Ave. of Five Trading Days	89%	–7.31%	0.0967	0.1020
Estimation result: Figure 2				

This table reports the option-based estimator of the passage of GDPR, including the estimated probability of GDPR passage (Prob.), estimated return of GDPR ($\widehat{S_u/S_d} - 1$), the estimated implied volatility when the event does not happen (Ave. $\widehat{\sigma_u}$) and when the event happens (Ave. $\widehat{\sigma_d}$).

Table 3: The Option-Estimated Impact of the Passage of Data Privacy Regulations: The Passage of CCPA

Date	Prob.	$\widehat{S_u/S_d} - 1$	Ave. $\widehat{\sigma_u}$	Ave. $\widehat{\sigma_d}$
June 21, 2018	71%	−7.02%	0.0525	0.0553
June 22, 2018	62%	−6.29%	0.0475	0.0493
June 25, 2018	45%	−6.00%	0.0478	0.0485
June 26, 2018	78%	−5.35%	0.0391	0.0392
June 27, 2018	83%	−6.66%	0.0391	0.0396
Ave. of Five Trading Days	68%	−6.26%	0.0452	0.0464
Estimation result: Figure 3				

This table reports the option-based estimator of the passage of CCPA, including the estimated probability of CCPA passage (Prob.), estimated return of CCPA ($\widehat{S_u/S_d} - 1$), the estimated implied volatility when the event does not happen (Ave. $\widehat{\sigma_u}$) and when the event happens (Ave. $\widehat{\sigma_d}$).

Table 4: The Option-Estimated Impact of the Passage of Data Privacy Regulations: The Passage of DSLC

Date	Prob.	$\widehat{S_u/S_d} - 1$	Ave. $\widehat{\sigma_u}$	Ave. $\widehat{\sigma_d}$
June 3, 2021	79%	−8.02%	0.0684	0.0733
June 4, 2021	79%	−8.21%	0.0608	0.0645
June 7, 2021	52%	−6.56%	0.0536	0.0558
June 8, 2021	60%	−6.40%	0.0506	0.0512
June 9, 2021	90%	−6.26%	0.0472	0.0493
Ave. of Five Trading Days	72%	−7.09%	0.0561	0.0588
Estimation result: Figure 4				

This table reports the option-based estimator of the passage of DSLC, including the estimated probability of DSLC passage (Prob.), estimated return of DSLC ($\widehat{S_u/S_d} - 1$), the estimated implied volatility when the event does not happen (Ave. $\widehat{\sigma_u}$) and when the event happens (Ave. $\widehat{\sigma_d}$).

Table 5: The Traditional Event Study Methods on the Events of Data Privacy Regulation Passage

Panel A: The Passage of GDPR			
	Event study window: Event day = 0		
	[−1; 0]	[−3; 0]	[−5; 0]
On April 14, 2016, the date of GDPR passage			
Cumulative abnormal return adjusted by Fama-French 5 factors	0.83%**	0.37%	0.05%
	(2.1740)	(0.7315)	(0.0949)
Panel B: The Passage of CCPA			
	Event study window: Event day = 0		
	[−1; 0]	[−3; 0]	[−5; 0]
On June 28, 2018, the date of CCPA passage			
Cumulative abnormal return adjusted by Fama-French 5 factors	0.76%**	0.90%**	1.49%*
	(2.4387)	(1.9806)	(1.9213)
Panel C: The Passage of DSLC			
	Event study window: Event day = 0		
	[−1; 0]	[−3; 0]	[−5; 0]
On June 10, 2021, the signature of DSLC by President Xi			
Cumulative abnormal return adjusted by Fama-French 5 factors	−1.40%**	−3.30%***	−3.89%***
	(−2.4080)	(−4.0603)	(−3.5440)

Continued

Note: This table reports the cumulative abnormal returns around the passage of GDPR, CCPA, and DSLC. The cumualtive abormal returns are adjusted by Fama French 5 factors.

Table 6: The Capital Loss in the Events of Passage of Data Privacy Regulations for Firms

Panel A: The Passage of GDPR

No.	Company Name	PERMNO	$\widehat{S_u/S_d} - 1$	Ave. $\widehat{\sigma_u}$	Ave. $\widehat{\sigma_d}$	Mkt. Cap.	Est. Loss in Mkt. Cap.
1	Liberty Global	90866	–9.56%	0.1490	0.1591	23.81	2.28
2	Vodafone	75418	–9.27%	0.0483	0.0526	12.52	1.16
3	Comcast	89525	–8.95%	0.0376	0.0427	137.29	12.28
4	Baidu	90857	–8.73%	0.0589	0.0589	51.23	4.47
5	Amazon	84788	–8.69%	0.0417	0.0409	318.34	27.66
6	Apple	14593	–8.22%	0.0446	0.0477	583.61	47.97
7	eBay	86356	–8.11%	0.0510	0.0524	32.54	2.64
8	Adobe	75510	–7.68%	0.0409	0.0409	46.76	3.59
9	TripAdvisor	13168	–7.43%	0.0769	0.0812	11.29	0.84
10	Twitter	14295	–7.33%	0.1209	0.1271	15.80	1.16
11	PayPal	15488	–7.12%	0.0511	0.0548	44.31	3.16
12	Microsoft	10107	–6.98%	0.0445	0.0445	439.68	30.68
13	Disney	26403	–6.93%	0.0709	0.0689	173.72	12.03
14	Activision Blizzard	79678	–6.86%	0.0538	0.0554	28.43	1.95
15	Meta Platforms Inc	13407	–6.83%	0.0403	0.0433	240.19	16.42
16	McDonald's	43449	–6.44%	0.0272	0.0267	108.48	6.98
17	Electronic Arts	75828	–6.39%	0.0449	0.0490	21.30	1.36
18	Expedia, Inc.	90808	–6.17%	0.0780	0.0858	16.90	1.04
19	Under Armour	90979	–5.89%	0.8983	0.9578	14.52	0.86
20	Verizon	65875	–5.68%	0.0281	0.0262	188.06	10.68
21	Alphabet Cl A	14542	–4.28%	0.0244	0.0269	261.63	11.20

Sum of all firms' loss in GDPR passage: $200.40 Million

Continued

Panel B: The Passage of CCPA

No.	Company Name	PERMNO	$\widehat{S_u/S_d} - 1$	Ave. $\widehat{\sigma_u}$	Ave. $\widehat{\sigma_d}$	Mkt. Cap.	Est. Loss in Mkt. Cap.
1	Bank of America	59408	–9.38%	0.0434	0.0482	307.91	28.89
2	SiriusXM Holdings Inc.	80924	–9.15%	0.0919	0.0994	24.27	2.22
3	Meta Platforms Inc	13407	–9.12%	0.0362	0.0386	422.97	38.57
4	Snap	16595	–8.41%	0.0804	0.0823	12.61	1.06
5	Twitter	14295	–7.50%	0.0658	0.0682	17.83	1.34
6	Walmart	55976	–7.38%	0.0269	0.0264	292.54	21.60
7	Microsoft	10107	–7.29%	0.0296	0.0329	659.09	48.06
8	Wells Fargo & Co	38703	–7.11%	0.0446	0.0443	298.75	21.24
9	Electronic Arts	75828	–6.98%	0.0530	0.0530	32.25	2.25
10	AT&T	66093	–6.98%	0.0366	0.0366	238.68	16.65
11	Verizon	65875	–6.32%	0.0308	0.0288	215.92	13.65
12	Comcast	89525	–6.29%	0.0553	0.0572	185.63	11.68
13	Jpmorgan Chase &	47896	–5.85%	0.0395	0.0418	371.05	21.71
14	Apple	14593	–5.52%	0.0329	0.0332	860.88	47.51
15	Capital One	81055	–5.21%	0.0409	0.0394	48.27	2.51
16	PayPal	15488	–4.82%	0.0431	0.0447	88.34	4.26
17	Disney	26403	–4.80%	0.0321	0.0324	162.05	7.78
18	Take Two Interactive	84761	–4.15%	0.0460	0.0507	12.55	0.52
19	Amazon	84788	–3.69%	0.0423	0.0431	563.53	20.78
20	Alphabet Cl A	14542	–2.83%	0.0312	0.0311	365.55	10.36
21	Activision Blizzard	79678	–2.77%	0.0465	0.0416	47.97	1.33

Sum of all firms' loss in CCPA passage: $323.98 Million

Continued

Panel C: The Passage of DSLC

No.	Company Name	PERMNO	$\widehat{S_u/S_d}-1$	Ave. $\widehat{\sigma_u}$	Ave. $\widehat{\sigma_d}$	Mkt. Cap.	Est. Loss in Mkt. Cap.
1	Unity Technologies	19794	−10.59%	0.0998	0.1081	41.56	4.40
2	Bilibili	17346	−9.57%	0.0778	0.0801	17.03	1.63
3	Zoom Video	18484	−8.71%	0.0615	0.0699	65.70	5.72
4	Take Two Interactive	84761	−8.53%	0.0511	0.0547	23.91	2.04
5	Baidu	90857	−8.48%	0.0631	0.0655	58.68	4.97
6	Alibaba Group	14888	−8.28%	0.0416	0.0439	264.27	21.87
7	Pinduoduo Inc ADR	17972	−8.16%	0.0782	0.0854	61.38	5.01
8	Vipshop Holdings Ltd	13315	−7.89%	0.1033	0.1061	12.84	1.01
9	Trip.com Group	89927	−6.98%	0.1026	0.1026	17.77	1.24
10	JD.com	14655	−6.98%	0.0594	0.0594	73.02	5.09
11	Microsoft	10107	−6.77%	0.0262	0.0260	1678.38	113.66
12	Activision Blizzard	79678	−6.73%	0.0427	0.0467	71.89	4.84
13	Electronic Arts	75828	−6.71%	0.0485	0.0519	41.36	2.78
14	NetEase	88362	−6.35%	0.0595	0.0595	28.69	1.82
15	Nike Inc	57665	−5.89%	0.0321	0.0313	177.52	10.45
16	Apple	14593	−5.29%	0.0303	0.0316	2232.28	118.04
17	Adobe	75510	−5.20%	0.0326	0.0348	239.56	12.46
18	Amazon	84788	−4.14%	0.0303	0.0326	1638.24	67.79
19	Alphabet Cl A	14542	−3.48%	0.0258	0.0274	575.75	20.06
Sum of all firms' loss in DSLC passage: $404.90 Million							

Note: This table reports the option-based estimation of returns for each firm during the passage of GDPR, CCPA, and DSLC. We report firms' name, PERNO, option-estimated average returns across five trading days ($\widehat{S_u/S_d}-1$), average implied volatilities (Ave. $\widehat{\sigma_u}$ and Ave. $\widehat{\sigma_d}$), market capital, as well as the estimation of the loss in market capital.

Table 7: The Heterogeneous Impact of the Passage of Privacy Protection Laws

Panel A: The Passage of GDPR

	OLS				VWLS	
	(1)	(2)	(3)	(4)	(5)	(6)
Log App DAU	0.3029**		0.3185*		0.4572***	
	(1.8581)		(1.7284)		(2.6894)	
Log App Down		0.3500		0.3720		0.6293***
		(1.4508)		(1.3076)		(2.2534)
Log Mkt Cap			−0.0493	−0.0413	−0.3977	−0.4590
			(−0.2022)	(−0.1575)	(−1.2793)	(−1.3460)
Constance	−7.7284***	−8.6565***	−7.5454***	−8.5699***	−6.0498***	−7.5561***
	(−21.9703)	(−8.9389)	(−7.7438)	(−7.5415)	(−3.6873)	(−4.2834)
R^2	0.154	0.100	0.156	0.101	0.292	0.226
N	21	21	21	21	21	21

Panel B: The Passage of CCPA

	OLS				VWLS	
	(1)	(2)	(3)	(4)	(5)	(6)
Log App DAU	−0.1973		−0.1940		0.0722	
	(−0.5727)		(−0.5482)		(0.2428)	
Log App Down		0.5374		0.5285		0.3305
		(0.9703)		(0.9219)		(0.6776)
Log Mkt Cap			0.0722	0.0414	0.1835	0.1776
			(0.2122)	(0.1227)	(0.3018)	(0.2961)
Constance	−5.6846***	−8.7487***	−6.0470***	−8.9103***	−7.4950**	−8.8001**
	(−5.1531)	(−3.3701)	(−2.9511)	(−2.9969)	(−1.9693)	(−2.0551)
R^2	0.017	0.047	0.019	0.048	0.008	0.029
N	21	21	21	21	21	21

Continued

Panel C: The Passage of DSLC

	OLS				VWLS	
	(1)	(2)	(3)	(4)	(5)	(6)
Log App DAU	0.9024**		0.4955		0.1703	
	(2.5048)		(1.2234)		(0.5336)	
Log App Down		0.6054		−0.0736		−0.3502
		(1.1326)		(−0.1380)		(−0.9342)
Log Mkt Cap			0.4955*	0.7001**	0.2026	0.3370
			(1.8120)	(2.5402)	(0.5890)	(0.9715)
China	−2.9222**	−2.3716*	−1.5241	−0.1631	−2.5150	−1.0663
	(−2.8791)	(−1.7547)	(−1.2457)	(−0.1121)	(−1.5258)	(−0.6026)
Constance	−7.1135***	−8.2633***	−9.4358***	−10.0353***	−6.9778**	−6.6798**
	(−14.7929)	(−5.4986)	(−6.9468)	(−6.8109)	(−2.8616)	(−2.7577)
R^2	0.355	0.168	0.471	0.419	0.282	0.309
N	19	19	19	19	19	19

Note: In this table, we report the heterogeneity in the option-based estimated impact of the passage of data protection regulations. We run the regression: $\text{OptRet}_i = \beta \text{FirmChar}_i + \alpha + \varepsilon_i$. The dependent variable in this regression is the estimated impact, and the independent variable is the firm characteristics of each firm.

Table 8: Impact of Adding/Removing a Permission Label in Android Apps

	(1) Add			(2) Remove			
Permission	Coef.	*t*-stat	No.	Coef.	*t*-stat	No.	Diff. in *t*-stat
(i) FinTech related permissions: Financial payments							
UseBiometric	−0.10%	−0.2857	145	−1.00%**	−2.0083	18	**−1.7226**
UseFingerprint	0.01%	0.0443	178	−0.34%*	−1.6779	78	**−1.7222**
(ii) Data-collection permissions							
AccessCoarseLocation	0.04%	0.2389	217	−0.29%	−1.6308	200	**−1.8696**
AccessBackgroundLocation	0.13%	0.5362	137	−0.04%	−0.1676	63	−0.7039
AccessFineLocation	0.33%*	1.9163	238	−0.05%	−0.3394	179	**−2.2558**
Bluetooth	0.14%	0.9583	178	−0.17%	−1.1024	143	**−2.0607**
PackageUsageStats	0.13%	0.3649	81	−0.24%	−1.4764	56	**−1.8413**
ReadPrivilegedPhoneState	0.03%	0.1105	52	−0.70%***	−2.9055	15	**−3.0160**
ReceiveBootCompleted	0.54%	0.7189	462	−0.62%***	−3.9196	139	**−4.6385**
WriteExternalStorage	0.10%	0.3040	100	−0.70%**	−2.4521	89	**−2.7561**
(iii) Other important permissions							
AccessWifiState	0.21%	1.2632	274	−0.15%	−0.7314	135	**−1.9946**
Flashlight	−0.10%	−0.1859	34	−0.79%**	−2.0783	23	**−1.8923**
Vibrate	0.40%**	2.0468	203	0.00%	0.0001	119	**−2.0467**

Note: This table reports the estimated cumulative abnormal returns around the events of adding/removing a certain permission label. In Column (1), we report the cumulative abnormal returns when firms add one permission label to their app, and in Column (2), we report the cumulative abnormal returns when firms drop one permission label from their app. For each column, we report the average cumulative abnormal returns (Coef.), *t*-statistics, and the total number of events for each kind of event. Additionally, we also report the difference in the *t*-statistics between removing and adding a certain permission label. We report three important categories of permissions, including FinTech (financial payments) related permissions, data-collection permissions, and other important permissions. * for p ≤ 0.1, ** for p ≤ 0.05, and *** for p ≤ 0.01.

Table 9: Impact of Privacy Laws on App Activities

Panel A: The Impact of the Passage of GDPR on the App Activities

	$\log(\text{Downloads}_{i,t})$			
	(1)	(2)	(3)	(4)
	All	$\text{PermNo}_i > 0$	$\text{PermNo}_i > 0$ & Top 500	$\text{PermNo}_i > 0$ & Top 500-1,000
$\text{PermNo}_i \times \text{Post}_t$	−0.0134	−0.0066	0.0025	−0.0161*
	(−1.5797)	(−0.8943)	(0.2148)	(−1.7675)
ID FE	Yes	Yes	Yes	Yes
Year-Week FE	Yes	Yes	Yes	Yes
ID Linear Trend	Yes	Yes	Yes	Yes
R^2	0.781	0.795	0.767	0.546
N	41,269	39,792	19,864	19,928
	$\log(\text{DAU}_{i,t})$			
	(1)	(2)	(3)	(4)
	All	$\text{PermNo}_i > 0$	$\text{PermNo}_i > 0$ & Top 500	$\text{PermNo}_i > 0$ & Top 500-1,000
$\text{PermNo}_i \times \text{Post}_t$	−0.0269***	−0.0167**	−0.0108	−0.0229**
	(−2.8940)	(−2.4923)	(−1.0992)	(−2.4931)
ID FE	Yes	Yes	Yes	Yes
Year-Week FE	Yes	Yes	Yes	Yes
ID Linear Trend	Yes	Yes	Yes	Yes
R^2	0.893	0.904	0.908	0.796
N	41,269	39,792	19,864	19,928

Continued

Panel B: The Impact of the Passage of CCPA on the App Activities

	$\log(\text{Downloads}_{i,t})$			
	(1)	(2)	(3)	(4)
	All	$\text{PermNo}_i > 0$	$\text{PermNo}_i > 0$ & Top 500	$\text{PermNo}_i > 0$ & Top 500-1,000
$\text{PermNo}_i \times \text{Post}_t$	0.0066	0.0057	0.0124	0.0004
	(0.9629)	(0.7710)	(1.1266)	(0.0364)
ID FE	Yes	Yes	Yes	Yes
Year-Week FE	Yes	Yes	Yes	Yes
ID Linear Trend	Yes	Yes	Yes	Yes
R^2	0.754	0.759	0.723	0.572
N	40,072	38,255	19,082	19,173
	$\log(\text{DAU}_{i,t})$			
	(1)	(2)	(3)	(4)
	All	$\text{PermNo}_i > 0$	$\text{PermNo}_i > 0$ & Top 500	$\text{PermNo}_i > 0$ & Top 500-1,000
$\text{PermNo}_i \times \text{Post}_t$	−0.0139*	−0.0111	−0.0049	−0.0169*
	(−1.9006)	(−1.6197)	(−0.4719)	(−1.8888)
ID FE	Yes	Yes	Yes	Yes
Year-Week FE	Yes	Yes	Yes	Yes
ID Linear Trend	Yes	Yes	Yes	Yes
R^2	0.878	0.887	0.892	0.777
N	40,072	38,255	19,082	19,173

Note: This table reports the difference-in-difference estimators of the impact of data protection regulations on apps' activities, including the weekly downloads as well as the average daily active users within a week. In Panel A, we report the estimated impact of GDPR passage, and in Panel B, we show that of CCPA passage. We report t-statistics clustered by App ID in parenthesis, and * for $p \leq 0.1$, ** for $p \leq 0.05$, and *** for $p \leq 0.01$.

Table 10: Impact of Privacy Laws by Different Permission Labels

Panel A: The Impact of the Passage of GDPR on the App Activities

	(1) $\log(\text{Downloads}_{i,t})$		(2) $\log(\text{DAU}_{i,t})$	
	Coef.	t-stat	Coef.	t-stat
$\text{AppTracking}_i \times \text{Post}_t$	−0.0503	−0.4753	−0.0283	−0.2985
$\text{BackgroundLocation}_i \times \text{Post}_t$	−0.0967**	−2.0578	−0.0985**	−2.3785
$\text{Bluetooth}_i \times \text{Post}_t$	−0.0600	−1.4847	−0.0586*	−1.7799
$\text{Calendar}_i \times \text{Post}_t$	0.0000	0.0001	0.0417	0.9927
$\text{Camera}_i \times \text{Post}_t$	−0.0989	−1.4548	−0.1113*	−1.6960
$\text{Contacts}_i \times \text{Post}_t$	0.0017	0.0443	−0.0210	−0.6142
$\text{FaceID}_i \times \text{Post}_t$	−0.1054***	−2.8846	−0.1077***	−3.2839
$\text{ForegroundLocation}_i \times \text{Post}_t$	0.1562***	2.6759	0.0967*	1.7505
$\text{GameKit}_i \times \text{Post}_t$	0.0054	0.0604	−0.0999	−1.2252
$\text{Health}_i \times \text{Post}_t$	0.1313**	2.3449	0.0665	1.5509
$\text{HomeKit}_i \times \text{Post}_t$	−0.0751	−0.6800	−0.0586	−0.5572
$\text{InAppPurchase}_i \times \text{Post}_t$	0.0047	0.0391	−0.1173	−1.0699
$\text{LocalNetwork}_i \times \text{Post}_t$	0.0681	0.6804	0.1187	1.3073
$\text{Microphone}_i \times \text{Post}_t$	−0.0003	−0.0081	−0.0675*	−1.8239
$\text{MotionActivity}_i \times \text{Post}_t$	0.0710	1.4424	0.0213	0.4292
$\text{NFC}_i \times \text{Post}_t$	0.1064	1.4130	0.0812	1.2394
$\text{Notifications}_i \times \text{Post}_t$	−0.0600	−1.2458	−0.1021**	−2.4766
$\text{Photos}_i \times \text{Post}_t$	−0.0523	−0.5374	−0.1047	−1.0607
$\text{Reminders}_i \times \text{Post}_t$	−0.1691**	−2.1119	−0.1258***	−2.5815
$\text{Siri}_i \times \text{Post}_t$	−0.0640	−1.3267	−0.0580	−1.2639
$\text{SpeechRecognition}_i \times \text{Post}_t$	−0.0302	−0.4783	0.0090	0.1665
$\text{TurnOnBluetooth}_i \times \text{Post}_t$	0.1647	0.9458	0.1817	1.0687
$\text{TurnOnLocation}_i \times \text{Post}_t$	0.1483	1.4900	0.1161	1.2886
$\text{YourMusicAndVideoActivity}_i \times \text{Post}_t$	−0.0077	−0.1927	0.0109	0.2804
ID FE	Yes		Yes	
Year-Week FE	Yes		Yes	
ID Linear Trend	Yes		Yes	
R^2	0.782		0.894	
N	41,269		41,269	

Continued

Panel B: The Impact of the Passage of CCPA on the App Activities

	(1) $\log(\text{Downloads}_{i,t})$		(2) $\log(\text{DAU}_{i,t})$	
	Coef.	t-stat	Coef.	t-stat
$\text{AppTracking}_i \times \text{Post}_t$	−0.0535	−0.5281	−0.0673	−1.0539
$\text{BackgroundLocation}_i \times \text{Post}_t$	−0.0330	−0.7442	−0.0283	−0.7505
$\text{Bluetooth}_i \times \text{Post}_t$	0.1036**	2.0096	0.0402	0.9315
$\text{Calendar}_i \times \text{Post}_t$	0.0483	1.0450	0.0302	0.7066
$\text{Camera}_i \times \text{Post}_t$	−0.0183	−0.2499	−0.1026	−1.3288
$\text{Contacts}_i \times \text{Post}_t$	−0.0406	−0.7466	−0.0361	−0.8628
$\text{FaceID}_i \times \text{Post}_t$	−0.0420	−1.0624	−0.0692**	−2.5279
$\text{ForegroundLocation}_i \times \text{Post}_t$	0.0197	0.3207	0.0251	0.4476
$\text{GameKit}_i \times \text{Post}_t$	−0.1265**	−2.4448	−0.1100**	−2.4233
$\text{Health}_i \times \text{Post}_t$	−0.1580*	−1.8065	−0.0830	−1.3834
$\text{HomeKit}_i \times \text{Post}_t$	0.0536	0.4951	0.0190	0.2642
$\text{InAppPurchase}_i \times \text{Post}_t$	−0.8379**	−2.2253	−0.9532*	−1.8373
$\text{LocalNetwork}_i \times \text{Post}_t$	0.0303	0.2778	−0.0064	−0.0509
$\text{Microphone}_i \times \text{Post}_t$	−0.0224	−0.5006	−0.0397	−0.9634
$\text{MotionActivity}_i \times \text{Post}_t$	0.0280	0.5959	0.0007	0.0179
$\text{NFC}_i \times \text{Post}_t$	0.2097**	1.9935	0.1616**	2.0698
$\text{Notifications}_i \times \text{Post}_t$	−0.0113	−0.1971	−0.0077	−0.1307
$\text{Photos}_i \times \text{Post}_t$	0.1337	1.5775	0.0676	0.6949
$\text{Reminders}_i \times \text{Post}_t$	−0.0769	−0.7918	−0.0966**	−2.1642
$\text{Siri}_i \times \text{Post}_t$	−0.0742	−1.4280	−0.0097	−0.2685
$\text{SpeechRecognition}_i \times \text{Post}_t$	0.0223	0.4268	−0.0156	−0.4447
$\text{TurnOnBluetooth}_i \times \text{Post}_t$	−0.0924	−0.8407	−0.0205	−0.2646
$\text{TurnOnLocation}_i \times \text{Post}_t$	0.0890	1.1132	0.0166	0.3542
$\text{YourMusicAndVideoActivity}_i \times \text{Post}_t$	−0.0320	−0.5506	−0.0016	−0.0304
ID FE	Yes		Yes	
Year-Week FE	Yes		Yes	
ID Linear Trend	Yes		Yes	
R^2	0.754		0.878	
N	40,072		40,072	

Continued

Note: This table reports the impact of data protection regulations on apps' activities with different permission labels. The app activities include the weekly downloads as well as the average daily active users within a week. In Panel A, we report the estimated impact of GDPR passage, and in Panel B, we show that of CCPA passage. We report *t*-statistics clustered by App ID in parenthesis, and * for $p \leq 0.1$, ** for $p \leq 0.05$, and *** for $p \leq 0.01$.

Appendix A Additional Figures

List of Figures in Appendix

A1 The Privacy Label of LINE: An Example 51
A2 June 25, 2018 News: Confirmation of CCPA Passage Signatures by Secretary of State Alex Padilla 52

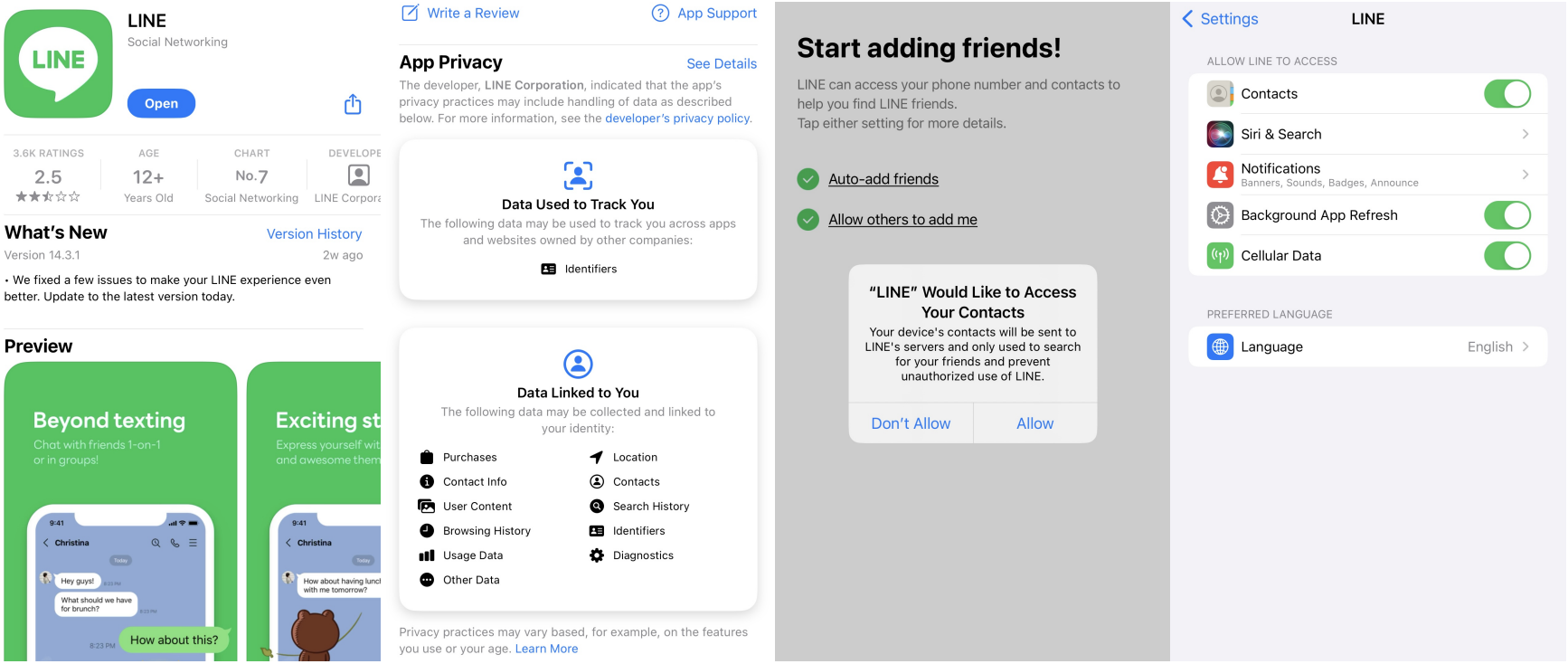


Figure A1: The Privacy Label of LINE: An Example

Print Version (PDF)

AP18:102

For Immediate Release
June 25, 2018
Contact:
Sam Mahood
(916) 653-6575

New Measure Eligible for California's November 2018 Ballot

Establishes New Consumer Privacy Rights; Expands Liability for Consumer Data Breaches. Initiative Statute.

SACRAMENTO - Secretary of State Alex Padilla today announced that an initiative is eligible for the November 6, 2018, General Election ballot.

In order to become eligible for the ballot, the initiative needed 365,880 valid petition signatures, which is equal to five percent of the total votes cast for governor in the November 2014 General Election.

An initiative can qualify via random sampling of petition signatures if the sampling projects a number of valid signatures greater than 110 percent of the required number. The initiative needed at least 402,468 projected valid signatures to qualify by random sampling, and it exceeded that threshold today.

On June 28, 2018, the Secretary of State will certify the initiative as qualified for the November 6, 2018 General Election ballot, unless the proponent withdraws the initiative prior to that date pursuant to Elections Code section 9604(b).

The Attorney General's official title and summary of the initiative is as follows:

ESTABLISHES NEW CONSUMER PRIVACY RIGHTS; EXPANDS LIABILITY FOR CONSUMER DATA BREACHES. INITIATIVE STATUTE. Gives consumers right to learn categories of personal information that businesses collect, sell, or disclose about them, and to whom information is sold or disclosed. Gives consumers right to prevent businesses from selling or disclosing their personal information. Prohibits businesses from discriminating against consumers who exercise these rights. Allows consumers to sue businesses for security breaches of consumers' data, even if consumers cannot prove injury. Allows for enforcement by consumers, whistleblowers, or public agencies. Imposes civil penalties. Applies to online and brick-and-mortar businesses that meet specific criteria. Summary of estimate by Legislative Analyst and Director of Finance of fiscal impact on state and local government: **Increased costs, potentially reaching the low tens of millions of dollars annually, to state and local governments from implementing and enforcing the measure, some or all of which would be offset by increased penalty revenue or settlement proceeds authorized by the measure. Unknown impact on state and local tax revenues due to economic effects resulting from new requirements on businesses to protect consumer information.** (17-0039.)

Figure A2: June 25, 2018 News: Confirmation of CCPA Passage Signatures by Secretary of State Alex Padilla

Appendix B Additional Tables

List of Tables in Appendix

A1 U.S. Stock Market Listed Firms That are Most Consumer-App-Intensive . . 54

Table A1: U.S. Stock Market Listed Firms That are Most Consumer-App-Intensive

Panel A: The EU App Market, Before the Passage of GDPR

		EU App Market, Jan. 2015 to Dec. 2015					United States Stock Market, Dec. 2015					
No.	Parent Company	DAU	Down.	Rev.	No. iTunes	No. Google	Exchange	TICKER	PERMNO	SICCD	Market Capital	Digital
1	Alphabet Cl A	178.88	531.44	2.82	82	64	NASDAQ	GOOG	14542	7375	261.63	1
2	Meta Platforms Inc (formerly Facebook)	176.48	485.97	11.49	33	14	NASDAQ	FB	13407	7375	240.19	1
3	Electronic Arts	13.31	192.83	221.39	368	65	NASDAQ	EA	75828	7372	21.30	1
4	Microsoft	13.59	185.44	44.12	95	41	NASDAQ	MSFT	10107	7370	439.68	1
5	Activision Blizzard	12.56	182.07	501.00	50	28	NASDAQ	ATVI	79678	7370	28.43	1
6	Cheetah Mobile	9.34	156.14	1.74	13	34	NYSE	CMCM	14618	0000	0.19	0
7	Take Two Interactive	8.70	128.33	198.76	127	53	NASDAQ	TTWO	84761	7370	3.04	1
8	Apple	7.68	88.32	1.83	30	4	NASDAQ	AAPL	14593	3571	583.61	1
9	Comcast	5.11	62.59	10.96	68	26	NASDAQ	CMCSA	89525	4841	137.29	0
10	Amazon	3.42	55.01	0.39	39	18	NASDAQ	AMZN	84788	7370	318.34	1
11	Twitter	26.84	43.20	0.06	6	3	NYSE	TWTR	14295	7375	15.80	1
12	Baidu	1.77	39.65	0.37	32	5	NASDAQ	BIDU	90857	7370	51.23	1
13	Adobe	2.74	36.79	1.23	36	32	NASDAQ	ADBE	75510	7370	46.76	1
14	Disney	1.94	32.68	13.99	259	66	NYSE	DIS	26403	4841	173.72	0
15	Under Armour	2.43	28.57	14.81	16	8	NYSE	UA	90979	5611	14.52	0
16	Santander	2.13	27.71	0.00	22	6	NYSE	SC	14414	6141	5.67	0
17	Verizon	1.84	24.81	0.01	28	13	NYSE	VZ	65875	4813	188.06	0
18	Vodafone	1.49	22.64	0.00	112	39	NASDAQ	VOD	75418	4812	12.52	0
19	Match Group Inc	1.10	19.25	54.37	18	5	NASDAQ	MTCH	15850	9999	0.52	0
20	Liberty Global	0.92	18.10	0.35	44	13	NASDAQ	LBTYK	90866	4841	23.81	0

Continued

21	Orange SA	1.33	18.00	4.56	58	18	NYSE	ORAN	85425	4813	1.23	0
22	PayPal	1.86	15.40	0.00	6	1	NASDAQ	PYPL	15488	9999	44.31	0
23	Telefonica	1.23	15.36	0.00	41	16	NYSE	TEF	75049	4813	1.61	0
24	Hasbro	0.83	14.75	0.39	54	12	NASDAQ	HAS	52978	3944	8.41	0
25	TripAdvisor	0.40	13.56	0.00	12	3	NASDAQ	TRIP	13168	9999	11.29	0
26	McDonald's	0.70	12.36	0.00	29	17	NYSE	MCD	43449	5812	108.48	0
27	eBay	0.46	12.33	0.00	10	4	NASDAQ	EBAY	86356	7389	32.54	0
28	Expedia, Inc.	1.00	11.77	0.00	13	3	NASDAQ	EXPE	90808	4833	16.90	0
29	Telecom Italia	0.75	11.41	0.49	20	10	NYSE	TI	89817	4899	0.24	0
30	Restaurant Brands International	0.30	9.73	0.00	7	5	NYSE	QSR	15113	5812	7.56	0
31	Barclays Plc	0.76	9.01	0.00	16	3	NYSE	BCS	69761	6029	1.03	0
32	Netflix	1.66	8.41	2.27	3	1	NASDAQ	NFLX	89393	7841	48.95	0
33	ING Group	0.61	8.21	0.00	30	13	NYSE	ING	85081	6311	1.94	0
34	Hewlett-Packard	0.58	7.88	0.82	16	10	NYSE	HPQ	27828	3571	21.22	1
35	Nike Inc	0.57	7.08	0.05	10	1	NYSE	NKE	57665	3021	84.75	0
36	AT&T	0.39	6.36	1.80	13	6	NYSE	T	66093	4813	211.69	0
37	Alibaba Group	0.24	6.34	0.00	20	7	NYSE	BABA	14888	6799	81.06	0
38	Philips	0.21	6.05	2.18	15	5	NYSE	PHG	88487	3699	2.08	0
39	Garmin	0.32	5.93	27.74	51	12	NASDAQ	GRMN	88837	3812	7.05	0
40	GoPro	0.40	5.76	1.13	9	3	NASDAQ	GPRO	14694	9999	1.81	0
41	Sohu	0.40	5.75	0.01	10	4	NASDAQ	SOHU	19675	7379	2.21	0
42	Canon	0.29	5.33	0.01	17	4	NYSE	CAJ	21152	3861	0.70	0
43	Etsy	0.33	5.12	0.01	6	3	NASDAQ	ETSY	15291	9999	0.93	0
44	Capital One	0.40	4.68	0.00	1	1	NYSE	COF	81055	6021	38.40	0
45	News Corp	0.41	4.60	2.94	79	7	NASDAQ	NWSA	13963	9999	5.10	0
46	Mattel	0.14	4.52	0.49	98	13	NASDAQ	MAT	39538	3942	9.23	0
47	Blackstone Group	0.13	4.17	1.35	11	1	NYSE	BX	92108	6282	16.33	0
48	Groupon	0.09	4.02	0.00	5	1	NASDAQ	GRPN	13108	9999	1.81	0

Continued

49	Yelp	0.54	3.86	0.00	4	1	NYSE	YELP	13318	7375	1.90	1
50	HSBC	0.30	3.83	0.00	6	1	NYSE	HSBC	87033	6035	4.49	0
51	Johnson & Johnson	0.17	3.69	0.00	26	5	NYSE	JNJ	22111	2834	284.22	0
52	j2 Global	0.36	3.66	0.15	10	0	NASDAQ	JCOM	87075	4822	3.95	0
53	Bank of America	0.25	3.38	0.00	1	1	NYSE	BAC	59408	6021	175.24	0
54	NatWest Group	0.22	2.87	0.00	7	0	NYSE	RBS	92355	6029	0.25	0
55	Real Networks	0.16	2.86	3.99	43	9	NASDAQ	RNWK	85576	7372	0.16	1
56	Domino's Pizza	0.22	2.76	0.00	11	5	NYSE	DPZ	90248	5812	6.08	0
57	American Express	0.13	2.74	0.00	11	3	NYSE	AXP	59176	6141	68.45	0
58	BBVA	0.18	2.74	0.00	9	2	NYSE	BBVA	75381	6029	1.00	0
59	Vmware Inc	0.20	2.56	0.00	10	5	NYSE	VMW	92257	7372	6.85	1
60	World Wrestling Entertain	0.16	2.55	0.00	4	2	NYSE	WWE	87356	7812	0.61	0
61	NetEase	0.15	2.39	0.63	11	5	NASDAQ	NTES	88362	7379	13.67	0
62	SK Group	0.14	2.37	0.01	10	1	NYSE	SKM	83604	4812	1.68	0
63	Walmart	0.11	2.05	0.00	5	5	NYSE	WMT	55976	5331	196.28	0
64	Teladoc	0.16	1.78	0.62	12	4	NYSE	TDOC	15585	7363	0.69	0
65	Euronet Worldwide	0.17	1.74	0.05	2	1	NASDAQ	EEFT	84606	6099	3.84	0
66	Salesforce	0.12	1.70	0.00	14	2	NYSE	CRM	90215	7372	52.06	1
67	Caesars Entertainment	0.14	1.63	0.00	12	0	NASDAQ	CZR	13267	9999	1.14	0
68	Yum! Brands	0.08	1.59	0.00	14	1	NYSE	YUM	85348	5812	31.50	0
69	SiriusXM Holdings Inc.	0.15	1.58	0.34	2	2	NASDAQ	SIRI	80924	4832	20.95	0
70	Cisco	0.13	1.55	0.00	19	2	NASDAQ	CSCO	76076	3674	137.84	0
71	Nokia	0.12	1.42	0.01	4	1	NYSE	NOK	87128	3663	2.87	0
72	Walgreens Boots Alliance	0.03	1.31	0.00	5	0	NASDAQ	WBA	19502	5912	91.86	0

Continued

73	Penn National Gaming	0.07	1.27	0.00	22	3	NASDAQ	PENN	80563	7948	1.30	0
74	Trimble Inc.	0.11	1.26	12.78	34	8	NASDAQ	TRMB	76230	3810	5.38	0
75	Citrix	0.08	1.24	0.19	18	2	NASDAQ	CTXS	82686	7370	11.64	1
76	Chegg	0.12	1.18	0.43	24	0	NYSE	CHGG	14273	8231	0.59	0
77	Starbucks	0.10	1.14	0.00	5	1	NASDAQ	SBUX	77702	5810	89.18	0
78	Unilever	0.08	1.14	0.00	16	2	NYSE	UN	28310	2079	74.28	0
79	SAP SE	0.08	0.92	0.08	29	2	NYSE	SAP	89382	7372	3.33	1
80	Block, Inc.	0.05	0.83	1.28	6	1	NYSE	SQ	15826	7372	0.41	1
81	Deutsche Bank Ag	0.06	0.76	0.00	6	1	NYSE	DB	89199	6022	33.29	0
82	Coca-cola	0.01	0.74	0.00	10	1	NYSE	KO	11308	2086	186.83	0
83	Intel	0.03	0.72	0.02	9	4	NASDAQ	INTC	59328	3679	162.78	0
84	Logitech	0.04	0.72	0.00	11	1	NASDAQ	LOGI	84621	3577	2.46	1
85	GameStop	0.01	0.70	0.00	5	1	NYSE	GME	89301	5945	2.93	0
86	United Continental Holdings	0.05	0.69	0.00	1	1	NASDAQ	UAL	91103	4512	21.36	0
87	Abercrombie & Fitch Company	0.02	0.69	0.00	2	0	NYSE	ANF	83976	5651	1.81	0
88	IBM	0.05	0.64	0.00	20	2	NYSE	IBM	12490	7379	133.51	0
89	Atlassian	0.02	0.61	0.01	2	1	NASDAQ	TEAM	15909	9999	1.59	0
90	Live Nation Entertainment	0.04	0.60	0.00	14	1	NYSE	LYV	91041	7922	4.97	0
91	AMC Entertainment	0.05	0.57	0.00	1	1	NYSE	AMC	14328	7832	0.52	0
92	KKR	0.06	0.54	0.12	27	2	NYSE	KKR	11990	6282	7.25	0
93	Box, Inc	0.06	0.54	0.02	3	0	NYSE	BOX	15145	7375	0.57	1
94	Procter & Gamble Company	0.03	0.51	0.00	4	0	NYSE	PG	18163	2841	216.04	0
95	MasterCard	0.08	0.50	0.00	8	1	NYSE	MA	91233	7389	107.12	0
96	United Parcel Service	0.05	0.50	0.00	1	0	NYSE	UPS	87447	4513	66.99	0

Continued

97	Nuance	0.04	0.49	0.28	5	25	NASDAQ	NUAN	82759	7372	6.06	1
98	Quotient Technology	0.02	0.47	0.00	1	1	NYSE	QUOT	14504	7319	0.61	0
99	Western Digital Technologies	0.03	0.42	0.00	7	0	NASDAQ	WDC	66384	3572	13.93	1
100	Intercontinental Hotels Group Plc	0.03	0.41	0.00	1	1	NYSE	IHG	89704	7011	0.61	0

Panel B: The U.S. App Market, Before the Passage of CCPA

		U.S. App Market, Jan. 2017 to Dec. 2017					United States Stock Market, Dec. 2017					
No.	Parent Company	DAU	Down.	Rev.	No. iTunes	No. Google	Exchange	TICKER	PERMNO	SICCD	Market Capital	Digital
1	Alphabet Cl A	743.91	985.54	445.42	84	63	NASDAQ	GOOG	14542	7375	365.55	1
2	Meta Platforms Inc (formerly Facebook)	318.82	375.37	0.18	29	14	NASDAQ	FB	13407	7375	422.97	1
3	Take Two Interactive	15.38	191.27	533.14	101	64	NASDAQ	TTWO	84761	7370	12.55	1
4	Electronic Arts	14.84	174.97	558.47	124	64	NASDAQ	EA	75828	7372	32.25	1
5	Cheetah Mobile	12.90	163.60	60.95	18	32	NYSE	CMCM	14618	7372	0.14	1
6	Microsoft	15.24	162.81	95.55	79	25	NASDAQ	MSFT	10107	7370	659.09	1
7	AT&T	14.83	151.73	64.41	27	13	NYSE	T	66093	4813	238.68	0
8	Comcast	12.66	132.65	6.17	83	22	NASDAQ	CMCSA	89525	4841	185.63	0
9	Amazon	18.13	128.44	0.49	34	14	NASDAQ	AMZN	84788	7370	563.53	1
10	Disney	10.81	113.56	108.08	154	66	NYSE	DIS	26403	7313	162.05	0
11	Capital One	10.38	97.22	0.00	4	2	NYSE	COF	81055	6021	48.27	0
12	Verizon	8.43	91.11	0.78	38	20	NYSE	VZ	65875	4813	215.92	0
13	SiriusXM Holdings Inc.	138.35	86.42	325.85	2	2	NASDAQ	SIRI	80924	4832	24.27	0
14	Snap	21.82	82.33	3.49	3	0	NYSE	SNAP	16595	7372	12.61	1

Continued

15	Activision Blizzard	6.12	74.47	682.28	39	23	NASDAQ	ATVI	79678	7370	47.97	1
16	Bank of America	8.94	67.29	0.00	2	1	NYSE	BAC	59408	6021	307.91	0
17	Wells Fargo & Co	6.97	56.08	0.00	3	2	NYSE	WFC	38703	6021	298.75	0
18	Apple	5.03	49.48	2.06	25	4	NASDAQ	AAPL	14593	3571	860.88	1
19	PayPal	10.82	46.85	0.00	5	4	NASDAQ	PYPL	15488	9999	88.34	0
20	Zillow	5.45	45.48	0.00	10	4	NASDAQ	Z	15546	9999	5.21	0
21	Walmart	17.90	43.36	0.00	16	7	NYSE	WMT	55976	5331	292.54	0
22	J.P. Morgan Chase &	5.99	39.19	0.00	6	1	NYSE	JPM	47896	6021	371.05	0
23	Twitter	36.52	35.01	0.51	6	3	NYSE	TWTR	14295	7375	17.83	1
24	Iac/Interactive	3.21	33.47	23.00	43	10	NASDAQ	IAC	78840	4833	9.39	0
25	Adobe	2.69	29.74	2.83	20	5	NASDAQ	ADBE	75510	7370	86.09	1
26	Match Group Inc	3.59	28.50	247.63	11	4	NASDAQ	MTCH	15850	9999	2.02	0
27	Block, Inc.	2.48	26.74	52.54	5	1	NYSE	SQ	15826	3575	9.32	1
28	McDonald's	2.27	26.34	0.00	3	2	NYSE	MCD	43449	5812	137.21	0
29	Baidu	1.93	26.13	9.38	11	12	NASDAQ	BIDU	90857	7370	65.75	1
30	Target.com	2.10	25.82	0.00	5	3	NYSE	TGT	49154	5331	35.47	0
31	Netflix	12.11	25.80	216.11	4	0	NASDAQ	NFLX	89393	7841	83.19	0
32	Fox Corporation	2.17	23.64	0.00	12	5	NASDAQ	FOXA	90441	2711	36.39	0
33	T-Mobile US	1.49	22.57	0.00	12	6	NASDAQ	TMUS	91937	4812	54.58	0
34	Yelp	4.66	22.55	0.00	2	1	NYSE	YELP	13318	7375	3.48	1
35	News Corp	2.47	22.37	22.00	30	3	NASDAQ	NWSA	13963	9999	6.21	0
36	Expedia, Inc.	2.33	22.08	0.00	11	3	NASDAQ	EXPE	90808	4833	16.64	0
37	U.S. Bancorp	2.23	21.60	0.00	4	2	NYSE	USB	66157	6021	88.92	0
38	Intuit Inc	2.41	20.91	7.60	11	3	NASDAQ	INTU	78975	7370	40.34	1
39	Hasbro	1.63	20.58	4.92	28	10	NASDAQ	HAS	52978	3944	11.31	0
40	Under Armour	2.10	17.29	8.36	13	5	NYSE	UA	15980	2329	2.96	0
41	NetEase	0.56	16.52	17.56	14	7	NASDAQ	NTES	88362	7379	25.92	0
42	Roku	1.52	15.89	0.00	1	1	NASDAQ	ROKU	16932	9999	1.00	0
43	Starbucks	1.42	13.80	0.00	1	1	NASDAQ	SBUX	77702	5810	80.84	0

Continued

44	Groupon	1.81	13.80	0.00	4	1	NASDAQ	GRPN	13108	9999	2.86	0
45	Nike Inc	1.11	12.82	0.00	7	1	NYSE	NKE	57665	3021	82.07	0
46	Walgreens Boots Alliance	1.40	12.78	0.00	1	1	NASDAQ	WBA	19502	5912	71.94	0
47	Hewlett-Packard	1.20	12.44	0.32	6	5	NYSE	HPQ	27828	3571	34.57	1
48	United Continental Holdings	1.24	12.25	0.00	1	1	NASDAQ	UAL	91103	4512	19.97	0
49	KKR	1.22	11.28	0.01	7	2	NYSE	KKR	11990	6282	10.06	0
50	j2 Global	1.40	11.23	0.08	4	1	NASDAQ	JCOM	87075	4822	3.59	0
51	Yum! Brands	0.63	10.53	0.00	3	2	NYSE	YUM	85348	5812	27.50	0
52	CVS Health	1.13	9.99	0.00	3	1	NYSE	CVS	17005	5912	73.44	0
53	Southwest Airlines	1.10	9.86	0.00	1	1	NYSE	LUV	58683	4512	38.84	0
54	eBay	1.94	9.61	0.00	2	0	NASDAQ	EBAY	86356	7389	38.83	0
55	Live Nation Entertainment	0.92	9.08	0.00	2	2	NYSE	LYV	91041	7922	8.80	0
56	Domino's Pizza	0.95	8.89	0.00	1	1	NYSE	DPZ	90248	5812	8.26	0
57	Etsy	1.19	8.86	0.00	3	2	NASDAQ	ETSY	15291	9999	2.49	0
58	Alibaba Group	0.88	8.74	0.23	10	3	NYSE	BABA	14888	7375	195.80	1
59	Dish Network	0.72	8.18	0.18	4	3	NASDAQ	DISH	81696	4841	10.89	0
60	Dollar General	0.72	8.13	0.00	1	1	NYSE	DG	93096	5331	25.26	0
61	Progressive	0.87	8.07	0.00	2	1	NYSE	PGR	64390	6331	32.76	0
62	Automatic Data Processing, Inc. (ADP)	0.81	7.79	0.00	1	1	NASDAQ	ADP	44644	7374	51.88	1
63	Wayfair	0.10	7.61	0.00	2	1	NYSE	W	14983	5812	4.54	0
64	Mattel	0.44	6.92	0.30	44	10	NASDAQ	MAT	39538	3942	5.29	0
65	Canon	0.57	6.89	0.00	2	2	NYSE	CAJ	21152	3861	0.73	0
66	Delta Air Lines	0.76	6.88	0.00	1	1	NYSE	DAL	91926	4512	39.93	0
67	Teladoc	0.73	6.86	1.60	10	3	NYSE	TDOC	15585	7363	1.99	0
68	Kohl's	0.71	6.85	0.00	1	1	NYSE	KSS	77606	5311	9.11	0

Continued

69	American Express	0.74	6.80	0.00	4	1	NYSE	AXP	59176	6029	86.20	0
70	GoPro	0.53	6.00	4.64	6	2	NASDAQ	GPRO	14694	9999	0.76	0
71	The Home Depot	0.61	5.83	0.00	2	2	NYSE	HD	66181	5211	221.32	0
72	Cisco	0.65	5.77	0.00	7	1	NASDAQ	CSCO	76076	3674	189.34	0
73	Foot Locker	0.45	5.71	0.00	4	1	NYSE	FL	15456	5661	5.68	0
74	Citigroup	0.75	5.66	0.00	2	1	NYSE	C	70519	6021	196.74	0
75	Charter Communication	0.54	5.48	0.00	9	2	NASDAQ	CHTR	12308	4841	80.13	0
76	Instructure	0.59	5.39	0.00	2	1	NYSE	INST	15824	7371	0.99	1
77	Western Union	0.59	5.23	0.00	1	1	NYSE	WU	91461	6099	8.73	0
78	Macy's	0.58	5.10	0.00	1	1	NYSE	M	77462	5311	7.67	0
79	Best Buy	0.53	5.06	0.00	1	1	NYSE	BBY	85914	5731	20.02	0
80	Blackstone Group	0.33	4.91	11.25	4	3	NYSE	BX	92108	6282	20.20	0
81	Restaurant Brands International	0.45	4.88	0.00	3	2	NYSE	QSR	15113	5812	14.60	0
82	New York Times	0.58	4.69	16.30	5	3	NYSE	NYT	47466	2711	2.99	0
83	Salesforce	0.45	4.62	0.00	5	1	NYSE	CRM	90215	7372	73.84	1
84	Redfin	0.35	4.40	0.00	2	1	NASDAQ	RDFN	16829	9999	2.55	0
85	TripAdvisor	0.18	4.26	0.00	4	1	NASDAQ	TRIP	13168	9999	4.35	0
86	Morgan Stanley	0.45	4.26	0.00	3	1	NYSE	MS	69032	6211	94.86	0
87	American Airlines Group	0.52	4.23	0.00	1	0	NASDAQ	AAL	21020	4512	24.74	0
88	Allscripts	0.42	4.19	0.00	1	1	NASDAQ	MDRX	87078	7372	2.63	1
89	Kroger	0.39	4.03	0.00	5	1	NYSE	KR	16678	5411	24.19	0
90	Papa John's	0.33	3.93	0.00	1	1	NASDAQ	PZZA	79299	5810	1.90	0
91	Chegg	0.51	3.93	9.62	6	0	NYSE	CHGG	14273	8231	1.77	0
92	Apollo Global Management	0.31	3.90	0.06	16	1	NYSE	APO	12591	6282	6.48	0
93	AMC Networks	0.28	3.86	4.64	7	4	NASDAQ	AMCX	12880	9999	2.68	0

Continued

94	Penn National Gaming	0.42	3.76	6.19	4	4	NASDAQ	PENN	80563	7948	2.86	0
95	BlackBerry	0.32	3.66	0.04	8	1	NYSE	BB	86745	3661	5.99	0
96	Sohu	0.26	3.63	0.17	5	3	NASDAQ	SOHU	19675	7379	1.69	0
97	Hilton Worldwide	0.35	3.59	0.00	1	1	NYSE	HLT	14338	7011	25.55	0
98	General Motors	0.42	3.55	0.00	4	0	NYSE	GM	12369	3711	58.22	0
99	Cars.com	0.39	3.51	0.00	1	1	NYSE	CARS	16696	5511	2.07	0
100	Gogo	0.27	3.51	0.00	1	0	NASDAQ	GOGO	13956	9999	0.98	0

Panel C: The China's App Market, Before the Passage of DSLC

		China's App Market, Jan. 2020 to Dec. 2020					United States Stock Market, Dec. 2020					
No.	Parent Company	DAU	Down.	Rev.	No. iTunes	No. Google	Exchange	TICKER	PERMNO	SICCD	Market Capital	Digital
1	Alibaba Group	47.69	380.64	608.25	66	14	NYSE	BABA	14888	7375	264.27	1
2	NetEase	20.73	214.31	1453.71	145	10	NASDAQ	NTES	88362	7379	28.69	0
3	Baidu	22.65	190.25	274.13	130	3	NASDAQ	BIDU	90857	7370	58.68	1
4	Pinduoduo Inc ADR	8.94	94.75	0.27	3	1	NASDAQ	PDD	17972	9999	61.38	0
5	JD.com	9.25	79.34	0.67	18	3	NASDAQ	JD	14655	9999	73.02	0
6	China Mobile	6.69	65.81	5	72	3	NYSE	CHL	85421	4813	3.07	0
7	Alphabet Cl A	26.60	52.74	0	22	47	NASDAQ	GOOG	14542	7375	575.75	1
8	Apple	5.56	47.23	5.89	20	2	NASDAQ	AAPL	14593	3571	2232.28	1
9	Bilibili	3.96	39.08	89.73	23	0	NASDAQ	BILI	17346	9999	17.03	0
10	Sohu	3.99	34.43	29.28	22	3	NASDAQ	SOHU	88467	7379	0.64	0
11	Trip.com Group	3.77	27.58	0	9	3	NASDAQ	TCOM	89927	7389	17.77	0
12	Microsoft	2.60	24.95	1.75	26	24	NASDAQ	MSFT	10107	7370	1678.38	1
13	China Telecom	2.54	21	0.01	19	0	NYSE	CHA	89581	4813	0.15	0
14	AppLovin	1.19	20.87	1.70	52	45	NASDAQ	APP	91136	2389	0.02	0

Continued

15	Cheetah Mobile	1.87	19.30	0.87	26	14	NYSE	CMCM	14618	7371	0.02	1
16	Nike Inc	1.57	15.28	0	5	2	NYSE	NKE	57665	3021	177.52	0
17	Electronic Arts	1.46	14.55	11.36	31	2	NASDAQ	EA	75828	7372	41.36	1
18	Meta Platforms Inc (formerly Facebook)	29.56	13.25	0.02	9	8	NASDAQ	FB	13407	7375	657.22	1
19	Vipshop Holdings Ltd -	1.74	13.06	0	2	0	NYSE	VIPS	13315	7372	12.84	1
20	Luckin Coffee Inc ADR	1.21	12.52	0	2	0	NASDAQ	LK	18662	9999	0.15	0
21	Take Two Interactive	0.80	10.97	8.72	52	21	NASDAQ	TTWO	84761	7370	23.91	1
22	Unity Technologies	0.47	10.16	0.01	21	13	NYSE	U	19794	7371	41.56	1
23	Zoom Video Communications Cl A	0.95	8.37	0	3	1	NASDAQ	ZM	18484	9999	65.70	0
24	Adobe	1.13	8.20	0.53	4	1	NASDAQ	ADBE	75510	7372	239.56	1
25	Activision Blizzard	0.69	7.07	17.49	16	3	NASDAQ	ATVI	79678	7370	71.89	1
26	51job	0.93	7.05	0.44	4	0	NASDAQ	JOBS	90361	7361	2.76	0
27	Iac/Interactive	0.69	6.43	2.42	23	5	NASDAQ	IAC	78840	4833	15.71	0
28	Amazon	0.97	6.42	0.04	8	9	NASDAQ	AMZN	84788	7370	1638.24	1
29	Starbucks	0.69	5.17	0	1	0	NASDAQ	SBUX	77702	5810	125.94	0
30	Twitter	3.12	5.03	0	1	2	NYSE	TWTR	14295	7375	43.07	1
31	Expedia, Inc.	0.62	4.42	0.02	6	2	NASDAQ	EXPE	90808	4833	18.28	0
32	Snap	1.42	3.96	0	2	0	NYSE	SNAP	16595	7372	61.82	1
33	Disney	0.37	3.90	0.58	10	3	NYSE	DIS	26403	7313	328.02	0
34	Airbnb	0.65	3.67	0	1	1	NASDAQ	ABNB	20190	9999	16.96	0
35	Petrochina Co Ltd -	0.36	3.33	0	1	0	NYSE	PTR	87844	1311	0.24	0
36	Canon	0.35	3.31	0	4	2	NYSE	CAJ	21152	3861	0.32	0
37	China Eastern Airlines Corp Ltd	0.45	3.16	0	1	0	NYSE	CEA	84576	4522	0.05	0
38	Farfetch Ltd Cl A	0.17	2.52	0	1	1	NYSE	FTCH	18077	7389	18.95	0

Continued

39	Hewlett-Packard	0.33	2.42	0.01	3	3	NYSE	HPQ	27828	3571	31.71	1
40	Fox Factory Holding	0.19	2.41	0.03	8	0	NASDAQ	FOXF	14097	9999	4.42	0
41	Booking Holdings	0.35	2.34	0	4	7	NASDAQ	BKNG	86783	7389	91.23	0
42	Cisco	0.23	1.80	0	2	1	NASDAQ	CSCO	76076	3674	189.09	0
43	Real Networks	0.07	1.47	0.04	13	3	NASDAQ	RNWK	85576	7372	0.06	1
44	Uber Technologies	0.61	1.46	0	1	1	NYSE	UBER	18576	4119	94.25	0
45	Match Group Inc	0.21	1.45	1.66	2	1	NASDAQ	MTCH	15850	9999	40.42	0
46	Autodesk	0.12	1.19	0	1	0	NASDAQ	ADSK	85631	7370	67.14	1
47	Hilton Worldwide	0.07	1.02	0	2	1	NYSE	HLT	14338	7011	30.87	0
48	Renren	0.05	0.90	0.66	3	0	NYSE	RENN	12759	4813	0.02	0
49	Marriott International	0.11	0.85	0	1	0	NASDAQ	MAR	85913	7011	42.80	0
50	Hasbro	0.03	0.77	0	3	0	NASDAQ	HAS	52978	3944	12.84	0

Note: In this table, we provide the list of firms that have active apps on iTunes Connect or Google Play platforms.