Internet Appendix for

"Recovery from Fast Crashes: Role of Mutual Funds"

Ravi Jagannathan, *Kellogg School of Management, Northwestern University, NBER, ISB and SAIF*

Loriana Pelizzon, *Goethe University Frankfurt - Leibniz Institute for Financial Research SAFE, Ca'Foscari University of Venice, and CEPR*

Ernst Schaumburg

Mila Getmansky Sherman, *Isenberg School of Management, University of Massachusetts Amherst*

Darya Yuferova, *Norwegian School of Economics - NHH*

This Internet Appendix contains supplementary estimates, statistics, figures and tables that are described and mentioned in our paper but were not reported. The document is structured as follows. Section IA.1 provides summary statistics regarding trader and order types t for spot and single stock futures markets. Section IA.2 describes extended trader classification scheme. Section IA.3 describes the role of different trader types in providing liquidity using trading network centrality measure and market-making index for the whole sample period. Section IA.4 shows the results of the inventory sensitivity regression during crash periods in the spirit of Kirilenko, Kyle, Samadi, and Tuzun (2017). Section IA.5 describes the role of different trader types in providing liquidity using trading network centrality measure and market-making index during crash periods. Section IA.6 discusses the role of the short-term traders in causing crashes and recoveries.

IA.1. Traders and order types

In this section, we provide summary statistics regarding trader and order types that can be found in the data from National Stock Exchange of India (NSE) for spot and single stock futures markets.[1] Table IA.1 shows that there are 108,052 traders in the spot market, while in the futures market for this stock, there are only 35,951 traders during the sample period. In total, there were 137,830 traders that (i) traded in the spot market, (ii) traded in the futures market, (iii) traded in both spot and futures, or (iv) submitted the orders that were not executed during the period under consideration. The latter category includes 8.47% of traders (11,681 traders); therefore, the number of effective traders whose orders resulted in at least one trade during this time period is 126,149 (91.53%). The majority of the active traders on either the spot (70.65%) or futures (86.13%) markets execute their orders on both sides of the market (i.e., they both buy and sell). 67.47% of traders execute their orders in the spot market only, while 20.17% of traders execute their orders on the futures market only. Only 3.89% of traders are active in both markets; however, they are responsible for around 40% of trading activity in each of the markets.

INSERT TABLES IA.1 – IA.2 HERE

Table IA.2 shows that the majority of the order flow in the spot market is represented by new order submissions (around 71% for both buy and sell sides of the market), followed by cancellations (around 17% for the buy side and 15% for the sell side of the market) and modifications (around 13% for the buy side and 14% for the sell side of the market). Similar patterns also hold for the futures market.[2] We note that the numbers above are based on regular book orders only. Our data also include several stop-loss orders; however, none of them were executed during our sample period.

IA.2. Extended classification scheme

In this section, we extend the classification scheme used in the main text of the paper by zooming into the Other traders category. We note that traders that are classified as FIIs and MFs in the main text of the paper are the same as in this Internet Appendix. The NSE classifies all traders in terms of their legal affiliations. However, traders' legal classifications

[1] We note that this firm's stock is traded in both the spot and the single-stock futures markets, with the trading volume in the futures market being almost five times larger than the trading volume in the spot market.

[2] For example, momentum strategies employed by Numeric Investors (an investment-management company currently known as Man Numeric with assets under management around USD 30 billion in 2018) typically leave around 10% to 15% of orders unexecuted or cancelled (see Perold and Tierney (1997)).

might be not adequate to fully analyze traders' role in liquidity provision in different market conditions. Some traders could tolerate deviations from their desired inventory positions only for short periods of time, while other could tolerate persistent deviations from their target inventory positions. Therefore, we classify traders based on their trading behavior and their role in the market (see Figure IA.1). We focus our attention on those with a short inventory-holding horizon (STTs) and examine how their inventory positions affect market liquidity and how they manage their inventory risk. We do this based on the conjecture that STTs are continuously present in the market, whereas LTTs are present in the market only at periodic intervals and when trigger events happen.

INSERT FIGURE IA.1 HERE

As Figure IA.1 shows, on a given day, we classify traders into Small and Other. Small traders are traders whose trading volume is less than or equal to 750 shares (equivalent of one futures contract) on a given day.[3] Other traders' trading volume exceeds 750 shares on a given day. We further classify other traders by their end-of-day inventory. STTs are traders whose end-of-day inventory is less than 10% of traded volume. LTTs are traders whose end-of-day inventory is more than 10% of traded volume. We further split LTTs into MFs, FIIs, and other long-term traders (OLTTs). MFs and FIIs are legal entities according to the NSE. To determine a trader's final category, we look at its modal classification across days and select it as the trader's category unless the mode equals "Small" trader. If a mode classification is equal to "Small" trader, we assign it as a trader category if and only if it is classified as a Small trader on more than two-thirds of days; otherwise, we use the next most frequent classification as the trader's category.[4]

INSERT TABLE IA.3 HERE

Table IA.3 shows buy and sell trading volume for each of the three trader categories. In particular, we find that STTs are responsible for 61.1% (67.6%) of the total (buy and sell) trading volume for the spot (futures) market. LTTs are responsible for 22.4% (31.1%) of the total trading volume for the spot (futures) market. Small traders are responsible for 16.5% (1.3%) of the total trading volume for the spot (futures) market. Besides that, a considerable portion of trading activity stems from STTs who are active in spot and futures markets alike: 35.6% and 28.6% for spot and futures markets, respectively, while all other trader categories

[3]The size of a futures contract is 750 shares in our sample. Therefore, traders that trade less than 750 shares per day do not have an opportunity to use the futures market for hedging purposes.

[4]For some of the forthcoming analysis, we also split traders into those active in the spot market only, those active in the futures market only, and those active in both markets.

are active mainly in either the spot market or the futures market. We also note that the futures market is five times larger than the spot market, but the spot market is more diverse in terms of market participants.

The size difference between the spot and futures markets is caused by a security transaction tax (an important part of transaction costs) that is much larger for the spot market (around 10 basis points) than for the futures market (around 1 basis points). Moreover, it is easier to take short positions in the futures market than in the spot market. Overnight short positions in the spot market were not allowed during our sample period, except through participatory notes, but this way of borrowing shares was available to very few investors, mainly FIIs.

For the remainder of the Internet Appendix we use extended classification scheme.

IA.3. Liquidity provision: Alternative measures

In this section, we expand liquidity provision definition by considering degree centrality measure of different traders in both the spot and futures markets and market-making index (i.e., balance in terms of their passive buys and passive sells) for the whole sample period.

IA.3.1. Trading network

Table IA.4 shows the average degree centrality (i.e., the number of counterparties each individual trader has) across traders per each trader category during the whole trading day, during the first and last 30 minutes and the rest of the trading day. We note that there are more traders active during the rest of the day (4 hours and 30 minutes) than during the first and last 30 minutes of the trading day, as expected from the different duration of the periods under consideration.

INSERT TABLE IA.4 HERE

We document that top STTs (the largest STTs, who are jointly responsible for 50% of STTs' trading volume and are present on almost every day in our sample period) exhibit the highest degree centrality of more than 33,000 (5,000) counterparties on the spot (futures) market during the whole trading day, which is 46 (17) times larger than the amount of counterparties the next-most-connected trader category (FIIs) has. Intraday patterns on spot and futures markets also show that STTs' relative importance in the trading network is lower at the beginning and end of the trading day, with the most profound intraday patterns observed in the spot market. In particular, on the spot market, top STTs have 35 (20) times more connections than FIIs in the first (last) 30 minutes of the trading day, as compared to 42 times during the rest of the trading day. This intraday pattern is in line with the fact

that STTs prefer to end their day with flat inventory positions, and thus are less likely to act as intermediaries for other market participants in the first and last 30 minutes of the trading day.

We also note that although MFs have only 155 (67) counterparties during the whole trading day on the spot (futures) market, and thus are not central to the trading network during normal times, we show that their role is crucial during turbulent periods in Section IA.5.

INSERT FIGURE IA.2 HERE

Figure IA.2 plots the trading network for the spot and futures markets, with vertex's size representing the total trading volume by each trader category and the width of the edges representing the trading activity among the trader categories for the whole trading day. Figure IA.2 shows that the majority of the trading volume occurs between STTs themselves in both the spot and futures markets. We also show that STTs act as main counterparties for other trader categories in spot and futures markets alike, as depicted by the width of the edges connecting STTs and other trader categories. Overall, we document that STTs are in the center of the trading network for both spot and futures markets alike during normal times.

IA.3.2. Market-making index

We estimate a market-making index (absolute difference between passive buying and passive selling volume relative to passive trading volume) following Comerton-Forde, Malinova, and Park (2018) and Korajczyk and Murphy (2019). A trader engaging in market-making activity should be balanced in terms of its passive execution on both sides of the market. A fully balanced trader's market-making index should be close to zero.

INSERT TABLE IA.5 HERE

Table IA.5 shows the average market-making index for the trader category as a whole, as well as for individual traders within each trader category, for the whole trading day as well as during the first and last 30 minutes and the rest of the trading day separately for spot and futures markets. We show that as a whole, STTs have the smallest market-making index among all categories for both the spot (5.9%) and futures (8.3%) markets for the whole trading day. The respective number for LTTs is 15.9% (9.0%), and for their subsets (namely, FIIs and MFs), the respective number does not fall below 58.0% (81.5%) on the spot (futures) market.

At the individual trader level for STTs, the market-making index is larger than the one for STTs as a whole. We document that top STTs (who are the largest STTs, jointly responsible for 50% of STTs trading volume and are present on almost every day in our sample period) are the ones who exhibit the most pronounced market-maker characteristics with a market-making index of 26.6% (26.8%) for the whole trading day on the spot (futures) market. For comparison, Korajczyk and Murphy (2019) classifies traders as market-makers if their median market-making index is below 20%.

We note that intraday patterns are especially profound for STTs' liquidity provision. Namely, top STTs have a market-making index of 44.5% (46.5%) and 50.7% (50.5%) during the beginning and end of the trading day and 29.0% (29.2%) during the rest of the trading day for the spot (futures) market. Intraday patterns are in line with the fact that STTs tend to start and end their day flat in term of inventory, and therefore are less balanced in terms of trading volume direction in the beginning and end of the trading day. To sum up, our results suggest that STTs (especially top STTs) exhibit market-maker characteristics more than any other trader category.

IA.4. Inventory sensitivity regression during crashes as in Kirilenko, Kyle, Samadi, and Tuzun (2017)

IN this section, we investigate whether MFs, FIIs, and STTs change their behavior during crashes. We follow Kirilenko, Kyle, Samadi, and Tuzun (2017) and estimate the following equation that measures the sensitivity of the inventory changes, $\triangle Inv_{ikt}$, of trader category i (STT, FII, and MF) during time interval t on day k to the contemporaneous mid-quote return (Ret_{kt}) during market drawdown ($Down_{kt}$) and recovery (Up_{kt}) periods, controlling for lagged spot/futures inventory ($Inv_{ik,t-1}$) and lagged changes in the spot/futures inventory ($\triangle Inv_{ik,t-1}$), day fixed effects (FE_k), and time fixed effects (TD_b):

$$\begin{aligned}\triangle Inv_{ikt} =&\beta_1 Ret_{kt} + \beta_2 Down_{kt} Ret_{kt} + \beta_3 Up_{kt} Ret_{kt} + \\ &+ \beta_4 Down_{kt} + \beta_5 Up_{kt} + \beta_6 \triangle Inv_{ik,t-1} + \beta_7 Inv_{ik,t-1} + \\ &+ \beta_8 Down_{kt} \triangle Inv_{ik,t-1} + \beta_9 Down_{kt} Inv_{ik,t-1} + \\ &+ \beta_{10} Up_{kt} \triangle Inv_{ik,t-1} + \beta_{11} Up_{kt} Inv_{ik,t-1} + \\ &+ \sum_k \alpha_k FE_k + \sum_b d_b TD_b + \epsilon_{ikt}\end{aligned} \tag{IA.1}$$

where $Down_{kt}$ (Up_{kt}) is equal to one for – (+) 30 minutes from the trough of the crash and zero otherwise.

INSERT TABLE IA.8 HERE

In Table IA.8, we document the estimation results of equation (IA.1). The first column reports the sensitivity of STTs' as a whole (STT-All) inventories to the spot and futures returns (Panel A and Panel B, respectively). We show that for STT-All, the coefficient in front of the spot return is positive and significant, indicating that as a whole, STT-All move with the spot market (Panel A), and the coefficient in front of the futures return is negative and significant, indicating that STT-All are contrarian (Panel B). The result for the spot market is in line with Kirilenko, Kyle, Samadi, and Tuzun (2017), who document that HFTs are moving with the market during normal times (based on the coefficient in front of contemporaneous returns). However, this comparison is misleading, as some STTs trade in either the spot or futures market only, while other STTs trade across both markets. Hence, we split STT-All into three categories: STT-Spot, STT-Futures, and STT-Both.

The second column of Panel A of Table IA.8 reports the sensitivity of STT-Spot inventories with respect to the spot return. We show that this coefficient is negative and significant, indicating that STT-Spot are contrarian (i.e., in general, they provide liquidity). During market drawdown, STT-Spot inventory sensitivity to the spot return does not change, since the coefficient is not significant. However, during market recovery, STT-Spot inventory sensitivity to the spot return becomes zero (the interaction coefficient between dummy for the recovery and the spot return is positive and significant, and is of the same magnitude as the coefficient of the spot return itself). That is, STT-Spot withdraw from the market, perhaps due to exhausting their inventory capacity. In Section IA.6.2, we investigate this issue in depth.

The second column of Panel B in Table IA.8 performs the same analysis for STT-Futures. In this case, the coefficients are not statistically significant, indicating that, as a whole, STT-Futures do not exhibit any particular pattern of inventory sensitivity to the futures return.

The third column of Table IA.8 reports the sensitivity of STT-Both inventory with respect to spot return (Panel A) and futures return (Panel B). We show that, in general, STT-Both have a positive and significant coefficient in the spot market and a negative and significant coefficient in the futures market – that is, STT-Both are taking opposite positions in the spot and futures markets consistent with cross-market arbitrage activity. During market drawdown and recovery, STT-Both become contrarian in the spot market and less contrarian in the futures market.[5] This is consistent with them taking the same positions across both

[5]The result for the spot market is consistent with the contemporaneous results of Kirilenko, Kyle, Samadi, and Tuzun (2017) for HFTs. Therefore, based on the contemporaneous inventory sensitivity to spot/futures returns, we do observe a change in STTs' behavior during market drawdown and recovery periods. Unfortu-

markets (i.e., STT-Both did not seem to engage in cross-market arbitrage activities during the crashes), and thus cross-market arbitrage broke down during the crashes.

The analysis performed following Kirilenko, Kyle, Samadi, and Tuzun (2017) considers STTs as a whole and does not distinguish between different traders within the STT category. We open up the STT category and investigate the behavior of each individual trader (i.e., whether a trader withdraws from the market during the market drawdown period, and whether a trader hits her inventory constraints during crash days) in Section IA.6.

Table IA.8 also reports FIIs' and MFs' inventory sensitivity. It is important to emphasize that FIIs and MFs who trade in the spot and futures markets are different traders (i.e., they do not trade in both markets). Hence, both FIIs and MFs are not engaging in cross-market arbitrage. We document that FIIs move with the market during normal times and intensify such behavior during market drawdown in the spot market, while in the futures market, FIIs move with the price during normal times and become contrarian during drawdowns and recoveries.

We document that MFs' inventories seem to be insensitive to the price movement neither during normal nor during turbulent periods for the spot and futures markets alike. Due to the nature of MFs' slow-moving capital, MFs do not change their inventories as frequently as one-minute changes in returns.

IA.5. Liquidity provision during crashes: Alternative measures

In this section, we expand liquidity provision definition by considering degree centrality measure of different traders in both the spot and futures markets and market-making index (i.e., balance in terms of their passive buys and passive sells) during fast crash periods only.

IA.5.0.1. Trading network

Table IA.6 shows the average degree centrality (i.e., number of counterparties each individual trader has) across traders per each trader category during crashes and recovery defined as +/- 30 minutes from the crash's trough for the bidirectional network as well as a split between buy and sell networks.

INSERT TABLE IA.6 HERE

nately, trading activity in our data is not frequent enough to sample at as high frequency, as in Kirilenko, Kyle, Samadi, and Tuzun (2017), and thus we are not able to perform a joint test on the changes of inventory sensitivity to contemporaneous and lagged returns during market drawdown and recovery periods, which is the main test performed by Kirilenko, Kyle, Samadi, and Tuzun (2017).

We document that contrary to normal times (see Table IA.4), top STTs (the largest STTs, jointly responsible for 50% of STTs' trading volume and present on almost every day in our sample period) do not stand out in terms of the number of counterparties during crashes and recoveries. In particular, during crashes, the number of counterparties top STTs have is equal to the number of counterpaties FIIs have on the spot market and is only two times larger on the futures markets, as opposed to 46 (spot market) and 17 (futures market) times during normal periods. During recoveries, tops STTs are at par with FIIs in terms of number of counterparties on the spot market, and they lose their leading position to FIIs on the futures market.

Splitting up the bidirectional network into buy and sell networks yields interesting results. Namely, we show that while STTs remain relatively balanced during both crashes and recoveries on the spot and futures markets alike, FIIs and MFs tend to be present only on one side of the network. In particular, on the spot market, FIIs (MFs) are present only on the sell (buy) network, consistent with FIIs generating large selling pressure, leading to a crash. On the futures market, both FIIs and MFs tend to be present on the buy network only.

IA.5.0.2. Market-making index

We estimate a market-making index (absolute difference between passive buying and passive selling volume relative to passive trading volume) for crashes and recoveries defined as -/+ 30 minutes from the crash's trough.

INSERT TABLE IA.7 HERE

Table IA.7 shows the average market-making index for the trader category as a whole, as well as for individual traders within each trader category, for crashes and recoveries for both the spot and futures markets.

During crashes, STTs as a category have a market-making index of 17.5% (19.3%), as opposed to 5.9% (8.3%) during normal times for the spot (futures) market (see Table IA.5). At the individual trader level, top STTs have a market-making index of 40.7% (46.4%), as opposed to 26.6% (26.8%) during normal times for the spot (futures) market (see Table IA.5). Recoveries exhibit similar patterns.

This results suggest that STTs become less balanced in terms of their passive buys and sells during turbulent times. The market-making index for other trader categories remained largely unchanged.

IA.6. The role of STTs during crashes

In this section, we argue that STTs could not prevent crashes from happening as well as could not reduce recovery process due to limited inventory capacity and thus, there is a need for standby well-capitalized liquidity providers such as MFs. First, we show that STTs tried to "lean against the wind" by documenting their cash flows during the crash days, but could not do so (see Section IA.6.1). Second, we show that STTs indeed were inventory constrained during the crash days (see Section IA.6.2).

IA.6.1. STTs' cash flows

In this section, we provide evidence of whether STTs "lean against the wind." Given that STTs tend to end each day with flat positions, we make a simplifying assumption that at the end of the day, they do not have any positions to liquidate, and hence, each day, they start with a zero-inventory position. We note that we compute aggregate cash flows for the STT category. Hence, we do not exclude the possibility for vast heterogeneity within the STT category. In particular, for each one-minute interval t on day k with at least one transaction, we compute cumulative cash flow for STTs, $Cash\ Flow_{STTkt}$, which increases with sell transactions and decreases with buy transactions, and regress it on dummy variables for market drawdown ($Down_{kt}$) and recovery (Up_{kt}) periods, day fixed effects (FE_k), and half-hour time dummies (TD_b):

$$Cash\ Flow_{STTkt} = \gamma Down_{kt} + \delta Up_{kt} + \sum_k \alpha_k FE_k + \sum_b d_b TD_b + \epsilon_{kt} \tag{IA.2}$$

where $Down_{kt}$ (Up_{kt}) is equal to one for – (+) 30 minutes from the crash's trough and zero otherwise.

INSERT TABLE IA.9 HERE

Table IA.9 shows the results of the cash flow regression estimation around the two crashes in our sample (on May 19, 2006, and May 22, 2006) for the spot and futures markets. Panels A and B of Table IA.9 report the results of the cash flow analysis (in millions of rupees) for the spot and futures markets, respectively. We observe that cash flows decrease during the market drawdown period and increase during the market recovery period for both markets alike. Although we lack statistical power for this test, to further support our hypothesis, we depict STTs' cumulative cash flows during the two crash days (Figure IA.3). We find that STTs' cumulative cash flows decrease during market drawdowns and increase during recovery periods.

INSERT FIGURE IA.3 HERE

IA.6.2. STTs' inventory capacity

In this section, we provide evidence that STTs hit their inventory limits during the crash days. First, we show summary statistics of STTs' participation during the crash days. Second, we present the dynamics of STTs' inventory capacity at daily and intraday levels (the latter for the two crash days only).

INSERT FIGURE IA.4

Figure IA.4 shows the number of STTs that were active either on May 19, May 22, or both for the spot and futures markets (the latter one is reported in parentheses). We divide STTs into categories based on whether they belong to the top category of STTs or not, whether they are active during the market drawdown period or not, and whether they were inventory constrained or not.

We define top STTs as those with large trading volume who jointly generate 50% of STT trading volume. There are only 27 (64) top STTs out of 6,547 (20,524) STTs in the spot (futures) market. Naturally, having one of the top STTs hitting its inventory limits is more problematic for the market than one of the smaller STTs hitting its inventory limits.

We define STTs as inventory-constrained STTs if the trader's maximum of absolute value of one-minute median inventory, either on May 19 or on May 22 (or both), is above this trader's 95th percentile of the maximum of the absolute value of one-minute median inventory over the sample period, excluding May 19 and May 22.

We show that on the two crash days, there were 1,099 STTs on the spot market. Out of them, 26 traders were from the top category, with 19 of the top traders actively engaging in cross-market trading. Out of 19 top traders active on both markets, 17 participated during the crash, with 27% of them hitting their inventory constraints. Overall, 22 (17 + 5) traders from the top category of STTs participated during the market drawdown, with 27% of them hitting their inventory constraints. Out of the smaller STT category, 20% were active on both markets, but less than half of the smaller cross-market traders were active during the crash (86 traders). Moreover, 51 of these 86 traders were constrained during the crash days. Overall, out of the smaller STT category, only 441 (86 + 355) traders participated during the market drawdown (41%), with 275 (51 + 224) of them hitting their inventory constraints, and 632 (125 + 507) traders preferring to stay away from the market during the crash. Overall, more than 50% of STTs disappeared from the market during the turbulent periods, and 60% of those STTs who continued to participate in the market during the turbulent periods hit their inventory constraints. STTs in the futures market exhibited similar participation patterns. This detailed analysis shows, therefore, that not all STTs behave in the same way

during crashes as they do during normal times. In particular, many STTs hit their inventory constraints and withdraw from the market.

Figure IA.5 plots a time series of the STTs' inventory capacity for the daily frequency over the whole sample period (Panels A and B) and intraday inventory capacity on May 19 and May 22 (Panels C and F). At the daily frequency, inventory capacity is defined as follows. First, for each day, we compute the maximum absolute one-minute median inventory for each trader. Second, we normalize this number by the maximum for the whole sample period, excluding May 19 and May 22. Finally, we take the average across all traders. Hence, the larger the measure, the more constrained STTs are. Panels A and B of Figure IA.5 show the time series of daily inventory capacity measures for the spot and futures markets, respectively. For the spot market, the inventory capacity measure reached 80% (100%) on May 19 (May 22), while for other days in the sample period, it never exceeded 20%. For the futures market, the picture was similar, although less extreme.

Most traders have exhausted their inventory capacity during the crash days. We now zoom in and show the dynamics of STTs' inventory capacity at the intraday level. Panels C and F plot STTs' intraday capacity measure, which is an average ratio of the absolute value of one-minute median inventory to the whole-sample maximum of the absolute value of one-minute median inventory, excluding May 19 and May 22, for the spot and futures markets. We observe that capacity measure increased with the evolution of the crash and stabilized during the recovery period. On May 19, due to the second event, the capacity measure continued to increase after recovery had taken place. On May 22, the capacity measure decreased slowly after the recovery for the spot market and remained constant for the futures market.

INSERT FIGURE IA.5 HERE

Overall, this confirms that STTs tried to "lean against the wind" during the two crashes in our sample. However, their limited inventory capacity did not allow them to stop the crash.

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Table IA.1: Number of traders

This table shows the number and proportion of traders who are active in the spot and futures markets. We divide traders into those who execute trades on both sides of the market, or on only one side of the market, or do not execute trades at all, separately for the spot and futures markets. We also divide traders into those who execute trades in both the spot and futures markets, only in the spot market, only in the futures market, or do not execute trades at all. For the futures market, we include only those traders who submit orders and/or execute trades for contracts with maturity dates within the same month as the transaction occurs.

	Panel A: Spot Market		**Panel B: Futures Market**		**Panel C: Spot and Futures Market**		
Buy & Sell	76,343	70.65%	30,966	86.13%	Spot & Futures	5,362	3.89%
Only Buy	15,317	14.18%	941	2.62%	Only Spot	92,989	67.47%
Only Sell	6,691	6.19%	1,253	3.49%	Only Futures	27,798	20.17%
No Execution	9,701	8.98%	2,791	7.76%	No Execution	11,681	8.47%
Total	108,052	100.00%	35,951	100.00%	Total	137,830	100.00%

Table IA.2: Order types

This table shows the number and proportion of new orders, cancellations, and modifications for the spot and futures markets and for buy and sell sides, respectively. Only regular book orders are included in the sample (i.e., we exclude stop-loss orders). For the futures market, we include only those orders for contracts with maturity dates within the same month as the order was submitted, modified, or cancelled.

	Panel A: Spot Market				**Panel B: Futures Market**			
	Buy		Sell		Buy		Sell	
New	1,163,764	70.93%	1,173,244	70.59%	649,907	62.46%	642,629	63.13%
Cancel	271,342	16.54%	254,006	15.28%	244,271	23.48%	207,005	20.33%
Modify	205,615	12.53%	234,905	14.13%	146,309	14.06%	168,388	16.54%

Table IA.3: Trading volume per trader category

This table shows the number of traders in each trader category, the number of shares bought and sold by each trader category, as well as the total trading volume and proportion of trading volume attributable to each trader category (for traders active on one market only and on both markets). For the futures market, we include only transactions for the contracts with expiry dates within the same month as the transaction occurs. We classify traders into three categories: long-term traders (LTTs), short-term traders (STTs), and small traders (Small). We further split the LTT category into: foreign institutions (FIIs), domestic mutual funds (MFs), and other long-term traders (OLTTs).

Panel A: Spot market

	Active on spot market only					Active on both markets					Grand Total	
	# of traders	Buy	Sell	Total (Buy+Sell)		# of traders	Buy	Sell	Total (Buy+Sell)		(Buy+Sell)	
LTT	1,471	17,357,955	17,336,561	34,694,516	15.7%	219	7,622,099	7,260,429	14,882,528	6.7%	49,577,044	22.4%
FII	107	5,273,086	6,891,532	12,164,618	5.5%	20	1,746,656	1,934,157	3,680,813	1.7%	15,845,431	7.2%
MF	262	2,823,229	5,024,574	7,847,803	3.6%	6	124,500	158,950	283,450	0.1%	8,131,253	3.7%
OLTT	1,102	9,261,640	5,420,455	14,682,095	6.6%	193	5,750,943	5,167,322	10,918,265	4.9%	25,600,360	11.6%
STT	5,597	27,945,058	28,262,521	56,207,579	25.4%	950	39,287,510	39,373,997	78,661,507	35.6%	134,869,086	61.1%
Small	90,646	18,018,051	17,995,050	36,013,101	16.3%	513	213,797	215,912	429,709	0.2%	36,442,810	16.5%
											220,888,940	100.0%

Panel B: Futures market

	Active on futures market only					Active on both markets					Grand Total	
	# of traders	Buy	Sell	Total (Buy+Sell)		# of traders	Buy	Sell	Total (Buy+Sell)		(Buy+Sell)	
LTT	6,613	127,703,250	131,735,250	259,438,500	27.2%	219	21,497,250	15,598,500	37,095,750	3.9%	296,534,250	31.1%
FII	40	5,710,500	3,239,250	8,949,750	0.9%	20	7,121,250	2,894,250	10,015,500	1.0%	18,965,250	2.0%
MF	9	664,500	114,000	778,500	0.1%	6	150,750	214,500	365,250	0.0%	1,143,750	0.1%
OLTT	6,564	121,328,250	128,382,000	249,710,250	26.2%	193	14,225,250	12,489,750	26,715,000	2.8%	276,425,250	29.0%
STT	19,574	185,267,250	186,960,000	372,227,250	39.0%	950	136,363,500	136,211,250	272,574,750	28.6%	644,802,000	67.6%
Small	5,628	5,644,500	5,949,000	11,593,500	1.2%	513	614,250	636,000	1,250,250	0.1%	12,843,750	1.3%
											954,180,000	100.0%

Table IA.4: Trading network

This table shows the average degree centrality measure (number of counterparties) of bidirectional trading network (both buys and sells) for each trading category for spot (Panel A) and futures (Panel B) markets, respectively. We compute the degree centrality measure for the whole trading day, for the first and last 30 minutes of the trading day, and the rest of the trading day. For the futures market, we include only transactions for the contracts with an expiry date within the same month as the transaction occurs. We classify traders into three categories: long-term traders (LTTs), short-term traders (STTs), and small traders (Small). We further split the LTT category into foreign institutions (FIIs), domestic mutual funds (MFs), and other long-term traders (OLTTs). We further split the STT category into the largest STTs (STT Top), who jointly generate 50% of STT trading volume, and small STTs (STT Not Top).

	Panel A: Spot market				**Panel B: Futures market**			
	Total	First 30 minutes	The rest of the trading day	Last 30 minutes	Total	First 30 minutes	The rest of the trading day	Last 30 minutes
LTT	210	57	175	75	44	9	33	10
FII	713	111	602	164	291	52	244	42
MF	155	61	134	92	67	19	59	25
OLTT	171	50	138	62	42	9	31	10
STT	292	60	233	52	37	10	29	10
STT Not Top	156	30	124	31	20	5	16	6
STT Top	33,051	3,952	25,806	3,292	5,104	678	3,796	631
Small	14	4	11	4	3	1	2	1

Table IA.5: Market-making index

This table shows liquidity provision by trader categories as measured by market-making index ($\frac{|Passive\ buy\ volume - Passive\ sell\ volume|}{Passive\ buy\ volume + Passive\ sell\ volume}$). We report the market-making index for a trader category as a whole as well as on average for traders within each trader category for the spot (Panel A) and futures (Panel B) markets, respectively. We compute the market-making index for the whole trading day, for the first and last 30 minutes of the trading day, and the rest of the trading day. For the futures market, we include only transactions for the contracts with expiry date within the same month as the transaction occurs. We classify traders into three categories: long-term traders (LTTs), short-term traders (STTs), and small traders (Small). We further split the LTT category into foreign institutions (FIIs), domestic mutual funds (MFs), and other long-term traders (OLTTs). We further split the STT category into the largest STTs (STT Top), who jointly generate 50% of STT trading volume, and small STTs (STT Not Top).

	Total		First 30 minutes		The rest of the trading day		Last 30 minutes	
	By trader	By category	By trader	By category	By trader	By category	By trader	By category
Panel A: Spot market								
LTT	76.6%	15.9%	88.0%	43.9%	79.0%	20.1%	87.9%	36.5%
FII	100.0%	67.2%	99.5%	88.1%	100.0%	70.5%	100.0%	80.2%
MF	96.7%	58.0%	100.0%	89.6%	98.2%	65.1%	98.8%	84.5%
OLTT	72.9%	27.6%	86.3%	48.3%	75.4%	30.3%	86.0%	50.3%
STT	50.7%	5.9%	74.6%	10.2%	56.3%	6.6%	79.5%	15.0%
STT Not Top	51.8%	6.7%	78.2%	13.4%	57.7%	7.4%	82.1%	15.7%
STT Top	26.6%	6.2%	44.5%	12.6%	29.0%	7.4%	50.7%	18.5%
Small	68.9%	11.0%	88.8%	19.9%	72.3%	12.4%	90.6%	20.4%
Panel B: Futures market								
LTT	72.6%	9.9%	89.4%	16.5%	74.5%	11.5%	89.8%	17.8%
FII	96.5%	81.5%	100.0%	90.6%	97.0%	82.4%	98.6%	85.3%
MF	90.3%	83.2%	100.0%	100.0%	98.2%	92.4%	100.0%	100.0%
OLTT	72.3%	12.8%	89.2%	19.5%	74.1%	14.1%	89.6%	17.8%
STT	58.6%	8.3%	74.0%	10.5%	61.7%	8.2%	78.2%	15.0%
STT Not Top	60.3%	8.7%	78.4%	11.1%	63.8%	8.6%	82.5%	17.8%
STT Top	26.8%	8.1%	46.5%	11.6%	29.2%	8.3%	50.5%	13.6%
Small	94.8%	31.5%	98.7%	47.6%	94.9%	36.5%	97.9%	44.5%

Table IA.6: Trading network during crashes

This table shows the average degree centrality measure (number of counterparties) of the bidirectional trading network (both buys and sells) as well as buy and sell networks for each trading category for spot (Panel A) and futures (Panel B) markets, respectively. We compute the degree centrality measure for the crash and recovery periods as defined -/+ 30 minutes from the crash's trough. For the futures market, we include only transactions for the contracts with expiry date within the same month as the transaction occurs. We classify traders into three categories: long-term traders (LTT), short-term traders (STT), and small traders (Small). We further split the LTT category into foreign institutions (FIIs), domestic mutual funds (MFs), and other long-term traders (OLTTs). We further split the STT category into the largest STTs (STT Top), who jointly generate 50% of STT trading volume, and small STTs (STT Not Top).

	Panel A: Spot market						**Panel B: Futures market**					
	Crash			Recovery			Crash			Recovery		
	Total	Buy	Sell	Total	Buy	Sell	Total	Buy	Sell	Total	Buy	Sell
LTT	40	9	30	36	19	16	3	2	2	4	3	2
FII	262	0	262	157	0	157	13	12	1	62	54	8
MF	56	53	3	83	73	9	-	-	-	11	11	-
OLTT	20	7	13	25	14	11	3	1	2	4	2	2
STT	25	12	13	23	10	12	5	3	2	6	3	3
STT Not Top	13	6	7	13	6	7	3	2	1	3	1	2
STT Top	262	116	146	198	97	101	25	14	12	28	13	15
Small	2	2	1	2	1	1	1	0	1	1	0	1

Table IA.7: Market-making index during crashes

This table shows liquidity provision by trader categories as measured by market-making index ($\frac{|Passive\ buy\ volume - Passive\ sell\ volume|}{Passive\ buy\ volume + Passive\ sell\ volume}$). We report the market-making index for a trader category as a whole as well as on average for traders within each trader category for the spot (Panel A) and futures (Panel B) markets, respectively. We compute the market-making index for the crash and recovery periods as defined -/+ 30 minutes from the crash's trough. For the futures market, we include only transactions for the contracts with expiry date within the same month as the transaction occurs. We classify traders into three categories: long-term traders (LTTs), short-term traders (STTs), and small traders (Small). We further split the LTT category into foreign institutions (FIIs), domestic mutual funds (MFs), and other long-term traders (OLTTs). We further split the STT category into the largest STTs (STT Top), who jointly generate 50% of STT trading volume, and small STTs (STT Not Top).

	Panel A: Spot market				**Panel B: Futures market**			
	Crash		Recovery		Crash		Recovery	
	By trader	By category	By trader	By category	By trader	By category	By trader	By category
LTT	91.8%	16.0%	93.4%	43.9%	90.6%	10.2%	86.3%	17.5%
FII	100.0%	100.0%	100.0%	100.0%	100.0%	97.5%	100.0%	64.1%
MF	100.0%	97.0%	100.0%	85.3%	-	-	100.0%	100.0%
OLTT	89.9%	36.6%	91.5%	50.9%	90.3%	4.8%	85.9%	11.9%
STT	72.6%	17.5%	71.3%	6.1%	70.0%	19.3%	74.3%	19.0%
STT Not Top	76.0%	25.3%	75.0%	5.9%	75.6%	17.8%	80.6%	17.5%
STT Top	40.7%	10.2%	34.4%	10.9%	46.4%	21.4%	49.8%	21.1%
Small	89.2%	41.2%	85.1%	16.2%	96.7%	49.4%	97.5%	27.0%

Table IA.8: Inventory sensitivity to price movements during crashes

This table shows the results of the inventory-sensitivity regression estimation based on one-minute intervals from 16-May-2006 through 25-May-2006 for the spot (Panel A) and futures (Panel B) markets (see equation (IA.1)). We regress changes in inventory in the spot market for STTs, FIIs, and MFs on concurrent return and control variables omitted for brevity (lagged spot/futures inventory, lagged changes in spot/futures inventory). We also include interaction with down/up dummy variables defined as -/+ 30 minutes from the crash's trough. For the futures inventory computation, we use only transactions for the contracts with expiry dates within the same month as the transaction occurs. We use day fixed effects. We use robust standard errors. ***, **, and * denote significance level at 1%, 5%, and 10%, respectively. We classify traders into three categories: long-term traders (LTTs), short-term traders (STTs), and small traders (Small).

Panel A: Spot market

	STT			FII	MF
	STT-All	STT-Spot	STT-Both		
Spot Return	69.02**	-80.72***	138.08***	93.78***	24.36
	(2.07)	(-3.00)	(3.99)	(3.27)	(1.00)
Down*Spot Return	-274.02**	69.91	-346.47***	294.02*	31.52
	(-2.53)	(1.32)	(-3.33)	(1.81)	(0.55)
Up*Spot Return	-111.07**	87.46**	-174.03***	-55.02	-28.11
	(-2.50)	(2.25)	(-2.86)	(-1.18)	(-0.52)
Down	3.26**	1.16	1.58**	-0.36	3.08*
	(2.44)	(0.88)	(2.35)	(-0.53)	(1.93)
Up	-0.35	-0.36	0.09	-8.44***	3.61
	(-0.33)	(-0.36)	(0.13)	(-2.82)	(1.13)
Constant	-0.57	0.24	-0.50*	0.06	-0.09
	(-1.63)	(1.05)	(-1.92)	(0.37)	(-0.62)
Observations	1,909	1,909	1,909	1,909	1,909
Adjusted R^2	0.162	0.089	0.108	0.319	0.186

Panel B: Futures market

	STT			FII	MF
	STT-All	STT-Futures	STT-Both		
Futures Return	-235.59**	42.38	-316.23***	134.98***	-19.58
	(-2.44)	(0.61)	(-5.71)	(3.12)	(-0.55)
Down*Futures Return	161.79	-109.11	278.69**	-228.72***	23.59
	(0.63)	(-0.48)	(2.06)	(-3.13)	(0.64)
Up*Futures Return	3.38	-96.71	206.40**	-233.58*	39.53
	(0.02)	(-1.00)	(2.54)	(-1.83)	(0.99)
Down	5.95**	2.76**	3.32**	-0.25	-0.20
	(1.99)	(2.57)	(2.25)	(-0.57)	(-1.46)
Up	-3.76**	0.76	-2.38*	2.37	0.49
	(-2.19)	(0.71)	(-1.71)	(1.52)	(1.37)
Constant	-0.98	-1.28**	0.15	1.29***	-0.06
	(-1.22)	(-2.23)	(0.31)	(3.04)	(-0.56)
Observations	1,909	1,909	1,909	1,909	1,909
Adjusted R^2	0.099	0.068	0.111	0.280	0.292
Day FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes	Yes

Table IA.9: Cash flow regression for STTs during crashes

This table shows the results of the cash flow regression estimation based on one-minute intervals from 16-May-2006 through 25-May-2006 for the spot (Panel A) and futures (Panel B) markets. We regress cumulative one-minute cash flows for STTs on crash and recovery dummy variables defined as -/+ 30 minutes from the crash's trough (see equation (IA.2)). We use day and time fixed effects. We cluster standard errors by day. ***, **, and * denote significance level at 1%, 5%, and 10%, respectively. t-stats are reported in parentheses. For the futures market, we use only transactions for the contracts with maturity dates within the same month as the transaction occurs. We classify traders into three categories: long-term traders (LTTs), short-term traders (STTs), and small traders (Small).

	Panel A: Spot market			**Panel B: Futures market**		
	STT-All	STT-Both	STT-Spot	STT-All	STT-Both	STT-Futures
Down	-0.241	-0.192	0.013	-2.289	-0.631	-1.690*
	(-0.71)	(-0.63)	(0.23)	(-1.77)	(-1.28)	(-2.26)
Up	0.300	-0.002	-0.024	2.446	1.472	0.886
	(1.35)	(-0.01)	(-0.31)	(1.03)	(1.19)	(1.14)
Constant	-0.093	-0.052	0.053	0.545	-0.106	0.546*
	(-0.59)	(-0.32)	(0.89)	(1.07)	(-0.56)	(2.02)
Day FE		Yes			Yes	
Time FE		Yes			Yes	
Cluster SE		By Day			By Day	
Observations	1,871	1,709	1,839	1,871	1,709	1,839
Adjusted R^2	0.002	-0.003	0.003	0.012	0.007	0.006

Figure IA.1: Trader Classification

This figure shows the trader classification scheme used in this paper.

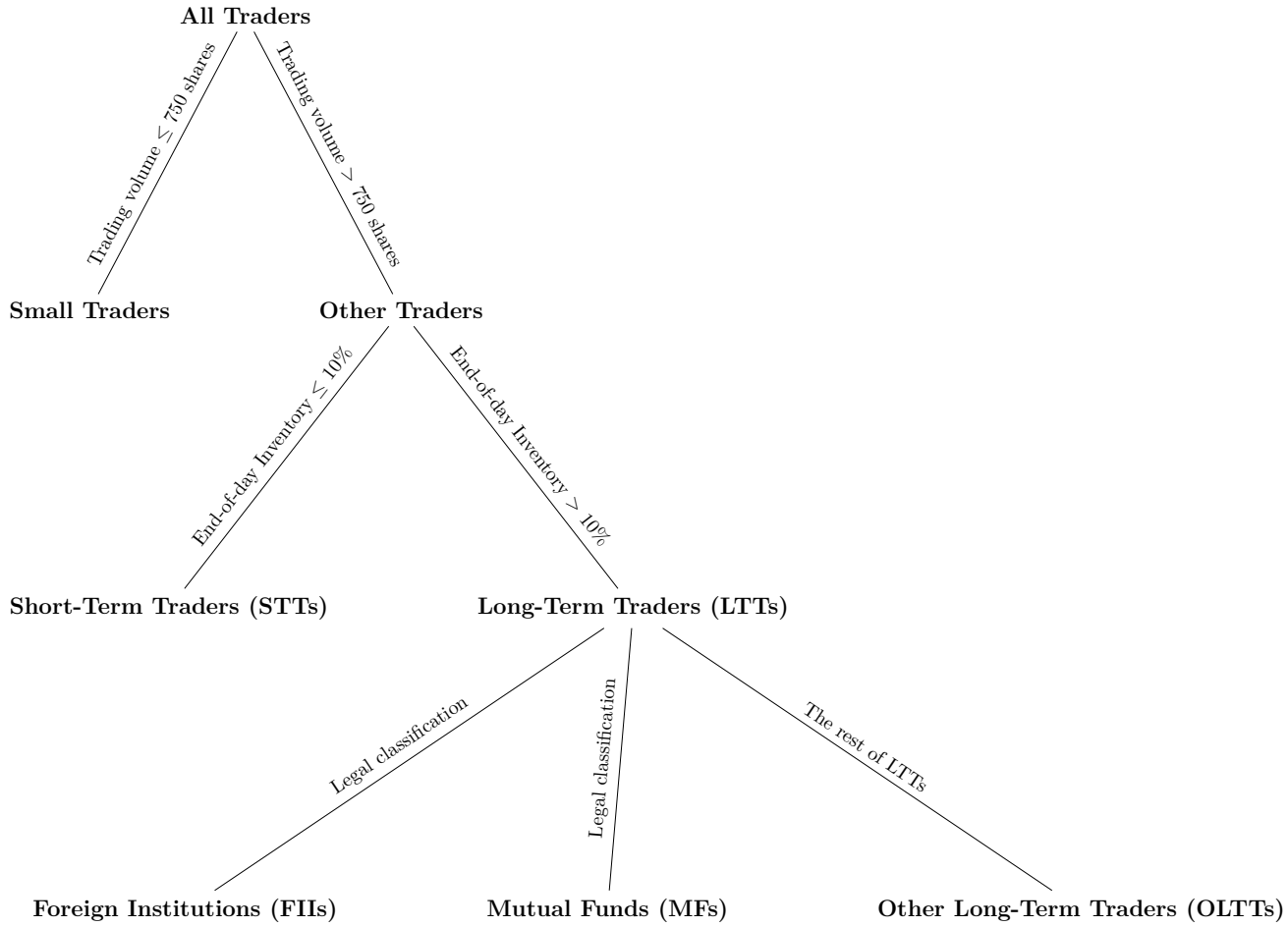
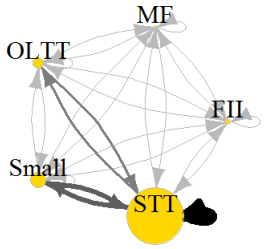


Figure IA.2: Trading network

This figure shows the trading network for the spot and futures markets for April-June, 2006, where each vertex corresponds to the trader type; the size of the vertex represents the proportion of total trading volume; and the width of the edges represents the proportion of total trading volume between two categories.

Panel A: Spot market



Panel B: Futures market

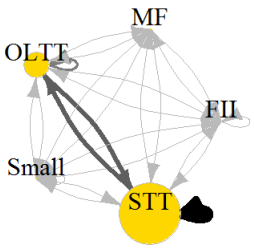
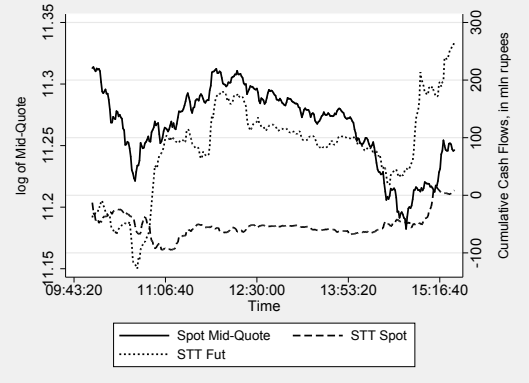


Figure IA.3: STTs' cumulative cash flows during the crashes

This figure shows STTs' cumulative cash flows of STTs at a one-minute frequency for the spot and futures markets during the two crash days: May 19 and May 22, 2006. Cumulative cash flows are computed as the cumulative sum of + (−) price times the number of shares traded in case of sell (buy) transactions.

Panel A: 19th of May 2006



Panel B: 22nd of May 2006

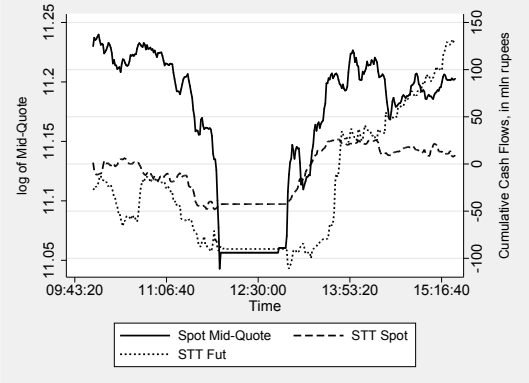


Figure IA.4: STTs' activity during the two crash days

This figure shows shows STTs' activity during the two crash days in our sample. We document the number of active traders for the crash, recovery, and normal periods during either May 19, 2006, or May 22, 2006, for the spot (futures) markets. Crash/recovery periods are measured as -/+30 minutes from the crash's trough. We split all active STTs on the crash days based on their activity during the crash periods, whether they belong to the most active STTs (STTs that generate 50% of total volume), and whether they were constrained during the crash days (their maximum one-minute inventory was above 95% of the maximum inventories on non-crash days).

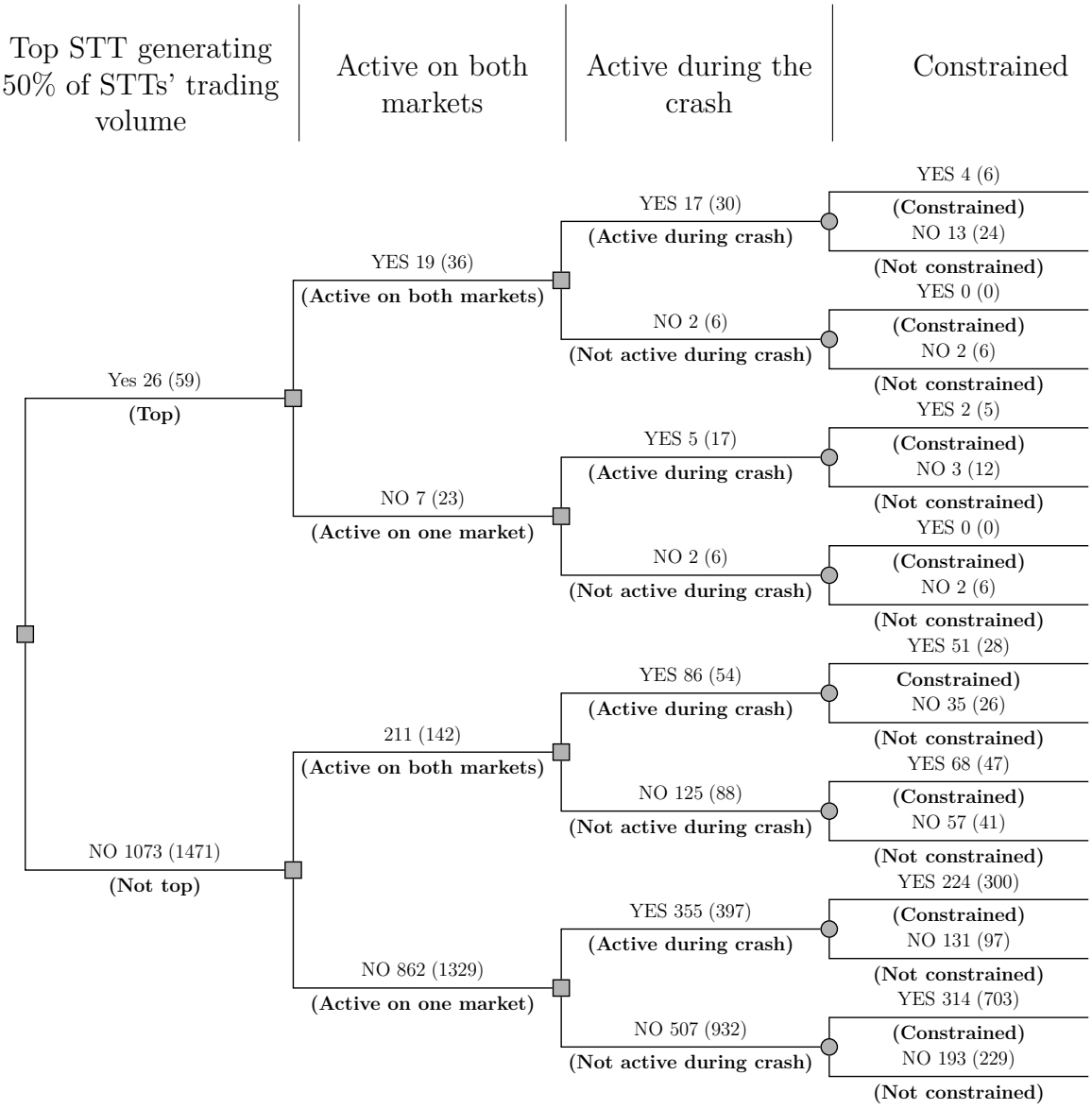
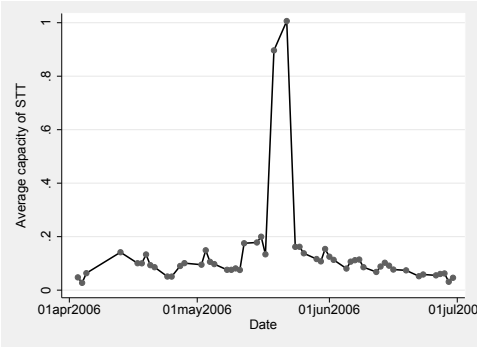


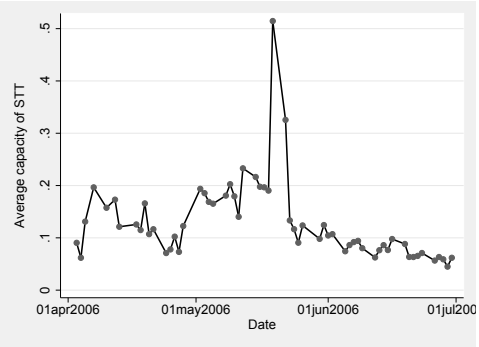
Figure IA.5: STTs' inventory capacity

This figure shows STTs' average capacity. Panels A and B show the maximum absolute value of one-minute median inventory positions during the day relative to the maximum absolute inventory position in our sample period, excluding the two crash days (May 19 and May 22, 2006) for the spot and futures markets, respectively. Panels C and D (Panels E and F) show the absolute value of one-minute median inventory positions relative to the maximum absolute inventory position in our sample period, excluding the two crash days (May 19 and May 22, 2006) for the spot and futures markets, respectively, for May 19 (22), 2006.

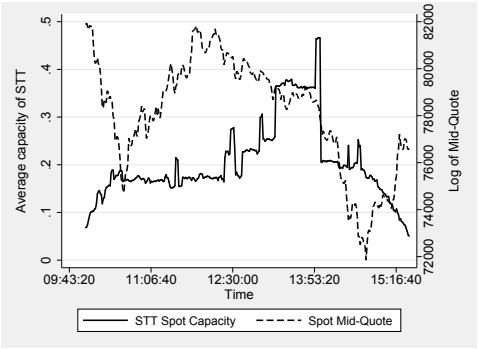
Panel A: Spot market



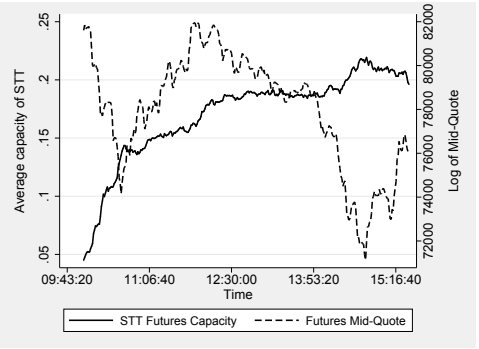
Panel B: Futures market



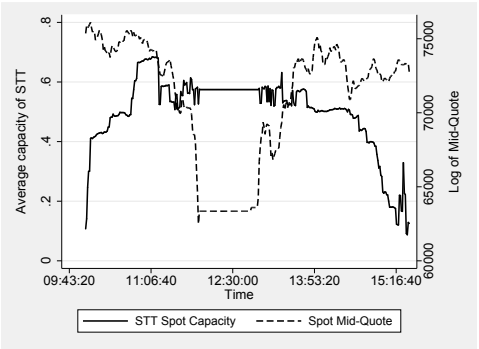
Panel C: Spot market, 19th of May 2006



Panel D: Futures market, 19th of May 2006



Panel C: Spot market, 22nd of May 2006



Panel D: Futures market, 22nd of May 2006