Do market-wide circuit breakers calm markets or panic them? Evidence from the COVID-19 pandemic

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August 13, 2020

Abstract

Market-wide circuit breakers (MWCBs), which halt trading for 15 minutes across all U.S. stock markets, have been triggered four times in March 2020 amid the COVID-19 pandemic. This paper provides some of the first evidence on the efficacy of MWCBs with tick-by-tick stock trading data. Using a difference-in-differences approach, we find that although MWCBs boost stocks' trading volume, they significantly increase stocks' realized volatility and bid-ask spread. Moreover, the market opening and reopening mechanisms of different stock exchanges complicate the operation of MWCBs. Our results suggest that MWCBs can have the unintended consequences of panicking the markets for a prolonged period of time, especially by aggravating market volatility and liquidity conditions.

Keywords: Circuit breakers; Volatility; Liquidity; COVID-19.

JEL: G01, G10, G14.

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1 Introduction

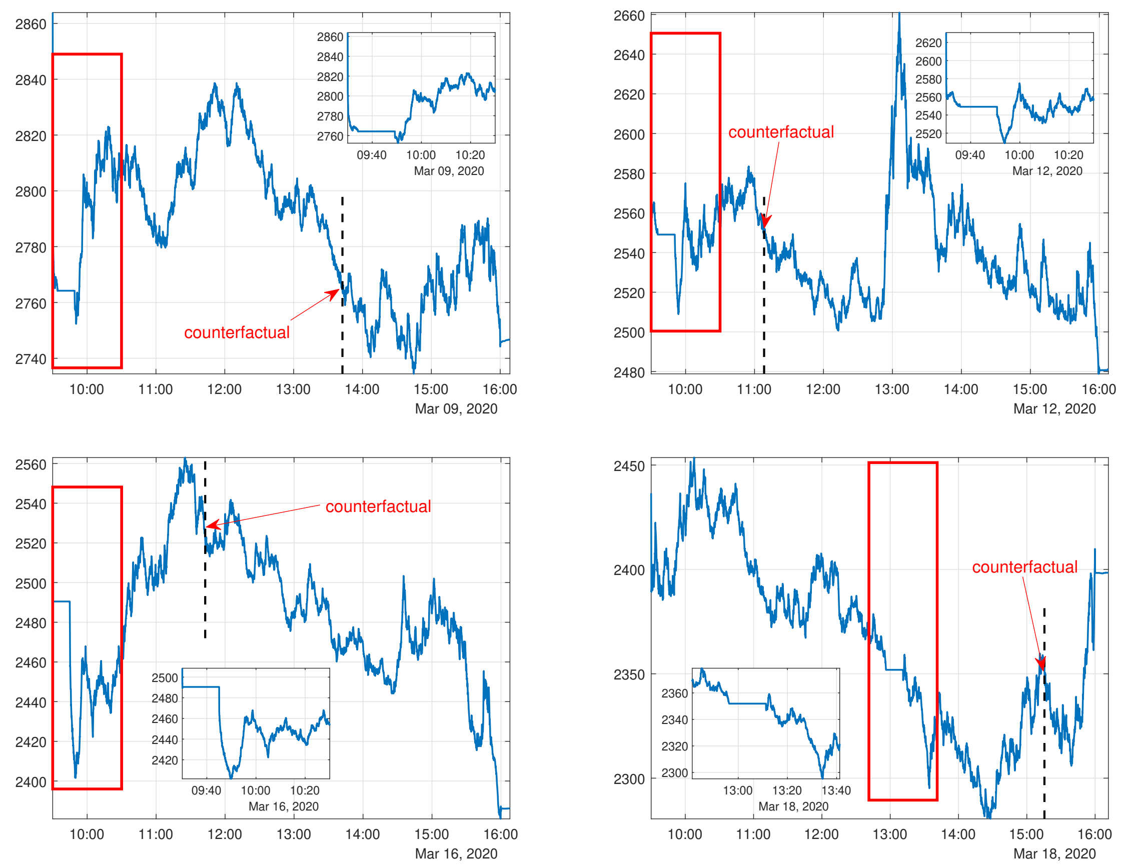
The novel coronavirus disease (COVID-19) has prompted unprecedented swings in stock markets worldwide. In the U.S., market volatilities in March 2020 rivaled or surpassed those last seen in October 1987 and December 2008 (Baker et al., 2020). Many security exchanges around the globe have stabilizing mechanisms in place to temporarily halt trading under extreme market conditions. One of the most prominent mechanisms is the market-wide circuit breakers (MWCBs) in the U.S., which were introduced following the Black Monday of 1987. MWCBs were advocated by the Brady Commission, who argued that these mechanisms "cushion the impact of market movements, which would otherwise damage market infrastructures" (Presidential Task Force on Market Mechanisms, 1988, pp. 66).

Despite the well-stated goals and wide adoption of MWCBs in many countries, it is not immediately apparent from a theoretical perspective that circuit breakers can achieve their mission. Early studies find that circuit breakers interrupt the natural movement of prices, prevent mutually beneficial trades (Grossman, 1990), and delay price discovery (Fama, 1989). Furthermore, circuit breakers may have the perverse effect of increasing volatility by forcing agents to advance their trades (Subrahmanyam, 1995) and causing volatility contagion (Liu and Zeng, 2020). Even worse, the very presence of circuit breakers makes it more likely for stock prices to reach the threshold levels, a so-called "magnet effect" (Subrahmanyam, 1994; Chen et al., 2018). In contrast, Kyle (1988) argues that trading halts help reduce volatility, resolve order imbalance by allowing market participants to process information and revise positions. Also, in the presence of limited participation and information asymmetry, circuit breakers can help restore market order by reducing transactional risk (Greenwald and Stein, 1991).

As with the theoretical literature, the empirical research regarding the merits of MWCBs is inconclusive, primarily because they have been triggered only once prior to March 2020. In this paper, we make a first attempt to evaluate the efficacy of MWCBs amid the COVID-19 pandemic. MWCBs, which halt trading across all markets, can be triggered at three thresholds that measure a decrease against the previous day's closing price of the S&P 500 index – 7% (level 1), 13% (level 2), and 20% (level 3). The precipitous drops of S&P 500 index triggered level 1 MWCBs (a 15-minute trading halt) during the opening hour on March 9, 12, and 16, and later in the day on March 18 (Figure 1).

We use tick history data of all S&P 500 constituent stocks from the Thomson Reuters DataScope. We construct minute-by-minute return, realized volatility, jump volatility, bid-ask spread, trading volume, and order imbalances for individual stocks surrounding each of the

Figure 1: S&P 500 index on days of trading halt



MWCBs. The challenge is to measure what would have happened in the absence of MWCBs. We exploit the fact that the same level of MWCBs can only be triggered once per trading day when the S&P 500 index drops below a certain threshold for the very first time. Therefore, we use four occasions where the S&P 500 index fell below the 7% threshold for the second time on the same day when the MWCBs were triggered as counterfactuals (Figure 1). We are essentially performing a difference-in-differences (DD) estimation by comparing the before-and-after MWCBs outcomes with the counterfactual outcomes. We track the dynamics from three minutes pre-halt to 30 minutes post-halt to allow for the time-varying responses to the MWCBs.

The effects of the MWCBs on market outcomes are large and dynamic — we find a significantly greater impact in the initial minutes than in subsequent minutes. The DD estimates reveal an immediate and intense increase in stocks' realized volatility. Within the very first minute post-halt, volatility soars to a level that is higher than counterfactuals by an annualized figure of 266%. Realized volatility stays elevated for over 10 minutes before subsiding to a level that is still ten percentage points greater than counterfactuals from the 15th minute post-halt. Similar results are found for the bid-ask spread. This evidence is consistent with Buiter and Sibert (2007)'s observation that market makers may lack the knowledge and the deep pockets to credibly post bid and ask prices in crisis. Despite the widened bid-ask spread, we find a significant increase in trading volume. Relative to counterfactuals, the trading volume is 119% higher in the first minute and remains roughly 40% higher for 10 minutes post-halt. Furthermore, bid volume outpaces ask volume by about 30% in the first five minutes post-halt. Although stocks which were hit hard before trading halts do experience heightened ask volume, they also enjoy higher bid volume, and there seems to be no evidence of panic sell-offs. When focusing on stock price movements in the pre-halt window, we find limited support for the "magnet effect" as neither prices nor returns exhibit accelerating declines as the drop in the S&P 500 index approaches the level 1 MWCBs' threshold. Taken together, the evidence indicates that while circuit breakers may help boosting trading volume, they panic the markets for a prolonged period of time.

We then turn our attention to a more fundamental question of whether the MWCBs operate smoothly. MWCBs were triggered shortly after the market opened on March 9 and 12, and were triggered literally at the opening bell on March 16. The market opening (and reopening) mechanisms differ substantially between the New York Stock Exchange's (NYSE) designated market makers (formerly known as "specialists") market and the National Association of Securities Dealers Automated Quotation's (NASDAQ) multi-dealer market. The transaction time analysis reveals substantial differences in price dissemination between the two stock exchanges. During the first three early morning trading sessions, only 42% of the NYSE-listed S&P 500 constituent stocks reported an opening trade before MWCBs were triggered, while the corresponding figure for NASDAQ was 93%. On average in our sample, it took NYSE stocks 150 seconds to report a trade after the market reopened, whereas all NASDAQ stocks resumed trading immediately after trading halt.[1] The speed and accuracy of price determination in financial markets are critical for price discovery. From this perspective, our findings highlight the important role of stock exchanges' opening mechanisms in the functioning of MWCBs.

Our paper contributes to the limited empirical literature on the effects of MWCBs. Goldstein and Kavajecz (2004) examine the behavior of market participants around October 27, 1997, the only time the circuit breaker has been triggered in the U.S. before 2020. They present evidence that traders attempt to advance transactions in anticipation of the trading halt. Based on evidence from the Tel-Aviv Stock Exchange during the 1987 market crash, Lauterbach and Ben-Zion (1993) conclude that trading halts help smooth the price adjustment and reduce order imbalances. Our results are also related to studies that investigate

[1] To illustrate this point, on March 9, Yum! Brands' (YUM.NYSE) first trade was its market open trade at 9:51:33 AM, more than two minutes after the end of the 15-minute trading halt imposed by the MWCBs.

whether other forms of firm-specific trading halts and price limits affect price volatility and market efficiencies (see, e.g., Lee et al., 1994; Corwin and Lipson, 2000; Christie et al., 2002; Brugler et al., 2018; Hautsch and Horvath, 2019). Apart from the obvious fact that we focus on the most recent occurrence of MWCBs amid COVID-19, our study employs a DD identification strategy to make inference about the effects of MWCBs. Contrary to the regulator's belief that MWCBs "provide coordinated means to address potentially destabilizing market volatility",[2] our results cast doubt on the validity of this claim.

As such, our paper is part of an ongoing effort attempting to understand how COVID-19 impacts financial markets. Alfaro et al. (2020) identify the relationship between unanticipated changes in predicted coronavirus infections and aggregate equity market returns. Ramelli and Wagner (2020) chronicle the stock market reaction to different stages of the COVID-19 outbreak. Contessi and De Pace (2020) investigate the transmission of COVID-19 shocks in a sample of 18 major stock markets. Baker et al. (2020) highlight the effects of policy responses in contributing to stock market volatility in the U.S. O'Hara and Zhou (2020) point out a new role of the Federal Reserve as the market maker of last resort in corporate bond markets. Our study examines the performance of a critical component of the financial market architecture originally designed to address challenges posed by extreme events such as COVID-19.

The remainder of the paper is organized as follows. Section 2 introduces the institutional background of MWCBs during the COVID-19 pandemic. Data and empirical methodology are outlined in Section 3. We present our findings in Section 4. Section 5 concludes.

2 Institutional Background

2.1 The Market-wide Circuit Breakers

Circuit breakers are market-wide trading halts designed to "to offer investors and the markets an opportunity to assess information and positions when the markets experienced a severe, rapid decline".[3] All U.S. futures and options exchanges also adopt concurrent trading halts to ensure cross-market coordination. The MWCBs were mandated by the U.S. Securities and Exchange Commission (SEC) in 1988 to prevent a market crash such as the Black Monday, October 19, 1987, when the Dow Jones Industrial Average (DJIA) plunged 22.6%. Since then, MWCBs have undergone a number of modifications. Table 1 summarizes these changes. Triggering thresholds of MWCBs were initially tied to changes in absolute points of DJIA. Trading would be halted for one hour and two hours when DJIA fell by 250 and 400 points,

[2] https://www.govinfo.gov/content/pkg/FR-1998-04-15/pdf/98-10027.pdf

[3] See the above footnote.

respectively. As the value of DJIA increased, the triggering thresholds of MWCBs were raised to 350 and 550 points since January 1997, with the length of trading halt reduced to 30 minutes and one hour, respectively.

Table 1: The evolution of MWCBs

Effective from	Thresholds	Index	Trading halt rule	Trigger time of the day
Black Monday, Oct 19, 1987				
Oct 1988	250 points	DJIA	Halt for 1 hour	
	400 points		Halt for 2 hours	
Jan 1997	350 points	DJIA	Halt for 30 minutes	
	550 points		Halt for 1 hour	
Mini-crash, Oct 27, 1997				
Apr 1998	10%	DJIA	Halt for 1 hour	9:30 AM – 2:00 PM
			Halt for 30 minutes	2:00 PM – 2:30 PM
			No halt	2:30 PM – 4:00 PM
	20%		Halt for 2 hours	9:30 AM – 1:00 PM
			Halt for 1 hour	1:00 PM – 2:00 PM
			Close market for the day	2:00 PM – 4:00 PM
	30%		Close market for the day	
Flash crash, May 6, 2010				
Feb 2013	7%	S&P500	Halt for 15 minutes	9:30 AM – 3:25 PM
			No halt	3:25 PM – 4:00 PM
	13%		Halt for 15 minutes	9:30 AM – 3:25 PM
			No halt	3:25 PM – 4:00 PM
	20%		Close market for the day	

Before March 2020, the only time that MWCBs were triggered occurred on October 27, 1997, known as the "mini-crash". At 2:36 PM that day, the DJIA fell by 350 points and triggered the circuit breakers, which halted trading for 30 minutes. Trading resumed at 3:06 PM, but the DJIA continued to drop, hitting the 550 points threshold at 3:30 PM, and eventually led to an early market closure. The Securities and Exchange Commission (SEC) investigated this event and concluded that the triggering was "needless at best", and the early market closure did not appear to be necessary (SEC, 1998). As a result, the triggering thresholds of MWCBs were changed to be based on relative to a benchmark, and the length of the trading halt would vary depending on the triggering time (Middle panel of Table 1).

The most recent changes to trading halt rules occurred in the aftermath of the "flash crash" on May 6, 2010, when a sudden 9% drop in DJIA within a few minutes was still not large enough to trigger the MWCBs. Since February 2013, a broader market measure of S&P 500 index replaced DJIA as the reference to measure market decline, and the triggering thresholds were again narrowed. In particular, the threshold levels were measured against the closing value of the previous day's price, rather than the average closing value for the month prior to a calendar quarter (Bottom panel of Table 1). Also, the rule of the triggering time periods was simplified to before and after 3:25 PM. In the current form, the MWCBs are triggered at three threshold levels: 7% (level 1), 13% (level 2), both of which will halt market-wide trading for a minimum of 15 minutes when the decline occurs for the first time between 9:30 AM and 3:25 PM; and 20% (level 3), which will halt market-wide trading for the remainder of the day. During trading halts, investors can cancel the resting orders, and stock exchanges continue to accept orders but do not match orders.

2.2 COVID-19 and the MWCBs

COVID-19 roiled the U.S. stock markets since late February 2020. On March 9, as Italy announced a nation-wide lockdown policy, the growing fear of a COVID-19 induced global recession coupled with plunging oil prices caused stock prices to decline, triggering the MWCBs at 9:34:13 AM. On March 11, the World Health Organization declared COVID-19 a global pandemic. Later on the same day, the U.S. president announced a travel ban on European countries. The MWCBs were triggered at 9:35:44 AM the following day. Many central banks in the world announced drastic monetary policy measures that week. For instance, the Federal Reserve announced an emergency rate cut of 100 basis-point on March 15, along with a massive quantitative easing program. These emergency policy actions were interpreted as extremely negative economic outlook by the market. Consequently, the MWCBs were triggered at 9:30:02 AM, two seconds after the market opened, on March 16. The fourth and last instance that triggered MWCBs occurred at 12:56:17 PM on March 18. In general, all four trading halts operated orderly, as we find little trading activities during the trading halts, and the market resumed trading precisely 15 minutes after the MWCBs were triggered.

3 Data and Methods

3.1 Data and Variables

We extract tick history data for all 505 constituent stocks of the S&P 500 index from DataScope Select maintained by Thomson Reuters.[4] The data set contains trade price, trade volume,

[4]There are 505 stocks because several companies have dual-class shares included in the S&P 500 index.

bid/ask prices, and volumes. We extract all trade records, and calculate minute-by-minute measures of (1) log-return; (2) average trade price; (3) total trade volume; (4) total bid volume; and (5) total ask volume. In addition, we calculate bid-ask spread as the average of (ask price − bid price)/ask price within each minute, expressed in percentage points. Following Chordia et al. (2002), we define order imbalance as the difference between log(bid volume) and log(ask volume); hence positive values of order imbalance represent higher bid volume than ask volume. We also calculate a high-frequency analog of the Amihud illiquidity measure (Amihud, 2002) using the absolute value of the 1-minute return divided by the total trade value for the same minute, then rescaled by 10^4. A higher value of Amihud illiquidity indicates lower liquidity of a given stock.

In addition, we calculate measures of local volatility within the 1-minute bins using 1-second synchronized trade price. To mitigate the impact of market microstructure noise, we use the average trade price within each second as the synchronized price for any stock. Denote the 1-second synchronized price for stock i as $p_{i,\tau}$, for $i = 1, \ldots, 505$, $\tau = 0, 1, 2, \ldots, 60$. The 1-second log-return is computed as $r_{i,\tau} = \log(p_{i,\tau}/p_{i,\tau-1})$, $\tau = 1, 2, \ldots, 60$. The realized variance for the t^{th} minute is calculated as

$$RV_{i,t} = \sum_{\tau=1}^{60} r_{i,\tau}^2.$$

As $RV_{i,t}$ includes variations from both the continuous Brownian movements of the price process as well as discrete jumps, we disentangle these two components using the bipower variation proposed by Barndorff-Nielsen and Shephard (2004):

$$BV_{i,t} = \frac{\pi}{2} \sum_{\tau=2}^{60} |r_{i,\tau}| \cdot |r_{i,\tau-1}|,$$

where $BV_{i,t}$ is a jump-robust measure of local volatility and only includes variations from the continuous Brownian component. The contribution of jumps to the overall realized variance, jump variation, is hence defined as the difference between these two

$$JV_{i,t} = \max\left(RV_{i,t} - BV_{i,t},\ 0\right),$$

and also truncates at 0, as $JV_{i,t}$ should be non-negative. We then take square root of these measures of volatility, and express them in percentage point form (*i.e.* realized volatility $\sqrt{RV_t} \times 100$ and jump volatility $\sqrt{JV_t} \times 100$).[5]

[5]In the Appendix, we present results for additional market outcomes, including market beta, another measure of order imbalance defined as the (bid volume - ask volume)/(bid volume + ask volume), trade size defined as

3.2 Identification Approach

Previous empirical attempts to assess the effectiveness of MWCBs have been hampered by the inherent difficulty in finding an appropriate counterfactual (Ackert et al., 2001). In this paper, we take advantage of the fact that level 1 MWCBs can only be triggered the first time when the market index drops below 7%, and identify four occasions when the S&P 500 index drops below 7% later on the same day as counterfactuals. The MWCBs were triggered four times, at 9:34:14 AM, March 9; 9:35:44 AM, March 12; 9:30:02 AM, March 16; and 12:56:17 PM, March 18. These are the four treatment events in our analysis. The four counterfactual time points are: 1:42:31 PM, March 9; 11:08:19 AM, March 12; 11:42:42 AM, March 16; and 3:15:28 PM, March 18, as depicted in Figure 1. There are a few advantages to this approach. Firstly, these counterfactuals allow us to directly observe what would have followed when the index drops below 7% in the absence of MWCBs. Secondly, the four days were triggered were among the worst days in stock market history. By choosing counterfactuals from the same day, the differences in firm characteristics and general market conditions between the treatments and counterfactuals are minimized. Nevertheless, we acknowledge that market participants can behave differently, knowing that level 1 MWCBs will not be triggered again on the same day. We experiment with an alternative counterfactual on March 18 when the S&P 500 index dropped by 6% in the morning but did not trigger MWCBs, and obtain similar conclusions. More details on this alternative will be presented in the next section.

We employ an "event-study" difference-in-differences (DD) specification and estimate the minute-by-minute treatment effects from 3 minutes pre-halt to 30 minutes post-halt.[6] By contrasting the market outcomes between treatments and counterfactuals, we estimate the treatment effects of the 15-minute trading halt imposed by MWCBs.

The baseline model is specified as

$$Y_{s,i,t} = \alpha + \sum_{t \neq -1} \gamma_t \, After_t + \sum_{t} \beta_t^{CB} \, Treat_s \times After_t + \varepsilon_{s,i,t}, \tag{1}$$

where $i = 1, \ldots, 505$, and $t = -3, -2, -1, 1, \ldots, 30$. In Equation (1), $Y_{s,i,t}$ denotes a given market outcome such as realized volatility, bid-ask spread, and the logarithm of trading volume, for stock i in the t^{th} minute around a circuit breaker event of s. $Treat_s$ is a dummy variable that equals one for periods surrounding when MWCBs were triggered, and zero for the counterfactuals. $After_t$ is a dummy variable corresponding to the t^{th} minute surround-

logarithm of average number of shares, and the logarithm of the number of trades.

[6]Our conclusions are qualitatively unchanged when we extend the post-halt window to 60 minutes. These results are available upon request.

ing the MWCBs for treatments, and surrounding when the S&P 500 index dropped below 7% for counterfactuals. Negative values of t correspond to minutes before the exact time for the treatment events and counterfactuals. The counterfactuals at $t = -1$ are omitted as benchmarks. We control for stock and day fixed effects, as well as time-of-the-day effect. The standard errors are clustered by stocks. The effects of MWCBs are captured by the coefficients estimates β_t^{CB}, $t = -3, -2, -1, \ldots, 30$.

4 Empirical Results

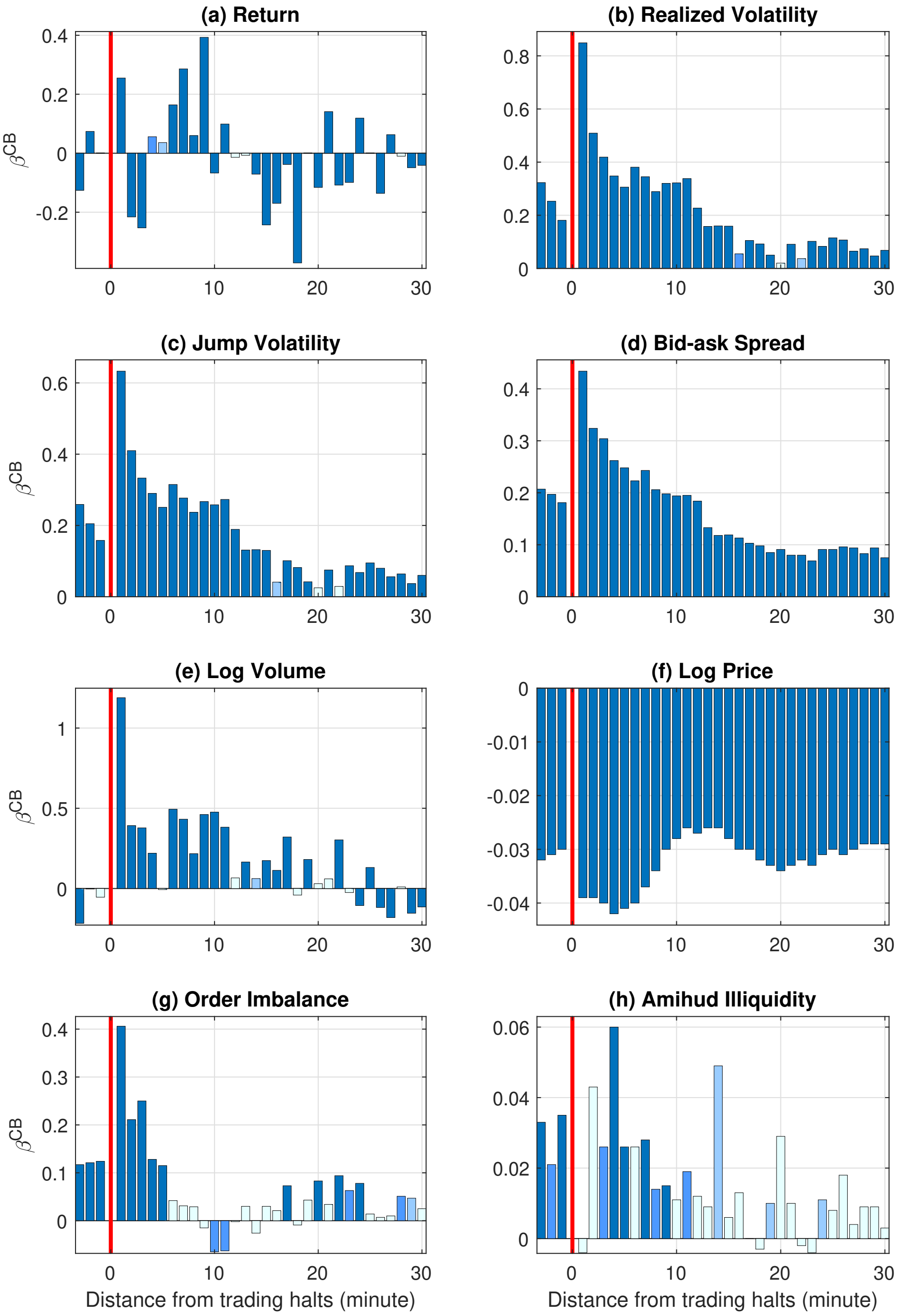
4.1 Effects of MWCBs

We plot the regression estimates β_t^{CB} in Figure 2. The trading halt is marked by the red vertical line at minute zero. The height of each bar corresponds to the magnitude of point estimate of β_t^{CB} for each minute, and the shadings from dark to light indicate the statistical significance of the estimates at 1%, 5%, and 10% level, with transparent bars indicating statistically insignificant estimates.

The validity of DD estimates relies on the assumption of parallel trends between treatments and counterfactuals. One way to test this assumption is to check the coefficients β_{-3}^{CB}, β_{-2}^{CB}, and β_{-1}^{CB}, which measure the difference between the treatment and counterfactual groups in the 3-minute period leading to the trading halt. During this period, although the treatment group exhibits significantly higher levels of volatility and bid-ask spread, the differences in levels are diminishing as we approach the trading halt. Despite a violation of parallel trends assumption, such bias works against us finding a reversal in trend, which manifests in the plots shown in Figure 2. For other outcomes such as returns and volumes, there are no clear pre-halt trends, and it suffices to say that MWCBs completely alter the trajectory of these outcomes post-halt.

We find an immediate and intense circuit breaker effect for almost all outcomes in the very first minute after trading resumes. Panel (a) of Figure 2 shows that relative to the counterfactuals, stock return increases by 0.26% in the first minute. But such an increase turns out to be transitory, as we find no consistent pattern in the 30-minute post-halt period. Panel (b) shows that the wedge in volatility between treatments and counterfactuals more than quadruples from the last minute pre-halt to first minute post-halt. In the very first minute after the market reopens, realized volatility is 0.85 percentage point greater than counterfactuals, which translates to an annualized volatility of 266%. Volatility stays elevated for about 10 minutes before starting to decline gradually; it hovers around a level which is still 0.1 percentage point higher than the counterfactuals from the 15^{th} minute post-halt. We find very similar results

Figure 2: Coefficient estimates β_t^{CB} using all 4 MWCBs.



Note: The horizontal axis represents each minute from 3 minutes pre-halt ($t = -3$) to 30 minutes post-halt ($t = 30$). The red vertical line at $t = 0$ denotes the time of the trading halt. The vertical axis shows the magnitude of the coefficient estimates β_t^{CB} for each minute t. The color of the bars indicates the statistical significance of the estimates. ▬ indicates statistically significant estimates at 1% level, ▬ at 5% level, ▬ at 10% level, ▭ insignificant estimates.

for jump volatility depicted in Panel (c), albeit in smaller magnitude. The finding that volatility levels are still heightened 30 minutes after market reopens suggests that circuit breakers do not calm down the markets, but rather escalate market volatility even further.

Bid-ask spread for treatments widens by over 0.4 percentage point more than counterfactuals in the first minute post-halt, before slowly easing to the pre-halt level in 12 minutes. From 13^{th} to 30^{th} minute post-halt, the bid-ask spread settles at around 0.1 percentage points greater than the counterfactuals. This evidence is consistent with the hypothesis that market makers are reluctant to post narrower spreads when facing liquidity crunch and uncertainty (O'Hara and Zhou, 2020). The fact that the bid-ask spread stays widened stretching over 30 minutes suggests that circuit breakers substantially raise investors' costs and reduce transaction efficiency.

The contrast for trading volume before and after trading halt is striking. The dependent variable $Y_{s,i,t}$ is the natural logarithm of trading volume in the t^{th} minute, hence the estimates β_t^{CB} represent percent changes. Three minutes before trading halts, average trading volume of the treatments is 22% lower than that of the counterfactuals. However, investors rush to trade immediately after the market reopens. Relative to counterfactuals, trading volume is 119% higher in the first minute and remains roughly 40% higher for about 10 minutes post-halt. The dramatic increase in trade volume immediately following the trading halt supports the discretionary liquidity trader arguments in Admati and Pfleiderer (1988). They show that trading volume is higher during certain periods when trading is concentrated because of the increased strategic liquidity-trading volume and the induced informed-trading volume as in Kyle (1985).

Our results reveal a positive volatility-volume relation in the first 20 minutes post-halt, which is consistent with the mixture-of-distribution hypothesis (MDH) in Clark (1973).[7] Using high-frequency intraday trading data, Bollerslev et al. (2018) present evidence that the positive volume-volatility relation can be best explained by the differences-of-opinion models (see, e.g. Harrison and Kreps, 1978; Harris and Raviv, 1993; Kandel and Pearson, 1995; Scheinkman and Xiong, 2003; Banerjee and Kremer, 2010, among others.). The differences in opinions among investors are acute during the COVID-19 pandemics. Based on a survey of market investors during February and March 2020, Giglio et al. (2020) find that disagreement among investors about economic and stock market outcomes increased substantially following the stock market crash. In this sense, MWCBs provide different types of investors an

[7]The MDH proposes that the distribution of price changes is subordinated to a normal distribution, whose speed of evolution is governed by a latent information arrival process. The intensity of information flow can be, in turn, measured by the distribution of trading volume. This hypothesis hence implies a positive and contemporaneous relationship between volatility and trading volume.

opportunity to rebalance portfolios and adjust their positions.

Panel (f) of Figure 2 shows that throughout the period before and after the trading halt, the price stays consistently lower for the treatments than the counterfactuals. Although the estimated price differential between the treatments and counterfactuals in the first minute post-halt (-4%) is lower than the last minute pre-halt (-3%), this does not provide any evidence of a price free-fall. Price continuity around MWCBs is examined using a Wilcoxon signed-rank test on stocks that have trades both before and after the trading halt. We take the last trade price pre-halt and the first trade price post-halt, and compare these adjacent prices set apart by the trading halts. Of all 1342 pairs of prices across all four trading halts, 1065 stocks exhibit a lower price post-halt, and only 239 stocks have a higher price. On average, the first trading price post-halt is 0.8% lower than the last trading price pre-halt, and this difference is statistically significant at 0.1% level. Therefore, MWCBs disrupt the price continuation process.

We present the results on order imbalance in Panel (g). Although both bid volume and ask volume experience substantial increases, bid volume outgains ask volume by more than 40%, resulting in a marked increase in order imbalance in the first minute post-halt. The spike in bid volume is temporary though, as the order imbalance for the treatments returns to a similar level as for the counterfactuals from the 5^{th} minute after the trading halt. The surge in trading volume in the first two minutes post-halt, shown in Panel (e), does not translate into higher stock liquidity in Panel (h). The results show that the treatment stocks exhibit comparable Amihud illiquidity figures as counterfactuals in the first minute post-halt. However, liquidity level worsens for the treatment stocks compared with the counterfactuals until 15 minutes after the trading halt. The trading halts exacerbate stock liquidity conditions, consistent with the results on bid-ask spreads discussed earlier.

In summary, despite the initial boost in trading volume, MWCBs panic the markets for a prolonged period of time, especially by aggravating market volatility and liquidity conditions.

4.2 Pre-halt Stock Returns and Post-halt Trading Volume

Our previous results indicate that stocks' bid volume and ask volume post-halt are greater than those of the counterfactuals, and bid volume outgrows ask volume after the market re-opens. One way that MWCBs can stabilize the market is to prevent or at least decelerate a sell-off for stocks that experience large intraday losses. To investigate this possibility, we regress the logarithm of trade volume in the first minute post-halt on the stock's pre-halt return from previous day's close price and present the results in Table 2.[8] We find a negative relationship between pre-halt return and post-halt volume, suggesting that the greater the fall in stock prices before the trading halt, the higher the trading volume, bid volume, and ask volume post-halt. The last column of order imbalance also exhibits a negative but insignificant relationship with the pre-halt return, indicating that bid volumes outgrow ask volumes, although the difference is statistically indistinguishable from zero. This evidence implies that MWCBs prompt investors to purchase more than sell off stocks that were hit hard, thereby stabilizing the markets by preventing a downward spiral.

Table 2: Regression of post-halt volume on pre-halt return

	(1) Trade volume	(2) Bid volume	(3) Ask volume	(4) Imbalance
Pre-halt return	−2.203***	−3.375**	−3.100**	−0.275
	(0.667)	(1.563)	(1.353)	(1.373)
Constant	9.534***	5.529***	5.313***	0.215*
	(0.060)	(0.140)	(0.122)	(0.123)
Stock FE	Yes	Yes	Yes	Yes
Observations	976	969	969	969
R^2	0.888	0.839	0.845	0.507

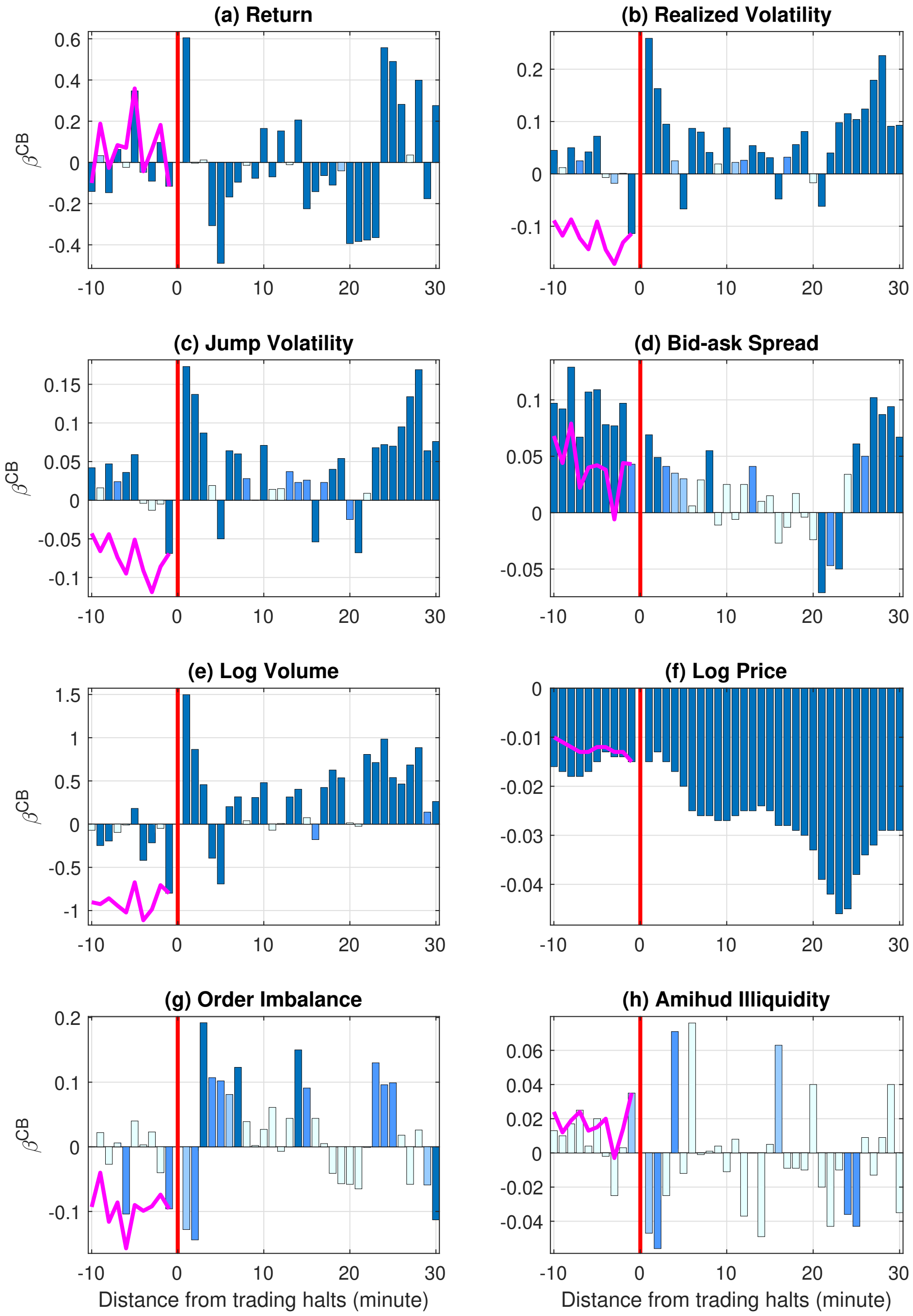
Note: The dependent variables include the total trade volume, bid volume, ask volume (all in logarithm), and imbalance (log(bid volume) − log(ask volume)) for the first minute post-halt. The pre-halt return is calculated by subtracting the logarithm of prior trading day's close price from the logarithm of the last price before trading halt. We control for stock fixed effects and report the standard errors clustered by stock in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.3 Magnet Effect

Magnet effect, arguably a major unintended consequence of MWCBs (see, e.g. Subrahmanyam, 1994; Chen et al., 2018), implies that the very presence of circuit breakers can accelerate the movements of prices toward the thresholds as stock prices get closer to the thresholds. Relatedly, Subrahmanyam (1995) suggests that circuit breakers can increase ex-ante price volatility by inducing investors to advance their trades earlier. However, our results in Figure 2 suggest that, relative to counterfactuals, stock price gradually increases while realized volatility decreases during the 3-minute period before the trading halt. Neither of these results is consistent the hypothesis of magnet effect. Considering that the first few minutes after the market opens may not be the ideal window to test the magnet effect, we conduct a separate analysis on March 18 alone.

[8] Results are very similar when we use post-halt trading volume in 3 minutes and 10 minutes.

Figure 3: Estimated DD coefficients β_t^{CB} using 11:14 AM on March 18 as counterfactual.



Note: The horizontal axis represents each minute from 10 minute pre-halt ($t = -10$) to 30 minute post-halt ($t = 30$). The red vertical line at $t = 0$ denotes the time of the trading halt. The vertical axis shows the magnitude of the estimated DD coefficients β_t^{CB} for each minute t. The color of the bars indicates the statistical significance of the estimates. ▇ represents statistically significant estimates at 1% level, ▇ at 5% level, ▇ at 10% level, ☐ insignificant estimates.

During the market decline on the morning of March 18, the S&P 500 index dropped within 20 points from the 7% threshold after 11 AM but rebounded before noon without triggering the circuit breakers. In particular, we use 11:14 AM, when the S&P 500 index dropped by 6%, as an alternative counterfactual time to conduct the analysis. The advantage of using this counterfactual time is that investors could feel the possibility of triggering MWCBs imminent, after watching the MWCBs being triggered three times in the previous 10 days. Figure 3 presents the estimates using the new counterfactual and treatment on March 18. As in Figure 2, we plot the point estimates in different minutes as bars but extend the pre-halt window to 10 minutes; further, we add a (pink) line connecting the point estimate for the treatment group in the pre-treatment period (the sum of the coefficients on $After_t$ and $Treat * After_t$ for $t = -10, \ldots, -1$). Throughout the 10-minute period leading to the trading halt, we find no evidence of a declining trend in stock returns. Although the stock prices of treatments are consistently lower than those of counterfactuals over the 10-minute period, there is no evidence of an accelerating downward movement as we approach the circuit breakers. Moreover, realized volatility, jump volatility, volume, and order imbalance display no clear trend leading up to the triggering of circuit breakers.[9] In fact, volatility and volume drop substantially in the very last minute before the trading halt. In sum, we do not find empirical support for the magnet effect hypothesis in our data.

The post-halt results in Figure 3 serve as a robustness check for our baseline results. Most of the earlier findings continue to hold, but some differences emerge. Most notably, realized volatility and bid-ask spread retreat considerably after the initial jump, but surge back to substantially higher levels 20 minutes post-halt. Stock prices enter a lengthy slump in the first 20 minutes after trading halt. Using the original counterfactual time at 3:15 PM on March 18 after MWCBs were triggered yields similar conclusions. The results are shown in Figures A.3 and A.4 in the Appendix. These results reinforce our conclusions that MWCBs panic the market for a prolonged period of time.

4.4 The Operation of MWCBs

The above results indicate that the responses are intense in the first few minutes post-halt. However, not all stocks resumed trading immediately after the trading reopened. In fact, many stocks did not even start trading before the MWCBs were triggered. This is particularly true for NYSE-listed stocks because the NYSE's centralized "manual" opening and reopening process can generate significant delays.

[9] The results remain very similar when we extend the pre-halt window to 30 minutes and when we use the original classification of counterfactuals. These results are available upon request.

On the NYSE, a call (i.e., batch) auction opens the market. During this opening mechanism, NYSE designated market makers (DMMs) determine an opening price by balancing the buy and sell orders. Similarly, those DMMs are responsible for facilitating the reopening auctions after trading halt and therefore have some discretion over when to reopen stock trading to maintain a fair and orderly reopening process.[10] For instance, if the imbalance is sufficiently large, the DMMs may delay the opening to collect more orders. In contrast, the NASDAQ is a decentralized system with bid and ask prices submitted by various dealers. On the NASDAQ market, multiple dealers who serve as market makers for a stock can post non-binding quotes before the market officially opens, at which time trading is conducted with dealers executing the orders they receive.

Of all 505 stocks in our sample, 135 are primarily listed on NASDAQ and 370 on NYSE.[11] We conduct a time analysis of stock trading by examining the extract time stamps of trades surrounding MWCBs. In Table 3, we summarize the time lapses between the last reported trade pre-halt and the triggering time for the MWCBs. The results reveal striking differences between NYSE stocks (Panel A) and NASDAQ stocks (Panel B). Out of all 370 NYSE stocks, only 202 stocks reported a trade before the MWCBs were triggered 254 seconds after normal trading began on March 9; the number grew to 248 on March 12 as the MWCBs were triggered 344 seconds after 9:30 AM. In comparison, for the first five trading days in March 2020, on average it takes these 370 NYSE-stocks 53 seconds after 9:30 AM to report the first trade, and the longest time is 269 seconds. In contrast, all 135 NASDAQ stocks reported a trade before the triggering of MWCBs. Even on March 16, when the MWCBs were triggered at 9:30:02 AM, 105 out 135 NASDAQ stocks reported a trade, whereas merely 12 NYSE stocks did so. Unfortunately, our results also show that some trading activities did occur during the 15-minute trading halt (even 7 seconds after the MWCBs were triggered), mostly on March 16 for NASDAQ stocks. Considering the triggering of MWCBs happened right after the opening bell, some communication glitches might have arisen.

For those stocks that completed a trade before the trading halt, the average time lapse between the last trade and the start time of the trading halt is significantly longer for NYSE stocks, which suggests that their trading is more sporadic in the opening minutes than NASDAQ stocks. When we turn to the time lapse between the end of the trading halt and the first trade post-halt in Panels C and D, we find that on average it takes NYSE stocks 150 seconds to post the first trade after trading resumes, while the corresponding time for NASDAQ stocks

[10] https://www.nyse.com/publicdocs/nyse/NYSE_MWCB_FAQ.pdf

[11] CBOE Global markets, the parent company of the Chicago Board Options Exchange, is listed on BATS Global Markets. In this study, we treat this company as NYSE-listed because we extract trading data from an unlisted trading privileges (UTP) through NYSE.

Table 3: Delays in market opening and reopening

Pre-halt time lapse between last trade and MWCBs (seconds)						
		Panel A: NYSE stocks				
Date	N	Mean	Std.Dev	Min	Median	Max
March 9	202	20.371	39.544	0	5	253
March 12	248	16.863	35.442	0	6	344
March 16	12	0.667	0.492	0	1	1
March 18	370	29.062	90.458	−1	14	1258
Total	832	22.906	66.495	−1	8	1258
		Panel B: NASDAQ stocks				
Date	N	Mean	Std.Dev	Min	Median	Max
March 9	135	8.244	19.269	0	2	151
March 12	135	4.807	6.907	0	2	35
March 16	105	−2.886	2.719	−7	−3	1
March 18	135	7.096	10.860	−1	2	63
Total	510	4.739	12.633	−7	1	151
Post-halt time lapse between MWCBs and first trade (seconds)						
		Panel C: NYSE stocks				
Date	N	Mean	Std.Dev	Min	Median	Max
March 9	370	190.438	219.533	0	117.5	1134
March 12	370	195.222	222.141	0	119	1146
March 16	370	159.616	196.081	0	94	1094
March 18	370	55.614	80.056	0	28	470
Total	1480	150.222	196.723	0	78	1146
		Panel D: NASDAQ stocks				
Date	N	Mean	Std.Dev	Min	Median	Max
March 9	135	0.778	6.471	0	0	62
March 12	135	0.356	4.045	0	0	47
March 16	105	0.170	0.377	0	0	1
March 18	135	0.111	0.315	0	0	1
Total	510	0.354	3.822	0	0	62

is less one second.

A stock exchange is operationally efficient if transactions can be completed quickly, accurately, and at a low cost. At the basic level, the delayed opening and reopening of NYSE stocks might have prevented two willing parties from realizing a mutually beneficial trade. Furthermore, the S&P 500 index has to rely on a constituent stock's previous trading day's close price until the stock opens trading. Therefore, the index can be rather stale during this turbulent period. If we assume that no explicit price discovery occurs before trading officially starts, the NYSE's market opening mechanisms complicate the operation and the effect of MWCBs.

4.5 Cross-sectional Heterogeneity

In this section, we present evidence on the cross-sectional heterogeneity in the effects of MWCBs. We first estimate the baseline regression in Equation (1) for stocks listed on the two exchanges separately, and plot the estimates in Figure 4. The coefficient estimates for NASDAQ stocks are in the top row of each panel, and those for NYSE stocks are in the bottom row. The color blocks represent the magnitudes of the coefficient estimates.[12] Most of the results are similar across exchanges but the differences in bid-ask spread stand out. In particular, we find that the bid-ask spread for NYSE stocks is considerably higher than NASDAQ stocks, and this difference persists for more than 15 minutes post-halt. Not surprisingly, NYSE stocks are less liquid according to the estimates using the Amihud illiquidity measures. We conjecture that these differences could be attributed to the role DMMs in NYSE play in posting the bid and ask prices. Despite the popular claim that DMMs' influences are diminishing in the electronic trading era, recent studies find that DMMs are still important. For instance, Bessembinder et al. (2015) argue that DMMs could prevent market failure and increase social welfare especially at times when uncertainties regarding fundamental value and asymmetric information are large. Clark-Joseph et al. (2017) show that DMMs play an economically significant influence in liquidity provision. To some extent, we support their core arguments as our results highlight the important role played by market makers in the extreme circumstances.

We proceed to investigate whether the effects vary across stocks of different sizes. Despite that all firms in the S&P 500 are among the largest in the U.S., there is significant variation in sizes. We sort firms according to their market capitalization at the end of 2019 into four groups: small (less than $10 billion), medium (between $10 billion and $50 billion), large

[12] For expositional purposes, we suppress the statistical significance results, which are available upon request.

Figure 4: Comparison of estimated coefficients across stock exchanges.

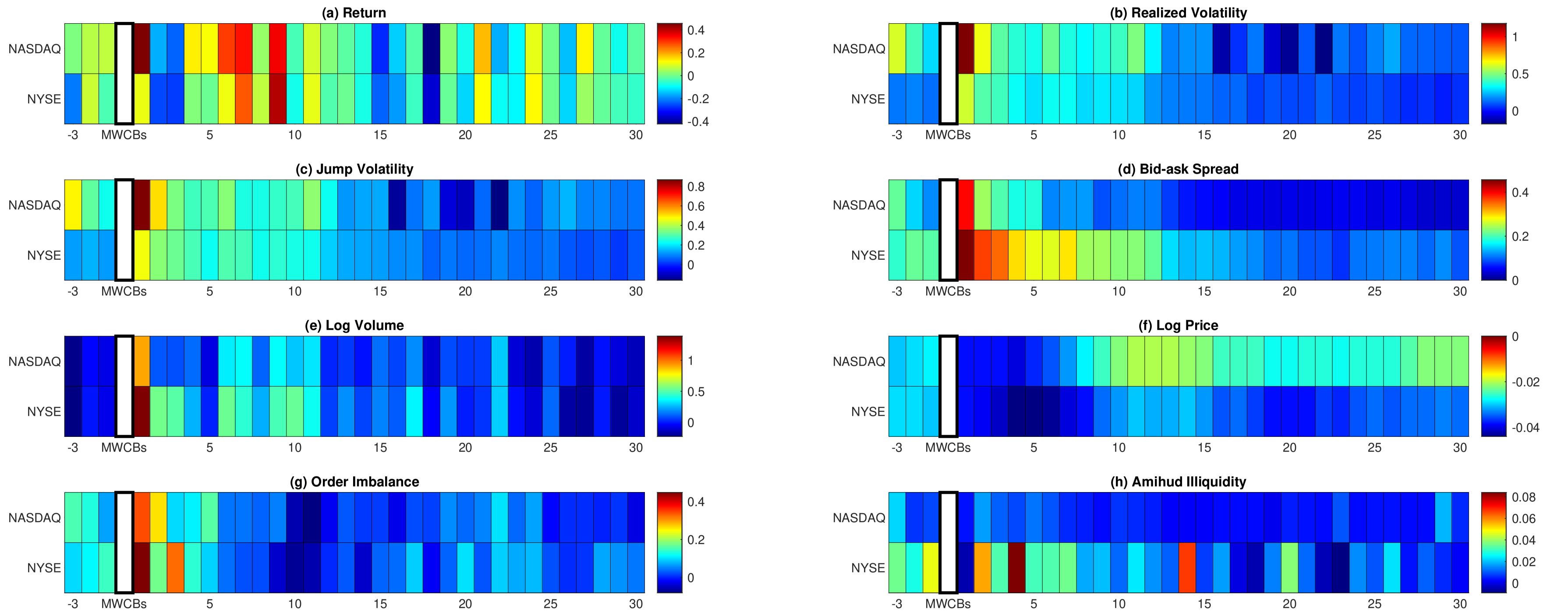
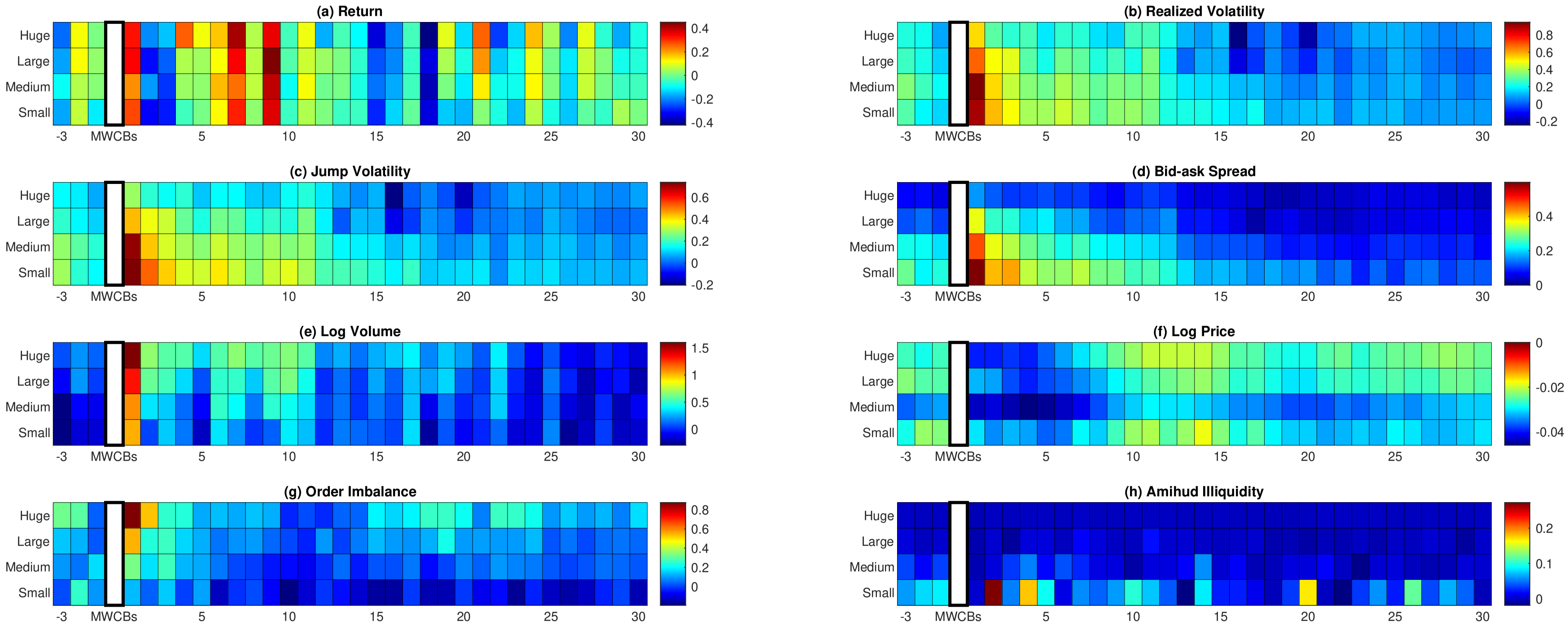


Figure 5: Comparison of estimated coefficients across size groups.



(between \$50 billion and \$100 billion), and huge (over \$100 billion). It is worth pointing out that the size distribution of stocks is very similar between the NYSE and NASDAQ and hence the estimates are not mainly driven by stock exchange differences. However, other differences, such as high frequency trading participation in stocks of different sizes can be important (Brogaard et al., 2014). We estimate Equation (1) for each size group separately, and stack the point estimates in Figure 5. The results indicate that post-halt outcomes vary greatly according to firm sizes. We find that smaller firms experience greater and more persistent increases in volatility and the bid-ask spread, yet less increase in trading volume than larger firms after the trading halt. From this perspective, smaller firms bear the brunt of the perverse effects of MWCBs.

5 Conclusions

The COVID-19 pandemic provides an unfortunate yet valuable opportunity to study several important aspects of financial market infrastructures. In this paper, we use four occurrences of MWCBs within a span of 10 days in March 2020 to evaluate their effectiveness. Previous studies on MWCBs are mostly from a theoretical perspective, and the findings on the effect of MWCBs are divided. This paper contributes to this ongoing debate by providing some of the first empirical evidence on the efficacy of MWCBs amid the COVID-19 pandemic.

Using tick-by-tick trading data for S&P 500 index constituent stocks and a difference-in-differences approach, we show that although MWCBs boost trading volume, they panic the markets by substantially increasing the spot volatility and bid-ask spread after the market reopens. Nonetheless, our results suggest that MWCBs help stabilize the markets by preventing panic sell-off for stocks that were hit hard. Furthermore, we do not find empirical support for the magnet effects hypothesis. The operation of MWCBs is further complicated by different stock exchanges' opening and reopening mechanisms, which can impede price discovery. Overall, our results indicate that MWCBs can have the perverse effects of panicking the markets for a prolonged period of time.

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A Supplementary Appendix

A.1 Additional regression results

Figure A.1: Estimated coefficients β_t^{CB} using all 4 days.

Figure A.2: Estimated coefficients β_t^{CB} on March 18 using 11:14 AM as counterfactual.

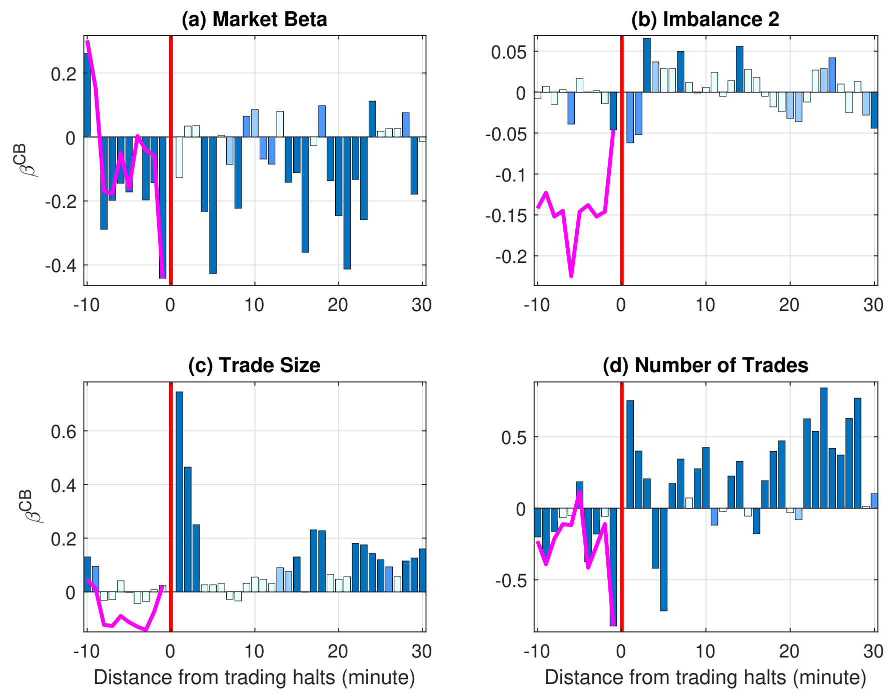

Figure A.3: Estimated coefficients β_t^{CB} on March 18 using 3:15 PM as counterfactual.

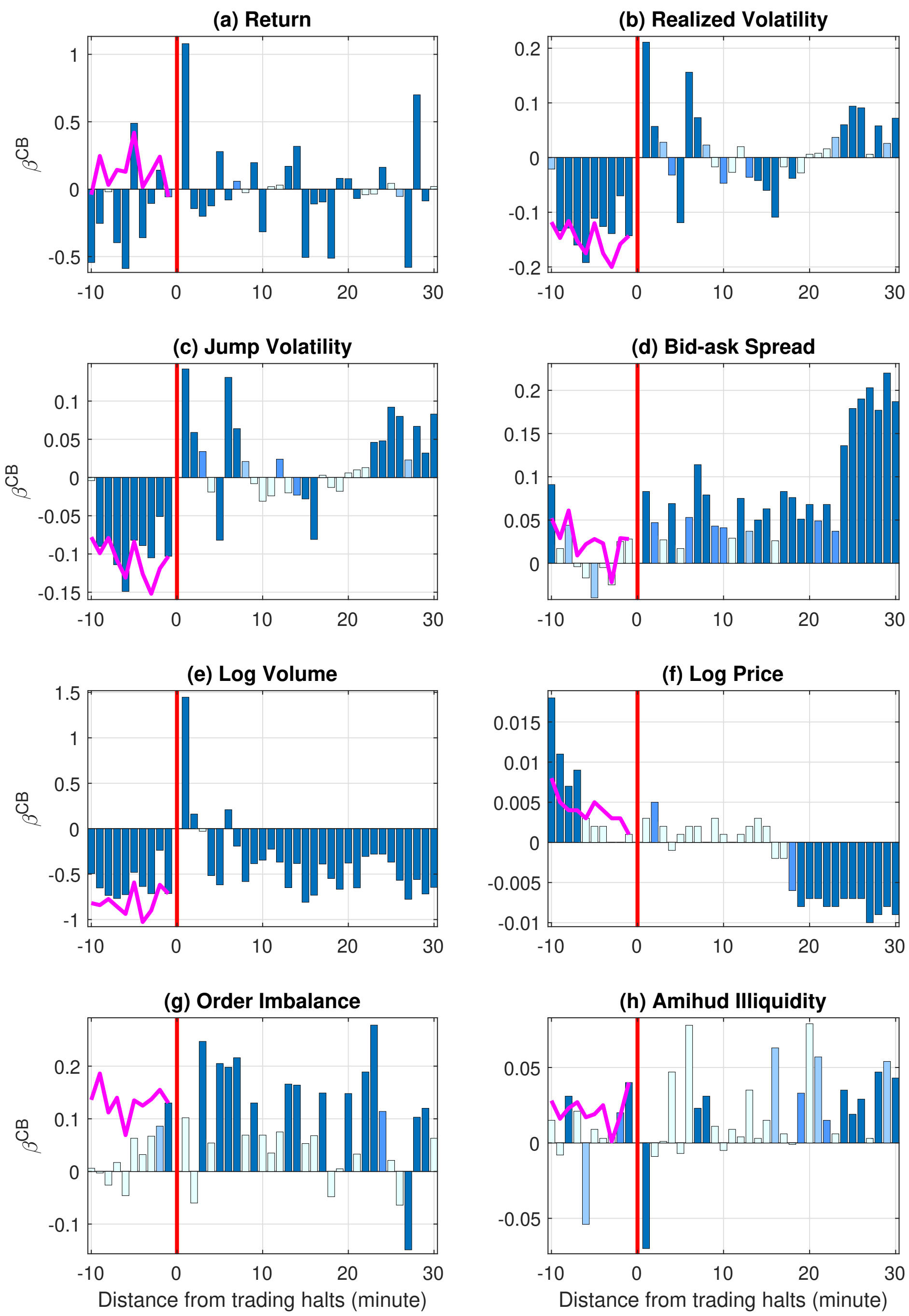

Figure A.4: Estimated coefficients β_t^{CB} on March 18 using 3:15 PM as counterfactual.