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News or noise: Mobile internet technology and stock market activity

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Abstract

Mobile internet devices reduce trading frictions and information search costs for investors, but also introduce attention-competing activities, such as social networking. We use exogenous nationwide and city-level outages of the Blackberry Internet Service (BIS) to investigate the effect of mobile internet technology on investors' information-gathering vs. attention-diverting activities. We find that trading volume and trading frequency surge by about 5% on days when mobile internet systems go dark, consistent with a greater role for devices (when not dark) in diverting the limited attention of investors *away* from information-gathering and trading—even when they are used by presumably more sophisticated investors.

Key words: mobile technology; investor activity; stock market liquidity; limited attention; distraction
JEL codes: D83, G12, G14, L86

1. Introduction

The past two decades have seen major advances in telecommunications technology. In turn, these advances have profoundly affected how news on corporate fundamentals is received and disseminated by investors and, accordingly, how this information is impounded into security prices (Miller and Skinner [2015]). Regulators and academics further suggest that telecommunication advances may play a key role in promoting capital market activity, primarily by lowering the barriers to trading and improving the flow of information across market participants (D'Avolio et al. [2002], SEC [1997], Stein [2018]).

Mobile internet technology is, perhaps, the most significant of these advances, in terms of enabling *on-demand* access to information on the web and social media from a mobile cellular device (cell phone, smart phone, tablet, PDA, etc.). This on-demand access has permeated capital markets, as recent surveys report that market participants rely considerably on mobile internet technology for trading, analysis, and communication. For example, 34% of Vanguard clients regularly access their accounts via a mobile device (Xu and Utkus [2019]) and, of Fidelity clients who access their accounts via a mobile device, more than half engage in technical analysis and trading via a smartphone (Fidelity Investments [2014]).

While mobile internet devices can be used by market participants to easily search, communicate, and trade in markets, these same devices are often used to carry out more routine (and perhaps distracting) personal activities such as non-stock-related social (including professional) networking. In addition, the ease of use of such devices may result in some users overinvesting their time in observing market information that is less useful in assessing their current or potential investments (i.e., Hirshleifer et al. [2009]). Accordingly, while mobile internet devices can promote trading and price formation in security markets, the technology may have an adverse effect by diverting the attention of market participants either toward less important market information or even away from stock market activity altogether. Our study addresses these potentially conflicting forces by investigating changes in stock market activity and conditions around exogenous (and extended) outages to the BlackBerry Internet Service, a widely-used mobile internet system during our sample period.

Mobile internet technology allows users, such as stock market participants, to wirelessly access financial information in real-time (from the internet, email, mobile apps, etc.), regardless of the time of day or the individual's location. One view is that this "on-the-go" access to stock information should lead to lower trading costs (one can easily access posted limit orders for a given stock), lower search costs (individuals do not need to find a computer, newspaper, or hard copies of corporate filings or analyst reports to collect and analyze price-relevant information), and lower information dissemination costs (users can email, text, and post information or their own opinions from the palm of their hand or the command of their voice; see Bartov et al. [2017], Jame et al. [2016]). Under this view, one might expect the widespread usage of mobile internet to promote stock market activity and price discovery in capital markets. That is, easier access to markets and faster impounding of fundamental information into stock prices may reduce the need for investors to engage in price-protection when trading (Blankespoor et al. [2013], Welker [1995]).

We refer to this view as the *Information Efficiency Hypothesis*. Recent research provides results consistent with this view. Brown et al. [2015] find that information search activity, trading volume, bid-ask spreads, and returns for local stocks all decline following state-level enforcements of distracted driving laws (which constrain the use of mobile devices by local individuals while driving). Thus, mobile communication and wireless internet access to stock information appears to have a positive influence on stock market activity, information flow, and price discovery in capital markets.

Conversely, a large literature in psychology and behavioral finance suggests that individuals are boundedly rational (Simon [1957, 1956]) and exhibit limited attention (Hirshleifer and Teoh [2003], Kahneman [1973]). For instance, Hirshleifer et al. [2009] find that the market reaction to a firm's earnings surprise is significantly weaker when the surprise occurs on a day with numerous other earnings announcements.[1] In other words, the easy availability of either market-related or non-market-related information (e.g., in the form of Twitter) may cause individuals to neglect some relevant stock valuation

[1] We note, here, that our arguments do not depend solely on the assumption that mobile internet users are price-setting traders in the market. Prior studies argue that market participants gather valuable stock information through local sources and social interactions with various informed individuals such as firm employees and other colleagues who are familiar with firms and their operations (Hong et al. [2004], Ivković and Weisbenner [2007]). Mobile internet usage could either promote or inhibit such information diffusion from non-market participants.

information, which could decrease the speed of information flow into stock prices. We refer to this alternative view as the *Limited Attention Hypothesis*.

Our study allows two important new perspectives to be addressed, relative to this prior literature. First, our setting allows a study of the tradeoff between the effect of the availability of a new technology on its impact on lowering the cost of information collection and stock market participation versus its demand on the limited attention of users of such technology. Second, our setting focuses on an internet technology (Blackberry) that was predominantly used by professionals in business and government—and, much less so by individuals not employed in professional (e.g., managerial) occupations. We expect that the effect of the availability of a new technology, rather than additional available information on existing technologies (e.g., additional news sources on a Bloomberg terminal), to have compounding effects. Put differently, portable internet devices allow easier access to existing information as well as enabling new sources of rapidly-disseminated information—such as group email messages and social media applications. Thus, such devices can represent a huge leap in the amount of information available to investors.

Our empirical tests take advantage of exogenous network outages of the BlackBerry Internet Service (BIS) and BlackBerry Enterprise Server (BES) as a novel identification strategy for distinguishing the informational versus attention-distracting effects of mobile internet technology on stock market activity. BlackBerry is a major smartphone brand produced by BlackBerry Limited (formerly Research in Motion). During our sample period (2009-2011), the BlackBerry brand held the largest share of the U.S. smartphone market (55% in 2009) and was the most popular handheld device among business and average consumers, reaching a peak of about 19 million U.S. subscribers in 2011.[2] The BIS (BES) was developed primarily for individual (business) consumers. The BES system was widely used by corporate entities, especially financial services firms, due to its security features (Brodkin [2011], Moore [2011], Rusli [2011]). The outages in our sample affect both the BIS and BES, but for simplicity we refer to both systems as the BIS.

The BIS supports numerous mobile web-based applications developed by both BlackBerry and

[2] The BlackBerry market share in U.S. smartphone operating systems declined from 55% in 2009 to 30% (10%) in 2010 (2011) (Dvorak et al. [2011]). Despite this decline, BlackBerry ranks as a top 3 smartphone brand during our sample period.

third parties. Several applications such as multi-media messaging (e.g., MMS and BlackBerry PIN Messenger), interactive gaming, mapping, and social networking services require access to the BIS (not just Wi-Fi) for use. BIS outages are widespread internet disruptions that typically affect an economically large cross-section of users and limit access to multiple applications that are frequently used by BIS subscribers. Given the extensive nature of these disruptions, BIS outage events could plausibly create measurable effects on stock market activity.

A key advantage of using BIS outages as our empirical setting is that the disruptions only affect the internet-based capabilities of the devices, i.e., mobile communication features such as mobile calling, standard text messaging (SMS),[3] and some non-BlackBerry applications continue to operate during outages.[4] This distinction is important for disentangling the informational versus distraction effects of mobile internet, as BIS outages impede BlackBerry users' mobile internet access, but do not interfere with other, lower-bandwidth BlackBerry functions like standard texting and calling. Thus, in contrast to the effect of an arguably more complete elimination of information diffusion, such as a cellular or electricity blackout, or the aforementioned distracted driving laws studied by Brown et al. [2015], a BIS outage imposes limits on the huge number of information sources that compete for a user's attention, while still allowing users to collect information through their social or professional networks. Another important advantage is that BIS outages are clearly exogenous, i.e., they are unplanned and are unrelated to market- or firm-specific information or conditions, an advantage over studies such as Brown et al. [2015].[5]

We identify 11 national BIS outages on trading days, across 8 distinct weeks, from 2009 to 2011[6]

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[3] Short text-only messages of up to 160 characters (SMS) are not affected by outages. Multimedia messaging (MMS), however, is affected since this service requires access to the Internet and the mobile carrier's server. MMS allows for the exchange of text greater than 160-characters and media such as pictures, audio, video, and slideshows of multiple images.

[4] According to Crackberry.com (a BlackBerry online user forum), some non-BlackBerry applications are still functional over Wi-Fi during BIS outages. However, BlackBerry applications are inoperable over Wi-Fi as access to the BlackBerry (RIM) servers are required for operation. Some BlackBerry users also experience intermittent disruptions to standard phone and SMS messaging features during BIS outages; however, such interruptions appear to be sporadic and dependent on the device type or wireless carrier as opposed to BlackBerry Limited.

[5] Specifically, Brown et al. [2015], in using distracted driving laws as an instrument for a shock in the use of cellular technology, may be susceptible to reverse-causality: an increase in the use of cellular technology, in particular locales during a particular period of time, may increase the enforcement of laws that seek to reduce such usage.

[6] We limit our sample to this three-year window to take advantage of the deep market penetration of the BlackBerry brand during this time period. This sampling choice allows for more targeted testing during a time period when we expect the stock market effect of BlackBerry outages to be most discernible.

(see Table 1 for a list of outage dates). We gather and confirm these network outage dates using news sources and Dataoutages.com, a popular online service that searches newsfeeds, blogs, and other sources for BIS outages and reports these events to subscribers via email and Twitter.[7] In univariate tests, we compare market activity on BIS *nationwide* outage dates to the activity on BIS operable dates within the same week (i.e., days when the system has no reported nationwide downtime). Since our market activity variables are not normally distributed, we use a non-parametric sign test, in addition to a simple *t*-test, to compare market activity on BIS outage days relative to BIS operable days. We also employ a series of ordered logistic models that estimate the daily ranks of a firm's market activity metrics within the [-1, +1 week] window around nationwide BIS outages. Furthermore, we use a series of fixed-effects OLS specifications estimating daily market activity in a [-30 day, +30 day] window around national BIS outages.

Our final tests involve a targeted event-study analysis of *localized, city-wide* BIS outages (also gathered from Dataoutages.com). We identify 7 city-level BIS outages spanning the 2009 to 2010 period. Using the city location of firms' headquarters to identify local stocks, we map these 7 outages to 106 stocks headquartered in the respective cities. Prior studies suggest that local investors hold disproportionately large ownership stakes in local firms and that they contribute significant amounts of information about these firms to the market (Ivković and Weisbenner [2005]). Accordingly, we expect the distinction between informational and distraction effects of mobile internet to be more evident for firms in local outage areas.

Our results for both *nationwide* and *local* BIS outages provide support for the Limited Attention Hypothesis as opposed to the Information Efficiency Hypothesis. Specifically, on days in which the BIS experiences a nationwide outage, the typical firm experiences a decline in closing spreads, as well as a 6% increase in the number of trades and a 4.3% increase in trading volume.[8] This uptick in trading activity

[7] We also search news reports and blogs to determine the source or cause of each outage. We find that most outages were due to hardware failures stemming from Blackberry Limited's poor expansion of its core and backup operating systems. One outage resulted from an application update of the Blackberry Messenger service. Importantly, we found no reports of abnormal surges in user volume (which could presumably be related to market stress events) as a driver of any of the outages.

[8] Increased adverse selection costs could be induced by BIS outages if such outages change the distribution of noise vs. sophisticated traders in the market. However, our results suggest that whatever upward pressure this effect has on spreads is overwhelmed by the significant increases in volume that accompany BIS outages. These pressures will have opposite effects, but given the size of the volume surge, empirically we observe overall decreases in closing spreads.

corresponds to a 4.7% increase in traded dollar volume and considerably greater liquidity, as measured by stock turnover (an increase of about 7.4%) and the Amihud illiquidity proxy. Consistent with the effects of nationwide outages, we find that stocks headquartered in local outage areas also experience sizable increases in trading volume and small increases stock prices on local BIS outage days. Our event study results indicate that local stocks experience a median two-day abnormal volume of about +19%, along with a median abnormal return of +49 basis points. This temporary, positive shock to liquidity corresponds to a positive abnormal return of $1.1 million for the median firm (median market capitalization ≈ $220 million). Together, these results are consistent with our distraction hypothesis and suggest that market activity increases when the presumably distracting features of mobile internet devices are inoperable.

Additional analyses indicate that stocks held primarily by institutions (retail investors) are the ones most (least) affected by BIS outages—stocks with high institutional ownership exhibit greater increases in traded volume and liquidity relative to stocks with high retail ownership. A targeted analysis of daily trading data corroborates this evidence, as we observe a 2.5% increase in the number of large trades on outage days. Since institutions are more likely to execute large trades, this result suggests that institutional traders—or, perhaps, those whom they collect information from—are more prone to mobile-induced distractions. While this evidence seems counterintuitive, it is consistent with the BlackBerry brand being ubiquitous with business professionals (especially in the financial services industry) during our sample period (Brodkin, [2011], Moore [2011], Rusli [2011]). It is also in line with evidence of distraction among professional investors (Corwin and Coughenour [2008], Fang et al. [2014], Liu et al. [2020], Schmidt [2019]).

Further robustness tests confirm that our results are not attributable to day-of-the-week variations in trading activity, the Friday distraction effect (Dellavigna and Pollet [2009]), or distractions arising from intense news events (Peress and Schmidt [2020]). Finally, our results hold for sub-samples of small and large firms, thus alleviating concerns that our evidence is strictly dependent on size related factors.

Our study makes several contributions. First, we contribute to the growing research on the investment effects of mobile technology (Brown et al. [2015], Brown et al. [2020], Clor-Proell et al. [2019], Grant [2020]) and to the broader literature on information technology advances in capital markets

(Blankespoor et al. [2013, 2018], Chen et al. [2014], Elliott et al. [2012], Jung et al. [2018]). While research finds that mobile communication promotes information flow and investor activity (Brown et al. [2015]), we provide the first empirical evidence that mobile technology also serves as a distraction and, at times, has a negative impact on market activity.[9] Our study examines broad-based interruptions to mobile internet connectivity across all service subscribers who are potentially engaging in multiple tasks at any given moment. This context builds on Brown et al. [2015], who examine constraints on mobile use when individuals are attending to presumably one (procedural) task, i.e., operating a vehicle. However, in that setting, individuals are constrained not only from engaging in mobile internet-based activities while driving, but also from engaging in standard mobile talking and texting. These features operate outside of mobile internet systems and are not constrained in our BlackBerry outage setting. BIS outages, thus, provide effective means for disentangling the distraction and informational effects of mobile internet technology.[10]

Second, we extend the growing literature on the effect of limited attention on the trading activity of professional investors. While inattention is well established for unsophisticated retail investors, new research suggests that institutional investors are also prone to distractions created by information overload and attention-grabbing events (Corwin and Coughenour [2008], Fang et al. [2014], Liu et al. [2020], Schmidt [2019]). Our results suggest that mobile internet is an important source of distraction that is likely to affect this investor group on a regular basis. Lastly, we extend the local bias literature by documenting that local mobile internet interruptions are correlated with increased trading activity for local firms. Thus, mobile internet connectivity is a source of distraction that also extends to local (better-informed) investors.

2. Literature Review and Hypothesis Development

2.1 MOBILE INTERNET TECHNOLOGY

The use of mobile internet increased at a staggering rate in the United States during the past decade.

[9] Brown et al. [2020] illustrate similar effects in a laboratory experiment, but we are the first to use real-world data to provide evidence suggestive of mobile devices distracting stock market participants to the detriment of overall stock market activity.
[10] The results of Brown et al. [2015] are consistent with limited substitutive means for gathering and diffusing stock information when mobile use while driving is constrained. In our setting, value-relevant stock information can be readily accessed using alternative means such as mobile and landline phone calls, mobile texting, and PC-based internet services, while extraneous information is less readily available.

Surveys report that as of February 2019 nearly 81% of American adults own a smartphone of some kind, up from just 35% in May 2011 (Pew Research Center [2019]). The rise in tablet devices is even more striking—52% of U.S. adults reported owning a tablet device in early 2019, an eighteen-fold increase from the 3% ownership share reported in mid-2010. This expanded use of mobile technology has also led to dramatic increases in mobile internet connectivity among users. Specifically, the wireless industry estimates that in 2018 Americans transmitted 28.58 trillion megabytes of mobile data—an amount that is 73 times higher than the data transmitted during 2010 (CTIA [2019]). In addition, mobile apps and mobile web are now one of the most dominant means of online connectivity, as smartphone penetration (81%) now exceeds desktop and laptop computer penetration (74%) among U.S. adults, with 17% of U.S. adults having only a smartphone and no computer access (Pew Research Center [2019]).

The usage of mobile internet in the U.S. spans a wide array of activities such as information search, news retrieval, personal finance, social networking, and other forms of entertainment. With respect to information retrieval and personal finance, survey statistics show that 57% of American adults use a mobile device often to follow news events (Walker [2019]), while 53% use a smartphone to conduct online banking and 28% to access credit card accounts (U.S. Federal Reserve Board [2016]). Moreover, there is mounting evidence that an economically large subset of investors and information intermediaries are dependent on mobile apps and web platforms to gather, evaluate, and even trade on stock information. For instance, half of surveyed investors report using a mobile device to access the internet (Roper [2014]), with a growing number of investors and financial analysts relying on mobile apps to conduct complex stock-related tasks such as technical analysis, stock charting, reviewing analyst reports, and listening to earnings calls (Cossette [2014], Fidelity Investments [2014]). Our setting is consistent with this trend, as Bloomberg Mobile ranks as a top 15 BlackBerry app during our sample period (Shar [2009]).

Reviews of industry websites also indicate that 65% of financial services firms provide online investment tools via mobile platforms (Roper [2014]). The adoption of these tools is fairly high as brokers and dealers estimate that about 15% to 20% of stock transactions take place on a mobile device (Carey [2014]), with around 7% of regular investors engaging with their brokerage primarily via mobile devices

(Patel [2014]). Note that our predictions do not rely on BlackBerry users trading on mobile devices, but rather using mobile devices to stay abreast of market events (which could motivate trades on any platform). That said, due to BlackBerry's widespread adoption among finance professionals, BlackBerry was the first major smartphone brand to provide stock trading apps to users, with the first such apps coming online in early 2009 (E*Trade and Fidelity; see Bruene [2009]). Android and Apple, by comparison, did not offer such services until 2010 (Tenerowicz [2010], Slivka [2010]).

While mobile internet has transformed the speed and efficiency of financial activities as well as the dissemination and consumption of market information, this technology poses significant distractions for market participants as mobile devices are often used to carry out more routine activities such as gaming, online shopping, entertainment, and non-stock-related emailing, messaging, and social networking. Indeed, recent surveys indicate that social media and entertainment apps such as Facebook, YouTube, Instagram, and Pandora are among the top 10 apps accessed by mobile users (Comscore [2017]). This mirrors the usage patterns of BlackBerry users during our sample period, as Facebook and gaming apps (notably Snake Deluxe 2 and Golden Thumb Blackjack) rank among the most popular BlackBerry apps during 2009 to 2011 (Shar [2009]). Unsurprisingly, the popularity of these apps contributes to mobile-induced distraction being common among users—57% of experienced users report feeling distracted by their mobile device (Smith [2015]). Recent experimental evidence also indicates that individual investors feel distracted by mobile devices even when the device is simply nearby (Brown et al. [2020]). Such evidence suggests that mobile-induced distractions could cause market participants to neglect information pertinent to the market or the need/desire to trade, which, in turn, impedes overall stock market activity. In this study, we examine how these conflicting pressures of mobile internet affect the amount of trading activity in stock markets.

2.2 Mobile Internet and Stock Market Activity

Market efficiency is contingent on information efficiency, the speed and accuracy with which financial markets incorporate information into security prices (Fama [1970]). In recent decades, advances in information efficiency have been closely tied to advances in technology. Recent research demonstrates that technological innovations, such as online brokerage platforms (Barber and Odean [2002, 2001], Choi, et al. [2002], Sicherman et al. [2016]), corporate websites (Ashbaugh et al. [1999]), webcast conference calls (Bushee et al. [2003]), online videos (Elliott et al. [2012]), and robo-journalism (Blankespoor et al. [2018]), significantly increase trading and the speed with which information is impounded into prices. Further, prior research suggests that individuals use new technologies such as Google searches (Da et al. [2011], Drake et al. [2012]), social media (Blankespoor et al. [2013], Jung et al. [2018]), the SEC's EDGAR system (Gao and Huang [2020]), and internet stock message boards and investment blogs (Antweiler and Frank [2004], Jame et al. [2016]) to further access, disseminate, and trade on firm news.

Research in economics and communication demonstrates that advances in telecommunication infrastructure are associated with improvements in economic growth (Hardy [1980], Jorgenson and Vu [2005], Leff [1984], Roller and Waverman [2001], Saunders et al. [1994], Waverman et al. [2005]). While there are numerous mechanisms through which these improvements operate, evidence suggests that lower transaction, search, and communication costs play an important role (Bakos [1997], Litan and Rivlin [2001], Norton [1992]). Studies on individual investors are also consistent with the information efficiency role of technological advances in communications. Specifically, Barber and Odean [2001] examine the effect of internet connectivity on investors' trading activity and find evidence that internet access increases stock market activity. Barber and Odean attribute much of this improvement to the ease of trading and breadth of information available internet investors.

Relatedly, in a discussion on the requirements of a well-functioning securities market, D'Avolio et al. [2002] highlight the importance of information availability and the ability of participants to process and transmit financial information free of excessive costs and constraints. Consistent with this notion, Choi et al. [2002] study changes in investor behavior arising from investors' ability to execute trades in their 401(k) accounts via the internet. The study finds that access to internet-based trading channels lead investors to trade much more frequently.

In studies similar to our own in approach, Brown et al. [2015] finds that restrictions of mobile communication while driving lead to reduced search activity and stock market activity for firms headquartered in affected areas, and Jensen [2007] and Aker [2010] observe improvements in the liquidity and information efficiency of commodity markets in developing nations following the introduction of mobile phone technology. These findings suggest that market participants use mobile technology in an effort to trade more frequently and better incorporate value-relevant information into stock and commodity prices, and that limiting this technology could have negative consequences for market activity.

In sum, research in both macroeconomics and individual markets suggests that rational economic agents take advantage of the lower trading, search, and communication costs associated with improved technology to trade more often and more quickly incorporate information into prices. This has the effect of increasing trading volumes directly, via easier access to trading, and indirectly, via more informative prices resulting in lower spreads (which further spurs trading; see Alampieski and Lepone [2009], Albuquerque et al. [2020]). If this is indeed the case, then exogenous disruptions to this improved technology (specifically, outages of mobile internet systems) could hinder stock market activity. We refer to this hypothesis, grounded in rational expectations, as the *Information Efficiency Hypothesis*.

> **Information Efficiency Hypothesis:** Disruptions in mobile internet correspond to lower trading activity and price discovery characterized by lower volume, fewer trades, higher bid-ask spreads, and diminished liquidity.

2.3 Mobile Internet and Distraction

While mobile internet certainly allows for lower trading, search, and communication costs, it could also serve as a distraction to market participants. A large literature in psychology and behavioral finance suggests that individuals are boundedly rational (Simon [1957, 1956]) and exhibit limited attention (Hirshleifer and Teoh [2003]). Limited attention is a necessary consequence of the vast amount of information available to individuals and limits to information processing power (Stice [2020]). Attention must be selective and requires effort (i.e., substitution of cognitive resources from other tasks; see Kahneman [1973]). Several well-known biases documented in psychology, finance, and accounting likely arise from limited attention, and the finance and accounting literatures suggest that limited attention affects trading behavior and prices in capital market settings (Hirshleifer [2001], Kothari [2001]).

As discussed in Hirshleifer and Teoh [2003], attention is required both to encode environmental stimuli (such as a webcast conference call or online financial disclosure in our setting) and to process ideas in conscious thought (such as the desire to trade on the information contained in the disclosure). Further, conscious thought involves a focus on particular ideas at the exclusion of others, thus an individual focusing on understanding the implications of one disclosure or message may be unable to process another disclosure or message carefully at the same time. In addition, attention tends to be drawn to stimuli that are goal- or task-related, but can also be misdirected. For example, attention is drawn to vivid stimuli or salient stimuli. In our setting, salient stimuli (some of which are unrelated to stock information) could be email or podcast alerts or push notifications from social networking and gaming apps emanating from individuals' mobile internet-enabled device.

Importantly, psychologists provide a large body of evidence documenting the difficulty of processing multiple information sources or performing multiple tasks at the same time.[11] Studies of divided attention and dual task performance ask participants to attend to multiple stimuli at the same time and to respond to them. These studies show that there is interference between tasks (Pashler [1999, 1994]), and that performance is much worse when the two tasks are similar, as with tasks involving the same sensory modalities (McLeod [1977], Treisman and Davies [1973]). Further, recent research suggests that these adverse performance effects are only exacerbated in media multi-tasking (Ophir et al. [2009]), a rapidly growing societal trend (Foehr et al. [2005]). This finding is particularly relevant to our setting in that market participants could be attempting to balance mobile internet use for personal and stock-related tasks simultaneously (e.g., allowing personal Facebook notifications to interrupt stock-market-related apps). Similarly, they could be attempting to balance personal mobile internet tasks with the use of other media channels for stock information purposes (e.g., attending to personal Twitter posts on a mobile device while accessing stock information on a PC). Finally, several studies provide evidence of investor distraction in a

[11] The interfering effect of extraneous information is illustrated by the famous Stroop task in which subjects are asked to name the color in which a word is printed when the word does not match its print color, for example, the word "blue" printed in red ink (Stroop [1935]). When the meaning of the word differs from its print color, subjects are slower to name its color, as compared to, for example, naming the color of a geometrical figure.

market setting by showing that extraneous or attention-grabbing news inhibits market reactions to relevant stock information (Dellavigna and Pollet [2009], Fang and Peress [2009], Hirshleifer et al. [2009], Peress and Schmidt [2020]). This evidence suggests that attending to extraneous activities on a mobile internet device could lead market participants to cut back on their stock market activity.

While our study is among the first to examine the distracting role of mobile devices in a market setting, there is an abundance of evidence on mobile internet distractions in other settings. Recently, evidence has surfaced in both the popular and academic press documenting the potential dangers to distracted mobile device users. Much of this research focuses on driving safety and documents the distractions individuals face when using mobile devices while driving (see Ferdinand and Menachemi [2014] and Horrey and Wickens [2006] for overviews of this literature). The general conclusion from this body of research is that the use of mobile devices while driving leads to delayed driver response times and greater accident risk. While much of this research focuses on mobile talking and texting while driving, public safety experts argue that accident risk is likely to be higher for devices that allow access to the internet (WHO [2011]). Consistent with this notion, anecdotal evidence from the Middle East suggests that mobile internet is particularly distracting for drivers. Specifically, during the October 2011 outage of the BIS (which we include in our study), the cities of Abu Dhabi and Dubai experienced corresponding reductions in traffic accidents of about 40% and 20%, respectively. Traffic authorities in the United Arab Emirates use this evidence to discourage drivers from using mobile internet and mobile phones behind the wheel (Mustafa and Malek [2011]).

Evidence from other fields suggests that drivers are not the only individuals distracted by the use of mobile technology. Schwebel et al. [2012] find that pedestrians are less aware of traffic and more likely to be struck by a vehicle when using mobile devices. Smith et al. [2011] find alarming evidence of mobile use by perfusionists[12] during surgery. Over 55% of surveyed perfusionists admit to mobile phone use during cardiopulmonary bypass surgery, while being very well aware of the hazards inherent in such use. Smith et

[12] Perfusionists are medical professionals trained and tasked with the use of heart-lung machines during heart surgery.

al. [2011] also document the explicit distraction posed by mobile internet, as sizable proportions of their sample of perfusionists report checking email (21%), surfing the internet (15%), and posting on social networking sites (3%) during surgery. Finally, research in pediatric medicine provides new empirical evidence of distracted parenting (Radesky et al. [2014]). The authors show that the degree of absorption in mobile devices exhibited by caregivers (i.e., extent to which caregivers were engaged with a mobile device as opposed to the child) resulted in child behaviors ranging from entertaining themselves to escalating bids for attention. Further, mobile-absorbed caregivers often responded more harshly to child misbehavior.

These findings all point to mobile internet technology distracting users, even if those users are professionals or individuals in the midst of important tasks with consequences for health, financial, or other relevant outcomes. While prior studies have not examined whether mobile internet similarly distracts market participants, these individuals likely have utility for social networking, personal email, and web browsing, as well as a utility for stock market participation. Thus, it is plausible that an inability to connect to the internet from a smartphone, by reducing the distraction caused by mobile internet apps, results in more active stock markets. We refer to this behavioral hypothesis as the *Limited Attention Hypothesis*.

> **Limited Attention Hypothesis:** Disruptions in mobile internet, which has the potential to distract individuals, correspond to higher trading activity and price discovery characterized by more trades, higher volume, lower bid-ask spreads, and improved liquidity.

3. Methods and Data

We base our main analyses on a sample of trading days around nationwide outages of the BlackBerry Internet Service (BIS) in the United States.[13] BlackBerry Limited and media sources report that these outages generally stem from technical problems, such as hardware failures or glitches in software updates. We identify 11 national BIS outages that overlap with trading days, spanning 8 separate weeks, from 2009 to 2011. We identify and confirm these network outages through news sources and

[13] While we focus on the effects of BIS outages on firms traded on U.S. markets, many of these outages are worldwide.

Dataoutages.com, a popular BlackBerry website that notifies users of service downtime.[14] Table 1 lists the BIS outage days examined in our study.

Our empirical approach is limited by the data, in that our exogenous nationwide outages occur simultaneously across the entire market, with full service being restored to most customers at the same time. As such, a difference-in-differences research design is not a good fit, as a suitable control sample is not available. We avoid these empirical issues by allowing, for each firm, non-outage (BIS operable) days around an outage day to proxy for the expected levels of market activity (volumes, trades, liquidity, trading costs, etc.) during the outage day.

3.1 Univariate Comparisons

We compare market activity for each firm on BIS outage days to the activity on days within the same week that the BIS is operable. We benchmark market activity within the same week to control for unobservable within-week effects. Consider, for example, that the dollar volume for firm X on Tuesday, a BIS outage day, was $1.8 million. We compare that BIS outage dollar volume to the dollar volume on the BIS operable days in the week of the outage, in this case Monday, Wednesday, Thursday, and Friday (let us assume that the dollar volumes for firm X on those days were $1.0 million, $1.4 million, $1.6 million, and $1.2 million). In our analysis, we would compare the BIS outage dollar volume for firm X ($1.8 million) with the mean ($1.35 million) and median ($1.3 million) dollar volume for BIS operable days in the same week. For weeks with multiple outage days, we use the mean or median dollar volume over the outage days as indicated by our treatment of the BIS operable variables (e.g., we compare the mean dollar volume for outage days to the mean dollar volume for operable days).

Since our variables of interest are not normally distributed, we compare outage day dollar volume to operable day dollar volumes using the nonparametric sign test to analyze differences in medians, in addition to the standard *t*-test to analyze differences in means.[15] The sign test weighs the ratio of positive

[14] The U.S. Federal Communications Commission (FCC) maintains a database of cellular network outages since 2004, but the data is not publicly available for reasons of national security. The U.S. Department of Homeland Security has voiced concerns that terrorists could exploit weaknesses in cell phone networks in future attacks.

[15] Our results also hold when using the Wilcoxon Sign Rank test to analyze median results.

to negative differences between the variables of interest under operable and outage statuses of the BIS. The null hypothesis of the sign test is that the proportions of negative to positive differences are equal. Specifically, if trading activity is unaffected by BIS outages, then a firm's outage-day dollar volume should be larger than those on comparable (same week) BIS operable days about as often as the firm's outage-day dollar volume is smaller than those on comparable operable days. Sign tests detect systematic departures from this null hypothesis.

Our measures of market activity include the raw and natural log values of closing spreads (scaled by closing price), the number of trades,[16] share volume, and dollar volume. We also compute share turnover (shares traded as a proportion of shares outstanding) and a variant of the Amihud [2002] illiquidity measure (the absolute value of return scaled by dollar volume traded). Higher measures of volume, trades, and turnover indicate more active markets, as do lower measures of closing spreads and the Amihud illiquidity proxy (i.e., lower transaction/adverse selection costs and less price reaction to volume, respectively). We extract our financial data exclusively from the CRSP daily file. Our sample consists of the entire NYSE and NASDAQ universe on CRSP and includes stocks that trade on at least one BIS outage day and one BIS operable day in the same week. Table 2 provides summary statistics for our full sample.

3.2 Ordered Logistic Regressions

In addition to our univariate comparisons, we also estimate ordered logistic regressions in an effort to control for important covariates. We order the variables of interest by the day within each firm-week for the weeks before, during, and after each nation-wide BIS outage. Consider the case where dollar volume for firm X was $1.8 million on Monday, $1.4 million on Tuesday, $1.6 million on Wednesday, $1.9 million on Thursday, and $1.3 million on Friday. Thursday has the highest closing dollar volume (assigned a rank of 5), followed by Monday (4), Wednesday (3), Tuesday (2), and finally Friday (1). In the ordered logistic regressions, we investigate whether the occurrence of BIS outages affects the relative ranking by using a BIS outage indicator as an independent variable.

[16] CRSP only reports the number of trades for NASDAQ firms. We therefore limit our analysis of this variable to the subsample of NASDAQ firms.

While each firm-week acts as its own control in this analysis (as a function of comparing relative market activity within each firm-week), there is still a need to control for information or systematic determinants of market activity and liquidity. We therefore control for several correlated factors in our models. These controls include the lagged (prior trading day) value of the dependent variable, daily stock returns (signed and absolute value, lagged and contemporaneous), and day of the week indicators. We include daily stock return measures to capture information-based changes in trading activity (more trades on days with lots of price-moving information). Our day-of-the-week indicator variables should capture systematic variations in trading activity across weekdays (Dellavigna and Pollet [2009]).

3.3 Fixed Effects OLS Regressions

The ordered logistic regressions provide ordinal comparisons within specific firm-weeks, which is a particularly useful approach in our setting as it makes few assumptions about the distribution of the underlying data and greatly limits the influence of outlier observations. However, for completeness we also estimate more conventional fixed effect OLS specifications. To do so, we draw data from TAQ (to include trade count data from NASDAQ, which is missing in CRSP) for the universe of TAQ firms in the [-30 day, +30 day] window around the nationwide BIS outages. With this window around the various outages in our data set, we estimate models predicting market activity and spreads as a function of a BIS outage indicator, firm fixed effects, week-year fixed effects, and day-of-week fixed effects. To adjust for correlated errors, we cluster at the firm level.

3.4 Event Studies of Local BIS Outages

As discussed above, we are unable to exploit difference-in-differences methods to investigate our hypotheses as all firms in the U.S. market are affected simultaneously by national BIS outages, and a domestic control group is unavailable. To alleviate this data issue, we collect a set of local BIS outage dates and conduct event studies of trading volume and stock returns to gauge the effect of the outages on the firms headquartered in the affected areas.

Research into local bias suggests that investors both (1) hold disproportionately large ownership stakes in locally headquartered firms and (2) have substantial informational advantages in trading in these firms (Ivković and Weisbenner [2005], Shive [2012]). Our Information Efficiency Hypothesis suggests that, as with national outages, a negative shock to the cost and speed with which local investors trade, search, and communicate in stock markets should result in decreased market activity for local firms during BIS outages. Our Distraction Hypothesis yields the opposite prediction—local BIS outages free local stock market participants from potential distractions, resulting in increased market activity during these periods.

We test these conjectures using an event study of the trading volume of local stocks on local BIS outage dates. We measure abnormal volume over the two-day window (0, +1) around the reported local BIS outage. Following Karafiath [2009], we define abnormal volume using the market model to estimate a firm-specific volume Beta during the estimation period (10 trading weeks preceding the outage), and then compare actual volume during the two-day outage window with the predicted volume (generated using the volume Beta). We use the Patell Z-statistic and the Generalized Signed Z-statistic, respectively, to evaluate the statistical significance of the mean and median abnormal volume during the local outage window (Patell [1976], Cowan [1992]).

4. Empirical Results

Our information efficiency and distraction hypotheses offer opposing predictions regarding the influence of mobile internet on stock market activity. To test these hypotheses, we take advantage of exogenous disruptions of mobile internet service—nationwide and local outages of the BIS.

4.1 UNIVARIATE COMPARISONS OF NATIONWIDE BIS OUTAGES

Table 3 reports the magnitude and statistical significance of the differences in our variables of interest observed on BIS outage and same firm-week BIS operable days.[17] The results from our *t*-tests suggest that dollar volume, number of trades, turnover, and trading volume increase on BIS outage days by 4.7% ($1.6 million), 6.0% (198 trades), 7.4%, and 4.3% (72,000 shares), respectively. These amounts are economically significant and suggest that substantially higher trading activity takes place on days in which

[17] The data underlying our main results are untransformed. In an untabulated robustness check, we find that our results are unchanged when we winsorize the variables of interest at the 1st and 99th percentiles.

the BIS experiences an outage. Non-parametric sign tests corroborate these findings and also indicate that trading liquidity increases (Amihud illiquidity proxy decreases) and adverse selection costs (closing spreads) decrease on BIS outage days (these latter results are not supported in the *t*-tests). In sum, this univariate evidence supports the distraction hypothesis and suggests that market activity and liquidity increase, while trading costs are reduced, when mobile internet connectivity is interrupted.

As prior research documents (DellaVigna and Pollet [2009]), trading volume is generally lower on Fridays relative to other weekdays due to high investor inattention before the weekend. This Friday effect could bias our results in favor of the distraction hypothesis as our analyses would be benchmarking higher volume outage days (all falling on non-Fridays) against a combination of high (non-Fridays) and low volume (Fridays) operable days. To alleviate this concern, we replicate our analysis (*t*-tests and sign tests) after excluding Fridays from the control sample of BIS operable days. This approach provides stricter evidence by comparing non-Friday outage days to similarly higher volume operable days within the same firm-week. Table 4 presents our replicated results. We continue to observe higher market activity and lower trading costs on days that the BIS goes dark relative to non-Friday operable days. These results indicate that our evidence is largely unaffected by investor inattention on Fridays and that our findings are unlikely to be biased by potential timing of firm disclosures on Fridays (Bagnoli [2002], Doyle and Magilke [2009]).

The next set of analyses investigate whether our results are robust to firm size effects. In Table 5, we replicate the paired *t*-tests and sign tests for large (> $5 billion market capitalization, Panel A), medium-sized (between $500 million and $5 billion, Panel B), and small firms (< $500 million, Panel C). With few exceptions, these panels document an increase in stock market activity corresponding to BIS outages across all three size partitions. This evidence provides further support for the distraction hypothesis and indicates that our inferences are generalizable with regard to firm size.

4.2 Ordered Logit Regressions of Nationwide BIS Outages

Table 6 reports the results of our ordered logistic regressions that model market activity in the [-1, +1 week] window around BIS outages. Consistent with our previous results, the estimated coefficients on the outage indicator variable provide evidence in support of the distraction hypothesis. With only one exception (Amihud illiquidity, in Model 5), the BIS outage indicator variable is significant ($p < 0.01$) and positively associated with the number of trades, dollar volume, share volume, and turnover, as well as negatively related to closing spreads. These results suggest that mobile internet disruptions are associated with higher market activity and lower than expected trading costs in a given firm-week.

In the previous section, we demonstrate that our inferences are robust to controlling for the Friday inattention effect. We further control for other sources of investor inattention using the ordered logit model. Prior studies show that investor inattention is heightened on days with intense media coverage of sensational news events (Peress and Schmidt [2020]). While Blackberry outages are unlikely to be systematically correlated with other national news, it is possible that some of our BIS operable days are correlated with intense news-days, leading to the appearance that trading activity is higher on BIS outage days. To address this concern, we re-estimate our ordered logit models while controlling for daily news pressure, as constructed by Eisensee and Strömberg [2007].[18] We find that our results (not tabulated) are robust to the inclusion of this covariate, easing concerns that our findings are driven by a news-related omitted variable. We also interact this news intensity measure with our BlackBerry outage indicator variable and find that the increased market activity and decreased illiquidity/spread we observe on outage days is moderated by high news pressure. That is, when other distractions, such as the Olympics or a salacious crime, are occurring, the absence of mobile internet distractions does not improve market activity by as large a margin.

4.3 WHO IS DISTRACTED BY MOBILE INTERNET?

We exploit the cross-sectional variation in institutional ownership to identify the types of stocks most affected by mobile internet distractions, and the types of investors who subsequently become more involved in stock information-related activities during BIS outages. While one would expect stocks held primarily by (unsophisticated) retail investors to be most susceptible to mobile-induced distractions, several studies demonstrate that stocks traded by professional investors are also subject to distraction or inattention

[18] We thank David Strömberg for sharing this data at http://perseus.iies.su.se/~dstro/. The variable is measured as the median number of minutes dedicated to the top three news segments across all daily news broadcasts on ABC, NBC, CBS (one half-hour in length), and CNN (one hour in length).

effects. For instance, Corwin and Coughenour [2008] document that NYSE specialists reduce liquidity for assigned stocks when they are distracted by events affecting other stocks, and Fang et al. [2014] find that mutual funds pay unwarranted attention to stocks that receive heavy media coverage. Likewise, studies find that asset managers are distracted when undergoing emotional life events (Liu et al. [2020]) and when a large fraction of their portfolio stocks announce earnings in a given week (Schmidt [2019]). Given this evidence, it is largely an empirical question as to whether the market effects of mobile internet outages will be more dominant for stocks primarily held by retail or institutional investors.

We gather data on institutional ownership from the Thomson Financial 13F filings. For each stock in our data set, we create an indicator variable for firms with high levels of retail ownership (i.e., stocks with less than 50% of institutional ownership). We then re-estimate our ordered logit regressions after interacting this indicator for high retail ownership with our BIS outage indicator. Table 7 presents the results from our re-estimated models. Interestingly, we find that stocks with high institutional ownership are the ones most affected by mobile internet disruptions relative to those with high retail ownership. Specifically, the coefficient on the interaction term (*National BIS Outage* x *High Retail Ownership*) is negative for our market activity measures (volumes, turnover, etc.) and positive for our proxies of trading costs and illiquidity. This finding is not unreasonable given evidence of institutional distraction (see discussion above) and that BlackBerry's customer base is heavily tilted towards corporate clients during our sample period, particularly those in the financial services industry (Brodkin [2011], Moore [2011], Rusli [2011]).

4.3.1 Controlling for DGTW Firm Characteristics

To ensure that our results are not driven by characteristic-based differences in retail versus institutional holdings, we replicate our institutional ownership tests using balanced portfolios matched on firm characteristics. For each year in our sample, we sort stocks into portfolios using the Daniel et al. ([1997]; hereafter, DGTW) characteristic benchmarks based on size, book-to-market, and momentum.[19] We then eliminate unbalanced portfolios in which the proportion of stocks with high retail ownership is

[19] The DGTW benchmarks are available at http://www.smith.umd.edu/faculty/rwermers/ftpsite/Dgtw/coverpage.htm.

less than 40% or greater than 60%. This leaves us with a set of portfolios in which a fairly even number of stocks have high levels of retail ownership (i.e., roughly 40-60% of the stocks in a given portfolio have high retail ownership). Since the stocks in each portfolio have similar characteristics, we consider these firms as equally attractive to retail or institutional investors, i.e., the characteristics of the firms in a given portfolio do not mechanically result in one predominant investor type or another.

Table 8 reports the results for our DGTW-matched sample. The evidence corroborates our previous inferences and suggests that stocks primarily held by institutions are most affected by mobile-induced distractions, even after adjusting for underlying differences in the stock characteristics of institutional holdings. A potential explanation for this result is that institutions are (rationally) exploiting lower trading costs during outages to execute needed trades. However, we can rule out this conjecture as we observe in model 6 of Table 8 that spreads do not systematically decrease with outages in this tighter, matched sample.

4.3.2 Other Robustness Tests

Similarly, institutional traders may take advantage of local BIS outages to trade in firms with high information asymmetries, with the thought being that these outages could reduce the participation of informed retail traders. We further assess this alternative hypothesis by examining a subset of stocks for which informed retail investors are likely to possess greater informational advantages compared to institutions. Following prior research (e.g., Shive [2012]), we focus on less researched stocks, namely, those with no analyst coverage. If our results reflect an institutional response to drops in adverse selection (i.e., fewer informed retail traders), then we would expect BIS outages to have a stronger effect on stocks with high retail ownership and zero analyst coverage. We re-run our regressions after adding a three-way interaction term, *Outage* x *High Retail Ownership* x *No Analyst Coverage*. The coefficients on this interaction (untabulated) are insignificant across all our variables of interest. We again conclude that our findings are unlikely attributable to a systematic exploitative response from institutional traders.

There is also some concern that our institutional results are driven by high frequency or algorithmic trading when individual market participants are inadvertently removed from the market. Recent research suggests that, while high frequency trading is responsible for about 70% of traded volume in major U.S.

equity markets, this form of trading is mostly limited to large stocks (Brogaard et al. [2014], Hendershott et al. [2011], Jones [2013]). Thus, we restrict our cross-sectional ownership tests to small-cap firms (market capitalization ≤ $500 million) to alleviate concerns of potential biases arising from algorithmic trading.[20] Table 9 presents ordered logistic regression results for small-cap firms, conditional on high retail ownership. We continue to find significantly negative coefficients on the interaction term, *Outage* x *High Retail Ownership*, for our trading activity variables. We also find that BIS outages correspond to lower spreads for small stocks with high institutional ownership, whereas spreads are largely unchanged for small stocks primarily held by retail investors (total interaction effect of -0.0038).

Lastly, in untabulated analyses, we confirm that our results hold for firms with zero institutional ownership. We find that these stocks still experience improvements in trading activity during BIS outages, but to a much smaller degree than stocks with some amount of institutional ownership. This result substantiates our inferences that mobile internet technology is a significant source of distraction, especially for institutional investors.

4.4 OLS Fixed Effect Models

The prior analyses rely on the CRSP daily stock file, which is aggregated at the daily level and and does not include granular NASDAQ data on trade frequencies or individual trade sizes. We now turn to detailed TAQ data to corroborate our inferences in a series of fixed effect OLS specifications. We run simple regressions predicting our outcome variables of interest in the [-30, +30] window around each BIS outage day, and we include fixed effects for firm, year-week, and day of the week.[21]

Table 10 reports these regressions, which largely confirm our prior analyses. Marginal effects are produced at the bottom of this table, and suggest that relative to other days in the [-30, +30] window, days with a nationwide BIS outage exhibit surges in stock market activity on the order of 2% to 5% in terms of dollar volume traded, share volume traded, number of trades, and the number of large trades (greater than

[20] These results persist when using more conservative size cutoffs, e.g., $250 million or $100 million.
[21] We also include firm-year-week fixed effects in untabulated specifications. These models generate results that are almost identical to those currently presented in Table 10.

or equal to \$10k). For example, the evidence from model 3 suggests that the number of trades in the average stock increase by about 140 trades on BIS outage days, up from a baseline mean of 5,529 trades (an increase of 2.53%). Likewise, the results from model 6 indicate that the increase in large trades (23 more trades) amounts to a 3.24% increase over the baseline mean level.

This larger percentage point increase in large trades provides meaningful evidence that institutional traders are distracted by mobile internet, as institutions are more likely to execute these transactions (Barber et al. [2009], Jones and Lipson [2005]). More evidence supportive of this conjecture emits from model 7, which estimates the percentage of trading volume attributable to retail investors (as in Boehmer et al. [2019]).[22] We observe in model 7 that retail trading makes up a smaller proportion of volume on national BIS outage days, and that this decrease amounts to about 0.4% relative to the baseline mean (though the coefficient of interest is not significant at conventional levels, with a two-tailed p-value = 0.26).

4.5 Event Study Analysis of Local BIS Outages

Table 11 presents event study results for our sample of local BIS outages. Similar to our sample of nationwide outages, we gather local outage information from Dataoutages.com. This web service reports local outages (as well as national outages) to subscribers via email and Twitter posts. Panel A lists the dates and locations of these local outages and reports the number of public firms (on NYSE or NASDAQ) headquartered in each affected city as of the outage date. In Panel B, we report the mean and median abnormal event volume over the two-day window [0, +1] when local BIS outages occur. The test statistic for the mean abnormal volume is the Patell z-statistic (Patell [1976]), while the test statistic for the median abnormal volume is the generalized sign z-statistic (Cowan [1992]). We report the p-values for these statistics as well as Monte Carlo p-values from randomized simulations of the mean and median abnormal volume. The simulations correct for cross-sectional dependence by randomly assigning the local outage events over the 2009 – 2010 period. We conduct 1,000 simulations and generate the Monte Carlo p-values

[22] We identify this value via the Boehmer et al. [2019] algorithm that exploits the fact that most retail trades are executed internally by financial institutions or outsourced to wholesalers. Trades executed by these parties are reported to FINRA in such a way that they are identifiable in TAQ thanks to the exchange code value.

that compare the actual event study results with the results of the simulated event studies (e.g., a Monte Carlo *p*-value of 0.05 indicates that the actual observed value was more extreme than 95% of the values observed in the simulations that randomly assigned outage dates in the cities in our local area analysis).

Panel B reports a mean (median) abnormal volume of roughly +36.7% (+18.7%), and both the conventional and Monte Carlo *p*-values indicate that this unexpected uptick in volume is statistically significant.[23] These results provide further support for the distraction hypothesis and suggest that local firms experience meaningful surges in trading activity when local outages occur. The Monte Carlo tests we find particularly convincing, as small sample tests like ours are always subject to concerns that a random noise on a particular day could influence reported results. The randomization test inferences from our Monte Carlo analysis suggests that such concerns are unwarranted in our setting, however, as few of the 1,000 *randomly* assigned sets of outages across the actual outage cities generate placebo abnormal volume more extreme than that observed on the actual outage dates. Importantly, recent econometrics work on randomization inference finds that such tests are quite powerful even in settings like ours where the number of treated observations is small (Hagemann [2019], MacKinnon and Webb [2020]).

Panel C reports the results of an abnormal returns event study for the two-day window around the outage dates.[24] We again report *p*-values for the Patell and generalized signed *z*-statistics as well as Monte Carlo *p*-values from our randomized simulation tests. Angelini [2008] finds a small price reaction to a purely temporary liquidity shock, and we expect to observe the same during local BIS outages. While a temporary BIS outage should not have lasting effects on local stock prices, a positive shock to liquidity (as documented in Panel B) should correspond to a contemporaneous positive price reaction, as investors assign higher values to newly (temporarily) liquid stocks (Amihud [2002]). In line with this prediction, we find (small) positive abnormal returns for local firms around city-wide BIS outages. These abnormal returns amount to +49 basis points ($1.1 million) for the median firm. In unreported tests at the firm level, we find

[23] The Monte Carlo *p*-values of 0.08 ([80+1]/[1000+1]) indicate that the simulated mean and median values are greater than our observed values (36.7% and 18.7%, respectively) in only 80 of the 1,000 randomized sets of local dates.
[24] Like the volume event studies, these return event studies estimate normal return using a pre-outage window of 10 weeks, the market model, and the value-weighted index.

that the abnormal returns during local BIS outages are weakly positively correlated with the local BIS outage abnormal volume, indicating that investors place more value on stocks that experience larger improvements in liquidity when mobile internet distractions are removed.

5. Conclusion

We find evidence suggesting that mobile internet negatively affects stock market activity, consistent with a distracting effect of mobile internet on the stock information-related activities of market participants. The costly distractions posed by mobile internet appear to outweigh its advantages of cheap trading, search, and communication costs. Specifically, on days when the BlackBerry Internet Service (BIS) experiences a nationwide outage in the United States, the stocks traded on major American markets (NYSE and NASDAQ) experience lower spreads, higher volumes, and more trades. Further, local outages of the BIS correspond to increased liquidity and market activity for firms headquartered in the affected cities. These effects are present in subsamples of large, medium, and small cap stocks, and are robust to the use of a variety of parametric and nonparametric methods. We also find that stocks with high levels of institutional ownership experience larger outage-induced improvements in market activity, suggesting that institutional investors are perhaps more distracted by mobile internet compared to retail investors. While this result goes against conventional wisdom, it is consistent with prior evidence of distraction among professional investors as well as the deep penetration of the BlackBerry brand among financial services professionals during our sample period.

Our results imply that better communications technology does not strictly enhance market activity. While Brown et al. [2015] find that mobile phone use *in general* supports more active markets, our result confirms that the specific effects of mobile internet are quite different and can create distractions that impede market activity. Broadly, we document that in some settings the costs imposed by communications technology may outweigh the benefits with regard to ease of market access and information flow.

Accordingly, our study advances the literature on investor distraction, in particular the notion that investor inattention can reduce stock market activity. Most of this research has focused on the distractions posed by external factors such as heavy news days (Hirshleifer et al. [2009]), holidays (Jacobs and Weber [2012]), and weekends (Dellavigna and Pollet [2009]). Our study, however, is the first to suggest that investors could be distracting themselves on a daily basis, and that a seemingly helpful technology is responsible. Moreover, our results indicate that professional investors are not immune to the distracting effects of mobile internet.

While we use the term *distraction* to describe individuals using mobile internet to attend to activities unrelated to stock markets, an alternative view is that mobile internet use presents a meaningful opportunity cost of financial market participation (e.g., Blankespoor et al. [2020], Drake et al. [2016]). With access to the internet, and entertaining options such as social media at their fingertips, individuals with internet-accessible smartphones have a higher opportunity cost of attending to stock-relevant information than those without. Other studies of the nonfinancial opportunity costs of market participation focus on trading on holidays when the market remains open and find that trading activity is considerably reduced (Frieder and Subrahmanyam [2004], Loughran and Schultz [2004]). Our findings contribute to this literature, in that mobile internet can now be thought of, in addition to holidays, as imposing a considerable nonfinancial opportunity cost on participating in financial markets.

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Table 1
List of Nationwide Outage Dates of the BlackBerry Internet System

This table lists the dates of U.S. nationwide outages of the BlackBerry Internet Service (BIS) from 2009 to 2011. We gather these dates from dataoutages.com, a web service popular among BlackBerry users that notifies subscribers of outages via email. The dates were then confirmed using various news sources.

BlackBerry Internet System Nationwide Outage Dates (2009-2011)	
1	Monday, April 13, 2009
2	Thursday, July 23, 2009
3	Wednesday, September 09, 2009
4	Tuesday, September 22, 2009
5	Thursday, December 17, 2009
6	Tuesday, December 22, 2009
7	Monday, March 08, 2010
8	Tuesday, March 09, 2010
9	Tuesday, October 11, 2011
10	Wednesday, October 12, 2011
11	Thursday, October 13, 2011

Table 2
Summary Statistics

This table reports summary statistics for several measures of market activity during operable days (Panel A) of the BlackBerry Internet System (BIS) as well as days that the BIS experiences an outage (Panel B) (within the same week). For ease of interpretation, we multiply *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Panel A: BIS Operable Days

Variable	n	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Amihud Illiquidity	109,836	1.01	119.50	0.00	0.00	0.01
Dollar Volume	111,843	34,889,530.07	173,776,725.51	118,249.36	1,621,584.64	14,490,703.33
Ln (*Dollar Volume*)	111,843	13.84	3.69	11.68	14.30	16.49
Spread (%)	111,842	1.01	0.06	1.00	1.00	1.01
Ln (*Spread,* %)	111,842	0.01	0.04	0.00	0.00	0.01
Trades	66,166	3,300.16	11,224.37	57.00	403.00	1,823.00
Ln (*Trades*)	66,166	5.77	2.47	4.06	6.00	7.51
Turnover	111,843	0.01	0.02	0.00	0.00	0.01
Volume	111,843	1,681,998.17	15,492,847.80	25,373.00	165,264.00	787,400.00
Ln (*Volume*)	111,843	11.62	2.98	10.14	12.02	13.58

Panel B: BIS Outage Days

Variable	n	Mean	Std. Dev.	1st Quartile	Median	3rd Quartile
Amihud Illiquidity	59,736	0.58	20.02	0.00	0.00	0.01
Dollar Volume	60,909	37,389,245.94	184,982,232.98	136,204.32	1,866,240.09	16,049,319.05
Ln (*Dollar Volume*)	60,909	13.94	3.74	11.82	14.44	16.59
Spread (%)	60,909	1.01	0.04	1.00	1.00	1.01
Ln (*Spread,* %)	60,909	0.01	0.03	0.00	0.00	0.01
Trades	35,790	3,558.74	11,775.27	58.00	450.50	2,018.00
Ln (*Trades*)	35,790	5.83	2.52	4.08	6.11	7.61
Turnover	60,912	0.01	0.02	0.00	0.00	0.01
Volume	60,912	1,601,439.27	11,645,066.45	25,967.00	170,731.00	828,250.00
Ln (*Volume*)	60,912	11.63	3.01	10.16	12.05	13.63

Table 3
The Market Impact of Mobile Internet Outages

This table documents the market impact of nationwide outages of the BlackBerry Internet System (BIS). We report parametric *t*-tests and non-parametric sign tests of changes in market activity during BIS outages. The reported difference-in-means values represent the mean value of the respective market variable on outage days minus the comparable mean value on BIS operable days within the same week. We report the *t*-statistics and *z*-statistics from our *t*-tests and sign tests, along with associated *p*-values. For ease of interpretation, we multiply *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Variable (Outage - Operational)	Firm Weeks	Difference-in-means	*t*-statistic	*p*-value (*t*-test)	Sign Test *z*-statistic	Sign Test *p*-value
Amihud Illiquidity	26,028	-0.68	-1.24	0.22	-919.50	0.00
Dollar Volume	26,459	1,646,654.92	4.39	0.00	1,052.00	0.00
Ln (*Dollar Volume*)	26,459	0.07	9.75	0.00	1,264.00	0.00
Spread (%)	26,460	0.00	-1.09	0.28	-158.50	0.05
Ln (*Spread,* %)	26,460	0.00	-1.13	0.26	-156.50	0.05
Trades	15,673	198.25	5.39	0.00	823.00	0.00
Ln (*Trades*)	15,673	0.08	15.23	0.00	964.50	0.00
Turnover	26,459	0.00	5.85	0.00	1,028.50	0.00
Volume	26,459	72,192.19	2.68	0.01	1,030.00	0.00
Ln (*Volume*)	26,459	0.07	10.87	0.00	1,269.00	0.00

Table 4
The Market Impact of Mobile Internet Outages: Controlling for the Friday Distraction Effect

We report the market impact of nationwide outages of the BlackBerry Internet System (BIS), while excluding daily observations that fall on Fridays. The reported difference-in-means values represent the mean value of the respective market variable on BIS outage days minus the comparable mean value on BIS operable days within the same week, excluding Fridays. We report the *t*-statistics and *z*-statistics from our *t*-tests and sign tests, along with associated *p*-values. For ease of interpretation, we multiply *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Variable (Outage - Operational)	Firm Weeks	Difference-in-means	*t*-statistic	*p*-value (*t*-test)	Sign Test *z*-statistic	Sign Test *p*-value
Amihud Illiquidity	25,960	-0.20	-0.99	0.32	-1,421.50	0.00
Dollar Volume	26,456	2,052,202.98	5.24	0.00	1,020.50	0.00
Ln (*Dollar Volume*)	26,456	0.08	10.58	0.00	1,163.50	0.00
Spread (%)	26,457	0.00	-1.40	0.16	-735.00	0.00
Ln (*Spread,* %)	26,457	0.00	-1.66	0.10	-731.00	0.00
Trades	15,670	178.10	4.52	0.00	492.00	0.00
Ln (*Trades*)	15,670	0.07	12.85	0.00	582.00	0.00
Turnover	26,456	0.00	6.66	0.00	903.00	0.00
Volume	26,456	72,756.83	2.56	0.01	900.00	0.00
Ln (*Volume*)	26,456	0.08	11.24	0.00	1,037.50	0.00

Table 5
Firm Size and the Market Impact of Mobile Internet Outages

This table reports the market impact of nationwide outages of the BlackBerry Internet System (BIS) by firm size. Panels A and B present separate results for large- (market capitalization > $5 billion) and mid-cap firms (market capitalization between $500 million and $5 billion), respectively. Panel C present results for small-cap firms (market capitalization < $500 million). The reported difference-in-means values represent the mean value of the respective market variable on BIS outage days minus the comparable mean value on BIS operable days within the same week. We report the t-statistics and z-statistics from our t-tests and sign tests, along with the associated p-values. For ease of interpretation, we multiply *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Panel A: Differenced market activity indicators for large-cap firms (market capitalization > $5 billion)

Variable (Outage - Operational)	Firm Weeks	Difference-in-means	t-statistic	p-value (t-test)	Sign Test z-statistic	Sign Test p-value
Amihud Illiquidity	16,020	-1.11	-1.24	0.22	-578.50	0.00
Dollar Volume	16,451	148,453.95	2.36	0.02	417.00	0.00
Ln (*Dollar Volume*)	16,451	0.07	5.94	0.00	602.00	0.00
Spread (%)	16,451	0.00	-1.08	0.28	-285.50	0.00
Ln (*Spread,* %)	16,451	0.00	-1.10	0.27	-283.50	0.00
Trades	12,187	67.23	2.64	0.01	560.00	0.00
Ln (*Trades*)	12,187	0.07	11.66	0.00	680.50	0.00
Turnover	16,451	0.00	3.83	0.00	423.00	0.00
Volume	16,451	38,847.58	3.44	0.00	425.50	0.00
Ln (*Volume*)	16,451	0.07	6.64	0.00	621.50	0.00

Panel B: Differenced market activity indicators for mid-cap firms (market capitalization between $500 million and $5 billion)

Variable (Outage - Operational)	Firm Weeks	Difference-in-means	t-statistic	p-value (t-test)	Sign Test z-statistic	Sign Test p-value
Amihud Illiquidity	8,601	0.00	0.95	0.34	-310.50	0.00
Dollar Volume	8,601	2,922,097.71	4.89	0.00	574.50	0.00
Ln (*Dollar Volume*)	8,601	0.08	16.71	0.00	600.50	0.00
Spread (%)	8,601	0.00	-0.14	0.89	72.00	0.12
Ln (*Spread,* %)	8,601	0.00	-0.33	0.74	72.00	0.12
Trades	3,233	509.89	5.17	0.00	246.50	0.00
Ln (*Trades*)	3,233	0.09	14.98	0.00	268.50	0.00
Turnover	8,601	0.00	5.10	0.00	547.00	0.00
Volume	8,601	128,049.17	3.11	0.00	546.00	0.00
Ln (*Volume*)	8,601	0.08	17.14	0.00	587.00	0.00

Table 5 continued

Panel C: Differenced market activity indicators for small-cap firms (market capitalization < $500 million)

Variable (Outage - Operational)	Firm Weeks	Difference-in-means	*t*-statistic	*p*-value (*t*-test)	Sign Test *z*-statistic	Sign Test *p*-value
Amihud Illiquidity	1,407	0.00	-4.05	0.00	-30.50	0.11
Dollar Volume	1,407	11,367,209.75	1.90	0.06	60.50	0.00
Ln (*Dollar Volume*)	1,407	0.06	7.17	0.00	61.50	0.00
Spread (%)	1,408	0.00	-1.30	0.19	55.00	0.00
Ln (*Spread,* %)	1,408	0.00	-1.30	0.19	55.00	0.00
Trades	253	2,527.19	1.75	0.08	16.50	0.04
Ln (*Trades*)	253	0.07	3.82	0.00	15.50	0.06
Turnover	1,407	0.00	2.08	0.04	58.50	0.00
Volume	1,407	120,611.73	0.29	0.77	58.50	0.00
Ln (*Volume*)	1,407	0.06	7.14	0.00	60.50	0.00

Table 6
Ordered Logistic Regression Results

This table presents the results of the ordered logistic regressions. The dependent variables (closing spread, trades, dollar volume, volume, turnover, and Amihud illiquidity) are ordered from highest to lowest by firm-day in the BIS outage week and the weeks before and after. The independent variables consist of the BIS outage indicator, the lagged (prior trading day) value of the respective dependent variable, daily stock returns (signed and absolute, lagged and contemporaneous), and day-of-the-week fixed effects. We provide *z*-statistics for the estimated coefficients in brackets. We suppress the intercepts and day-of-the-week fixed effects for brevity. ***, **, and * represent statistical significance at the 0.01, 0.05, and 0.10 levels, respectively. Standard errors are clustered at the firm level. For ease of interpretation, we multiple *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Dependent Variable	*Dollar Volume*	*Volume*	*Trades*	*Turnover*	*Amihud Illiquidity*	*Spread*
Model	1	2	3	4	5	6
National BIS Outage	0.23***	0.23***	0.22***	0.23***	0.07	-0.03***
	[24.49]	[24.65]	[18.74]	[24.72]	[0.67]	[-3.07]
Lag (*Dependent Variable*)	0.00***	0.00	0.00***	1.95***	-0.00***	0.00
	[3.82]	[1.53]	[8.58]	[6.91]	[-3.86]	[1.54]
Return	1.94***	0.57***	1.09***	0.59***	-2.30***	0.03
	[21.30]	[6.35]	[9.30]	[6.53]	[-18.38]	[0.34]
Abs (*Return*)	14.32***	14.59***	13.47***	14.57***	40.60***	2.58***
	[83.83]	[84.72]	[63.80]	[84.71]	[92.44]	[17.61]
Lag (*Return*)	1.09***	0.36***	0.80***	0.33***	0.21**	-0.11
	[12.30]	[4.02]	[7.35]	[3.70]	[2.13]	[-1.22]
Lag (*Abs* (*Return*))	-2.86***	-2.82***	-2.37***	-3.08***	-21.31***	0.11
	[-23.27]	[-22.76]	[-15.23]	[-23.94]	[-96.90]	[0.83]
Weekday Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	330,397	330,397	195,655	330,397	320,127	330,395
Pseudo R-squared	0.02	0.02	0.02	0.02	0.09	0.00

Table 7
The Interaction Effect of Retail Ownership

We present ordered logistic regressions of the market impact of BIS outages, conditional on high retail ownership. The dependent variables (closing spread, trades, dollar volume, volume, turnover, and Amihud illiquidity) are ordered from highest to lowest by firm-day in the BIS outage week and the weeks before and after. The independent variables consist of the BIS outage indicator, an indicator for high retail ownership (retail ownership ≥ 50%), an interaction of the BIS outage and high retail ownership indicators, the lagged (prior trading day) value of the respective dependent variable, daily stock returns (signed and absolute, lagged and contemporaneous), and day-of-the-week fixed effects. We provide *z*-statistics for the estimated coefficients in brackets. We suppress the intercepts and day-of-the-week fixed effects for brevity. ***, **, and * represent statistical significance at the 0.01, 0.05, and 0.10 levels, respectively. Standard errors are clustered at the firm level. For ease of interpretation, we multiply *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Dependent Variable	*Dollar Volume*	*Volume*	*Trades*	*Turnover*	*Amihud Illiquidity*	*Spread*
Model	1	2	3	4	5	6
National BIS Outage	0.28***	0.28***	0.27***	0.28***	-0.02*	-0.05***
	[23.53]	[23.83]	[17.11]	[23.91]	[-1.67]	[-3.87]
High Retail Ownership	-0.14***	-0.16***	-0.17***	-0.15***	-0.28***	0.22***
	[-23.69]	[-26.39]	[-22.62]	[-24.76]	[-35.24]	[17.19]
National BIS Outage X *High Retail Ownership*	-0.11***	-0.11***	-0.10***	-0.11***	0.07***	0.04**
	[-5.89]	[-5.95]	[-4.14]	[-6.01]	[3.64]	[2.10]
Lag (*Dependent Variable*)	0.00***	0.00*	0.00***	1.23***	-0.00***	0.00
	[3.82]	[1.78]	[8.18]	[5.92]	[-3.83]	[1.63]
Return	1.81***	0.42***	0.96***	0.44***	-2.55***	0.20**
	[19.65]	[4.65]	[8.10]	[4.88]	[-20.39]	[2.23]
Abs (*Return*)	14.71***	15.05***	13.88***	15.02***	41.38***	2.04***
	[86.81]	[87.95]	[65.99]	[87.83]	[95.69]	[14.18]
Lag (*Return*)	0.98***	0.23**	0.68***	0.22**	0.02	0.05
	[11.04]	[2.56]	[6.28]	[2.43]	[0.23]	[0.56]
Lag (*Abs* (*Return*))	-2.48***	-2.39***	-1.94***	-2.57***	-20.72***	-0.44***
	[-20.20]	[-19.32]	[-12.52]	[-20.13]	[-92.13]	[-3.33]
Weekday Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	330,397	330,397	195,655	330,397	320,127	330,395
Pseudo R-squared	0.02	0.02	0.02	0.02	0.09	0.00

Table 8
The Interaction Effect of Retail Ownership for DGTW-Matched Sample

This table presents ordered logistic regressions for a subsample of firms matched on size, book-to-market, and momentum using the Daniel, et al. 1997 (DGTW) portfolio benchmarks. The dependent variables (closing spread, trades, dollar volume, volume, turnover, and Amihud illiquidity) are ordered from highest to lowest by firm-day in the BIS outage week and the weeks before and after. The independent variables consist of the BIS outage indicator, an indicator for high levels of retail ownership (retail ownership ≥ 50%), an interaction of the outage and high retail ownership indicators, the lagged (prior trading day) value of the respective dependent variable, daily stock returns (signed and absolute, lagged and contemporaneous), and day of the week indicators. We present z-statistics for the estimated coefficients in brackets. The intercepts and day-of-the-week fixed effects are suppressed for brevity. ***, **, and * represent statistical significance at the 0.01, 0.05, and 0.10 levels, respectively. Standard errors are clustered at the firm level. For ease of interpretation, we multiply *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Dependent Variable	*Dollar Volume*	*Volume*	*Trades*	*Turnover*	*Amihud Illiquidity*	*Spread*
Model	1	2	3	4	5	6
National BIS Outage	0.25***	0.25***	0.31***	0.26***	-0.04	-0.03
	[6.16]	[6.40]	[6.62]	[6.54]	[-1.01]	[-0.72]
High Retail Ownership	-0.07***	-0.09***	-0.11***	-0.08***	-0.15***	0.16***
	[-4.530]	[-5.559]	[-6.487]	[-5.428]	[-7.753]	[5.43]
National BIS Outage X *High Retail Ownership*	-0.11**	-0.11**	-0.20***	-0.11**	0.13**	0.01
	[-2.02]	[-2.00]	[-3.16]	[-2.10]	[2.28]	[0.10]
Lag (*Dependent Variable*)	0.00	0.00	-0.00	0.46	-0.01**	0.16***
	[1.51]	[0.31]	[-0.42]	[1.25]	[-2.47]	[4.22]
Return	1.82***	0.46*	1.60***	0.48*	-2.47***	0.60**
	[6.52]	[1.68]	[4.62]	[1.76]	[-6.89]	[2.06]
Abs (*Return*)	15.87***	16.30***	14.48***	16.27***	41.44***	2.23***
	[33.24]	[33.72]	[24.96]	[33.47]	[43.61]	[5.05]
Lag (*Return*)	-0.37	-1.09***	-0.38	-1.09***	1.00***	-0.05
	[-1.25]	[-3.69]	[-1.16]	[-3.70]	[3.48]	[-0.19]
Lag (*Abs* (*Return*))	-2.64***	-2.44***	-1.69***	-2.48***	-18.62***	-1.55***
	[-7.00]	[-6.38]	[-3.68]	[-6.36]	[-37.77]	[-3.85]
Weekday Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	33,759	33,759	24,302	33,759	32,260	33,759
Pseudo R-squared	0.02	0.02	0.02	0.02	0.09	0.00

Table 9
The Interaction Effect of Retail Ownership for Small-Cap Firms

We present ordered logistic regressions of the cross-sectional effect of retail ownership for small cap firms (market capitalization ≤ \$500 million). The dependent variables (closing spread, trades, dollar volume, volume, turnover, and Amihud illiquidity) are ordered from highest to lowest by firm-day in the BIS outage week and the weeks before and after. The independent variables consist of the BIS outage indicator, an indicator for high levels of retail ownership (retail ownership ≥ 50%), an interaction of the outage and high retail ownership indicators, the lagged (prior trading day) value of the respective dependent variable, daily stock returns (signed and absolute, lagged and contemporaneous), and day of the week indicators. We present *z*-statistics for the estimated coefficients in brackets. The intercepts and day-of-the-week fixed effects are suppressed for brevity. ***, **, and * represent statistical significance at the 0.01, 0.05, and 0.10 levels, respectively. Standard errors are clustered at the firm level. For ease of interpretation, we multiply *Turnover* by 10^3 and the *Amihud Illiquidity* measure by 10^5.

Dependent Variable	*Dollar Volume*	*Volume*	*Trades*	*Turnover*	*Amihud Illiquidity*	*Spread*
Model	1	2	3	4	5	6
National BIS Outage	0.24***	0.24***	0.30***	0.25***	0.00	-0.06**
	[12.31]	[12.49]	[13.57]	[12.57]	[0.13]	[-2.57]
High Retail Ownership	-0.08***	-0.10***	-0.13***	-0.10***	-0.18***	0.16***
	[-11.63]	[-15.06]	[-16.33]	[-14.71]	[-20.55]	[9.88]
National BIS Outage X *High Retail Ownership*	-0.10***	-0.10***	-0.13***	-0.10***	0.04	0.05*
	[-4.03]	[-4.10]	[-4.76]	[-4.16]	[1.36]	[1.96]
Lag (*Dependent Variable*)	0.00**	0.00*	0.00***	0.69***	-0.00***	0.10***
	[2.07]	[1.65]	[5.31]	[3.90]	[-3.78]	[6.28]
Return	1.52***	0.33***	0.80***	0.35***	-3.03***	0.25**
	[14.53]	[3.21]	[6.32]	[3.36]	[-23.75]	[2.35]
Abs (*Return*)	12.79***	13.13***	12.35***	13.11***	33.20***	2.17***
	[71.47]	[71.98]	[59.75]	[71.91]	[96.52]	[13.62]
Lag (*Return*)	1.25***	0.65***	0.84***	0.64***	-0.13	0.17*
	[12.63]	[6.56]	[7.32]	[6.51]	[-1.25]	[1.69]
Lag (*Abs* (*Return*))	-2.35***	-2.24***	-1.93***	-2.32***	-16.16***	-1.01***
	[-16.44]	[-15.99]	[-11.44]	[-16.31]	[-82.64]	[-6.87]
Weekday Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	192,251	192,251	145,087	192,251	182,008	192,247
Pseudo R-squared	0.02	0.02	0.02	0.02	0.08	0.00

Table 10
TAQ Analysis for the [-30, +30] Window around Nationwide BIS Outages

This table presents OLS regressions estimating market activity in the [-30, +30] window around each nationwide BIS outage for every firm listed on NYSE and NASDAQ that is present in the TAQ database. Each regression includes firm, day-of-the-week, and week-year fixed effects. Standard errors are clustered at the firm level. We also report the mean levels of the dependent variables to better facilitate an analysis of marginal effects. The estimated coefficients for the intercepts and the fixed effects are suppressed for brevity. ***, **, and * represent statistical significance at the 0.01, 0.05, and 0.10 levels, respectively.

Dependent Variable	*Ln(Dollar Volume)*	*Ln(Volume)*	*Trades*	*Trades ≥ $10k*	*Turnover*	*Spread*	*% Retail Volume*
Model	1	2	3	4	5	6	7
National BIS Outage Indicator	0.05***	0.05***	139.64***	22.71***	0.0002	-0.005	-0.0004
	[19.48]	[18.98]	[7.48]	[5.87]	[1.53]	[-1.36]	[-1.11]
Weekday Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Week-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,226,733	1,226,733	1,226,733	1,226,733	1,226,733	1,223,640	1,029,518
R-squared	0.92	0.89	0.77	0.83	0.45	0.61	0.40
Marginal Effects							
Mean of Dependent Variable	14.09	11.71	5,529 trades	700 trades	1.03%	$0.11	10.12%
% change	4.78%	4.62%	2.53%	3.24%	1.94%	-4.39%	-0.40%

Table 11
Event Study of Local Mobile Internet Outages

This table reports the abnormal volume and return results for our sample of local BIS outages. Panel A reports the date and city affected by each local outage as well as the number of NYSE/NASDAQ listed firms headquartered in each city as of the outage date. Panel B (Panel C) reports the mean and median abnormal volume (return) for local stocks over the two-day trading window [0, +1] beginning on the date of the local BIS outage. We use the market model to estimate a firm-specific volume (return) beta over a 10-week-long window ending 25 days before the outage event. We then compute abnormal volume (return) as the actual two-day cumulative outage volume (return) minus the predicted volume (return). The test statistic for the mean abnormal volume (return) is the Patell (1976) z-statistic, while the test statistic for the median abnormal volume (return) is the generalized sign z-statistic (Cowan 1992). In Panels B and C, we report the p-values for the respective test statistics as well as the Monte Carlo p-values from randomized simulation tests of the mean and median abnormal volume and returns. The simulation tests correct for cross-sectional dependence by randomly assigning the outage events across our sample firms. We conduct 1,000 simulated sets of randomized outage dates and generate the Monte Carlo p-value for the likelihood of observing simulated mean and median values as extreme as our observed values.

Panel A: List of Local BIS Outages

Local Outage City	Local Outage Date	# Firms HQ'd in Affected City at Outage Date
San Diego, CA	Monday, March 30, 2009	64
Detroit, MI	Wednesday, April 08, 2009	4
Quebec, QC	Tuesday, May 12, 2009	2
Washington, DC	Friday, June 05, 2009	16
Baltimore, MD	Friday, June 05, 2009	7
Wilmington, DE	Wednesday, October 07, 2009	10
Lexington, KY	Thursday, August 12, 2010	3

Panel B: Abnormal Volume Results

Window: (0, +1) Firm-Events: 106	Volume Effect	*p* -value	Monte Carlo *p* -value
Mean Outage Abnormal Volume	36.75%	0.01	0.08
Median Outage Abnormal Volume	18.66%	0.03	0.08

Panel C: Abnormal Return Results

Window: (0, +1) Firm-Events: 106	Return Effect	*p* -value	Monte Carlo *p* -value
Mean Outage Abnormal Return	0.72%	0.07	0.21
Median Outage Abnormal Return	0.49%	0.06	0.05

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