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# Inside the Opening Auction

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## Abstract

The opening auction (“the auction”) can provide appealing price and liquidity opportunities. However the auction mechanics can be vague and complex. In this paper, we provide a consolidated and detailed explanation of the auction mechanics and available pre-auction information. We also analyze NYSE and NASDAQ imbalance data from January 2011 to June 2011 to profile auction behavior. There are three takeaways we believe are most important for traders. First, imbalance volume is not representative of all the buying and selling interest in the auction, only a slice of the interest revealed by the exchange. Second, in the NASDAQ auction, liquidity forms before any imbalance information is published, so traders need to carefully calculate how much can be traded while avoiding impact. Finally, in the NYSE auction, opening liquidity can change from orders added or cancelled at any time up to the auction, so traders need to actively monitor the published feed to avoid suddenly becoming a larger participant than intended.

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## I. Introduction and Motivation

For many institutional traders, the opening auction (“the auction”) can provide an important source of liquidity, especially for traders benchmarked to the previous close or open price who would incur risk by waiting to trade. For example, traders chasing high momentum stocks benefit from cheaper prices earlier in the day. Even passive traders should consider participating in the auction, thereby avoiding high spread costs existing early in the day.

The risk of price impact, however, makes the opening auction difficult to navigate. Trading in the auction requires a detailed understanding of the complex rules and behavior of each exchange, but information on auction rules is sparse and confusing. Few algorithmic trading strategies incorporate logic reflecting the implications of auction rules. As a result, some traders wait until after the open to begin their trading.

In this paper, we provide a detailed overview of both the NYSE and NASDAQ auction mechanisms. In particular, we carefully define the rules for trading the opening auctions, detail the pre-auction information available from the exchanges, discuss the role of the exchange in shaping the opening prices, and analyze the amount of liquidity available.

## II. Common Auction Mechanics

The opening auction occurs at the price that maximizes trading volume, called the “equilibrium” price. Insufficient buyers and sellers in an auction can result in volatile prices. To mitigate this unnecessary volatility, exchanges assist with price discovery in the opening auction. They do this by publishing imbalance information to attract more liquidity. A buy imbalance, for example, indicates an abundance of buying liquidity, in hopes of attracting sellers. The imbalance is calculated as the net buying and selling interest *at a single price point* in the auction, called the “reference” price, which is chosen by the exchange. Exchanges do not show the entire auction’s net buying and selling interest.

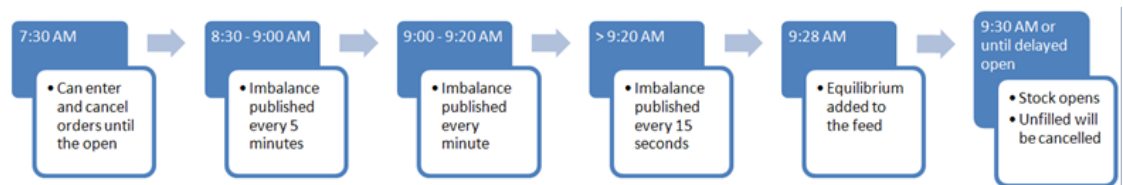
Exchanges have different methodologies to choose the reference price (explained in detail later for both NYSE and NASDAQ). Traders should be aware of how the chosen reference price at each exchange compares to the equilibrium price. If the selected reference price is below the equilibrium, the imbalance will indicate that there are relatively more buyers. However, if the selected reference price is above the equilibrium, the imbalance will indicate that there are relatively more sellers. Whether we see a buy or sell imbalance is completely subjective to what the exchange chooses as the reference price. It is possible, for example, to see a sell imbalance even though there is heavy buy interest and little sell interest, if the reference price is set higher than the equilibrium.

In addition to the reference price and imbalance side and quantity, exchanges publish paired volume. Paired volume represents matched buying and selling interest. Like imbalance, paired volume is calculated based on the reference price, so paired volume also may not represent the maximum shares that can cross in an auction.

### III. NYSE Opening Auction Mechanics

At the NYSE, the reference price is generally set to the previous close price. In the event of extremely high expected volatility, designated market makers (DMMs) can take measures to dampen the effect on opening price. There are few order placement restrictions, creating both opportunities and pitfalls for traders.

Figure 1: NYSE Auction Timeline



The NYSE holds an opening auction for each of its listed stocks. Traders can enter market-on-open (MOO) and limit-on-open (LOO) orders starting at 7:30 AM. Orders can be entered, modified, and cancelled until the stock opens, even if the opening is delayed. At 8:30 AM, the NYSE begins publishing imbalance data, including the NYSE-selected reference price, imbalance quantity, paired quantity, imbalance side, and equilibrium price. The equilibrium price is called the “continuous book clearing price” in the NYSE feed, and is not available until 9:28 AM. Data frequency increases closer to the auction, starting at five-minute intervals, and ending with 15-second intervals.<sup>1</sup>

The reference price used to calculate the imbalance is typically set to the previous close price. The resulting imbalance data is meant to attract liquidity and minimize volatility. The previous close price can be stale, as is the case when companies release news after hours or when overnight developments in Asia and Europe affect the US outlook. Therefore, the reference price may not reflect the true value of the stock.

In extremely heavy volatility, the DMM may choose not to use the previous close as the reference price. The designated market maker will choose a new reference price<sup>2</sup> when they believe prices will open far from the previous close. To qualify for a price change, the NYSE defines applicable price ranges for the distance between the previous close and the expected opening price.<sup>3</sup> The DMM can also intervene when there are heavy imbalances. The stock can be delayed to attract more liquidity from electronic orders (orders can still be entered even though it is after 9:30 AM), or verbal interest from floor brokers. If a stock’s auction is delayed, the imbalance data stops publishing at 9:35 AM. It is important to note that other markets can begin trading at any time, which is often the case when the NYSE opening is delayed.

<sup>1</sup>Imbalances publish every five minutes between 8:30 AM and 9:00 AM, every minute from 9:00 AM to 9:20 AM, and every 15 seconds from 9:20 AM to the opening time of the stock.

<sup>2</sup> To change the reference price, the DMM must publish an indication reflecting current market and liquidity conditions. If the indication bid is higher than the previous close, then the reference price will be the bid price. If indication offer is lower than previous close, then reference price will be the offer price. In the event of extreme market-wide volatility, indications do not have to be published. NYSE grants this exemption to help DMMs open the market in a timely manner (Rule 48).

<sup>3</sup>See NYSE Rule 15

When a stock opens, additional liquidity is added from the regular session, DMMs, and floor brokers. Day orders intended for trading in the regular session from 9:30 AM to 4:00 PM are swept into the auction when placed before 9:30 AM. DMM liquidity is an important part of the auction. The DMM is required to fill any unmatched marketable orders at the open price. Floor brokers may also supplement with their own capital. DMM and floor broker interest is usually not represented in imbalance data.

#### IV. NYSE Opening Auction Behavior

The average NYSE auction opening volume for very liquid names is 1% of median daily volume (MDV), which can rise to more than 6% of MDV on option expiration dates<sup>5</sup> (Figure 2). Illiquid names average a higher percentage of MDV in the auction (4%) and vary more widely. In liquid names, the median opening volume is 0.8% MDV, which drops by more than half in the 10<sup>th</sup> percentile and more than doubles in the 90<sup>th</sup> percentile. For illiquid names, the median is 1.2% MDV, which drops to zero in the 10<sup>th</sup> percentile and rises to 9.3% in the 90<sup>th</sup> percentile. The standard deviation for liquid names is 1.2% of MDV, while for illiquid names it can be much higher. This variability creates liquidity opportunities for traders, but also makes the auction risky, as it is easy to trade too much. Given this variability in opening volume, real time imbalances are very useful in providing traders a better sense of auction capacity.

Figure 2: NYSE opening volume

Opening size measured as a percent of 21-day median daily NYSE share volume<sup>6</sup>.

Trade Day Type	Liquidity Bucket	Average Open % MDV	Open % MDV Percentile		
			10%	50%	90%
Regular day	4M+	1.0%	0.3%	0.8%	1.7%
	1-4M	1.0%	0.3%	0.8%	1.8%
	.5-1M	1.2%	0.3%	0.8%	2.3%
	<.5M	4.2%	0.0%	1.2%	9.3%
Options expiry	4M+	6.5%	0.6%	5.3%	14.3%
	1-4M	6.0%	0.6%	4.7%	13.0%
	.5-1M	7.1%	0.5%	5.0%	15.7%
	<.5M	9.4%	0.0%	3.4%	24.7%

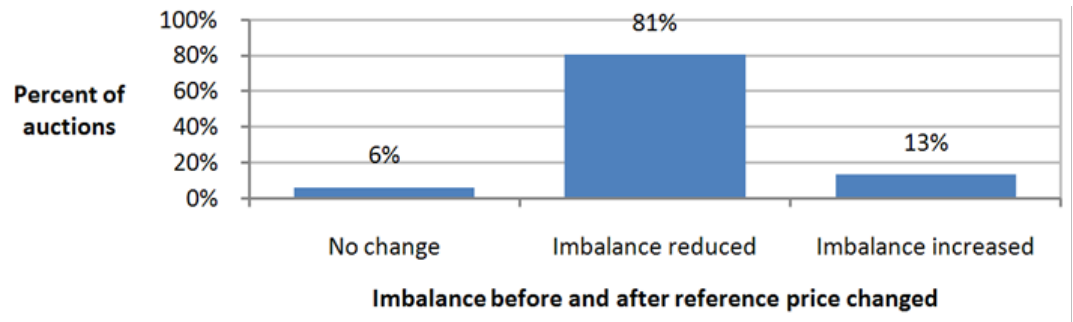
If the DMM expects severe volatility, he may change the reference price at the beginning of the auction process. This occurs in about 7% of the opening auctions.<sup>7</sup> Reference prices rarely change later in the auction. The new reference price is usually closer to the equilibrium price, naturally carrying a smaller imbalance (Figure 3).

<sup>4</sup>Floor broker interest is usually verbal and DMM interest is likely added last. The DMM has the “last look” at the auction liquidity, and can add their interest accordingly.

<sup>5</sup>Opening auction volume increases on options expiration dates because the corresponding open price is used for settlement of index options.

<sup>6</sup>Results are similar when dividing by day volume. We use MDV because the day’s volume is not available when trading the open.

Figure 3: When the NYSE reference price is changed, the imbalance is typically reduced



During the NYSE auction, liquidity can change, causing unexpected behavior such as imbalance side reversal and decreases in paired volume. For liquid stocks greater than four million shares MDV, side reversals happen in 8% of the auctions (Figure 4), though it varies much more for lower volume names. It is also possible for auction liquidity to decrease, creating potential for the stock to open further from the reference price. While most of the time there is no significant decrease in paired volume, paired volume decreases in 6% of the auctions for stocks < 0.5% MDV (Figure 5), on average.

Figure 4: Imbalance side reversal

We count only significant disappearance or appearance of paired volume, at least 0.5% MDV.

	Percentage of auctions			
	4M+	1-4M	.5-1M	<.5M
Side changed	8%	10%	13%	21%
Side did not change	92%	90%	87%	79%

Figure 5: Decreasing paired volume

We count only significant decreases in paired volume, of at least 0.5% MDV.

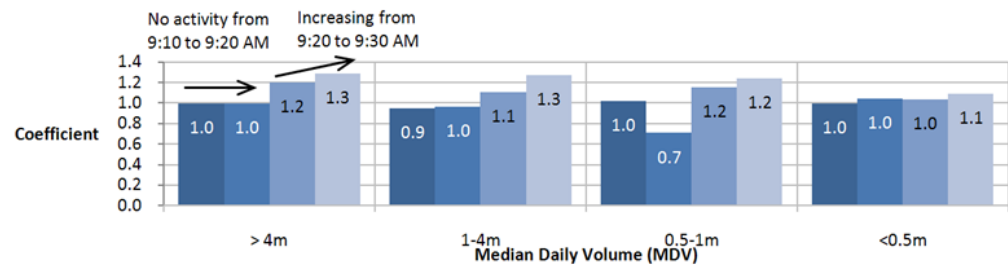
	Percentage of auctions			
	4M+	1-4M	.5-1M	<.5M
Paired volume did not drop	100%	99%	98%	94%
Paired volume dropped	0%	1%	2%	6%

<sup>7</sup>Calculated from June 2011 NYSE imbalance data by comparing the NYSE closing print with the reference price in the first imbalance message.

NYSE auction liquidity is unrestricted; orders can be added, corrected, and canceled until the stock opens. Though upon analysis, it seems that when there is an imbalance, the imbalance persists. Multiple regression analysis on imbalance data showed a strong persistence, even worsening, of the imbalance. First we use the 9:10 AM imbalance to explain the 9:15 AM imbalance, and then use the 9:15 AM imbalance to explain the 9:20 AM imbalance, and so forth. From 9:10 to 9:20 AM, the coefficients are very close to 1 (Figure 6). This means the imbalance doesn't change on average during this time. From 9:20 to 9:30 AM, the coefficients are larger than 1, indicating the imbalance actually increases on average.

**Figure 6: Regression shows NYSE imbalance unchanged (and by liquidity group)**

The charts below show the results of four independent regressions. Bars represent the regression coefficient of the later imbalance regressed on the earlier imbalance (times indicated by legend).



If the imbalance persists, the DMM may try to attract more liquidity by delaying the open. DMMs delay 19% of opening auctions on average (Figure 7). The probability of a delayed open increases with the size of the last imbalance (Figure 8). If the imbalance is 0-1% of MDV, for example, the probability of a delayed open is 4%. If the imbalance is 4-5% of MDV, the probability of a delayed open rises to 14%.

Because imbalance relative to the previous close tends to persist, stocks often open far from the reference price. Approximately 45% of stocks open outside of 50 bps from the reference price, and more than 15% of stocks open more than 100 bps from the reference price.

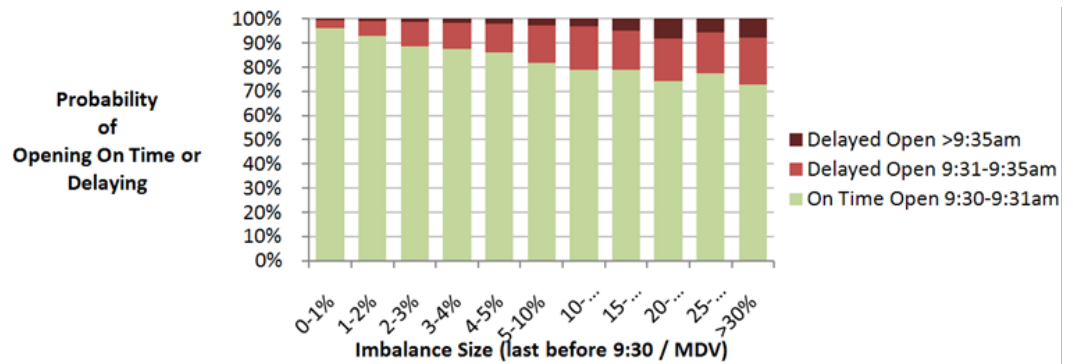
**Figure 7: Most of the time, stocks open at 9:30 AM, but late opens are noticeable**

Percentage of auctions opening on time or late. To conservatively estimate stocks opening late, stocks opening by 9:31 AM are classified as "on time."

Liquidity Group (MDV)	On Time Open 9:30 AM - 9:31 AM	Delayed Open 9:31 AM - 9:35 AM	Delayed Open > 9:35 AM
Overall	81%	18%	1%
4M+	85%	15%	0%
1-4M	82%	17%	0%
.5-1M	81%	19%	1%
<.5M	79%	19%	2%

**Figure 8: Imbalance increases probability of delayed open**

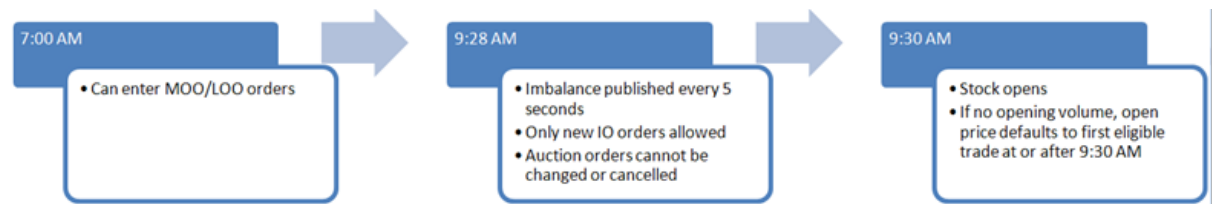
Increasing the imbalance by a large amount could delay the open. The imbalance comes from the last message before 9:30 AM as a percentage of 21 median day volume.



## V. NASDAQ Opening Auction Mechanics

The NASDAQ auction operates very differently than the NYSE auction.

**Figure 9: NASDAQ auction timeline**



NASDAQ holds opening auctions in NASDAQ and NYSE-listed stocks. Market-on-open (MOO) and limit-on-open (LOO) orders can be entered starting at 7:00 AM. MOO and LOO orders can be added, modified, and cancelled until 9:28 AM. During this time, no imbalance data is published. Accordingly, traders don't have to worry about information leakage, but at the same time, they do not know how much liquidity will be available in the auction. This can be problematic because opening liquidity is so volatile that traders could easily impact prices. Traders have to make their best guess on what to do without imbalance information because after 9:28 AM, they will not be able to undo their decisions. At 9:28 AM, imbalance information is published every five seconds, ending at 9:30 AM. The NASDAQ imbalance feed contains the reference price, paired volume, imbalance volume, imbalance direction, far price<sup>8</sup>, and near price<sup>9</sup> at the time of publication.

<sup>8</sup>Far price is the price where the most buying and selling interest match with auction liquidity.

<sup>9</sup>Near price is the price where the most buying and selling interest match with auction and premarket liquidity.

Imbalance quantity is based on a reference price constrained to be inside the NASDAQ best bid/offer (BBO). When the equilibrium price is below/above the BBO, the reference price is set to the bid/offer. When equilibrium price is inside the BBO, the reference price is chosen as the point where paired volume is maximized, imbalance is minimized, and distance to BBO midpoint is minimized (in that order). This series of conditions is applied to handle situations where there are multiple equilibrium points within the BBO. For example, an auction consisting exclusively of market orders to buy and sell has many equilibrium points. It is important to note the NASDAQ BBO need not be the same as the national best bid/offer. Better quotes from other exchanges and ECNs are ignored.

While imbalance information is published in the last two minutes of the auction, order placement is restricted during this time. No new MOO or LOO orders can be placed, and existing MOO and LOO orders cannot be corrected or cancelled after 9:28 AM. Traders can only enter imbalance only (IO) orders that offset available imbalance. IO orders can be placed at any time in the auction, must have limit prices<sup>10</sup>, and cannot be corrected or cancelled.

As the stock opens, orders from the NASDAQ premarket session are swept into the auction. This means traders can use the premarket session to get around the offset-only restrictions in the final two minutes before the auction occurs. The premarket session has no restrictions on order placement, but traders placing such orders should be cautious of inadvertently executing before the auction, missing the open price benchmark, and potentially impacting prices. Regular session limit orders (intended for trading from 9:30 AM to 4:00 PM) are also swept into the auction. Regular session limit orders will be converted to IO orders. In the event there is no opening liquidity for a particular stock, that stock will open with a quote.

## VI. NASDAQ Opening Auction Behavior

On average, the NASDAQ opening volume is 0.8% of MDV for very liquid names (Figure 10). The average volume grows as names become less liquid and can increase dramatically on option expiration days (up to 18% of MDV for illiquid names). In liquid names, the median opening volume is 0.7% of MDV, dropping by more than half in the 10<sup>th</sup> percentile and doubling in the 90<sup>th</sup> percentile. The variability increases dramatically for illiquid names. Extremely variable volume and inability to correct orders after 9:28 AM means reliable predictors of opening volume are essential for trading the NASDAQ auction in order to avoid price impact.

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<sup>10</sup>When the open occurs, aggressively priced imbalance only orders are re-priced to the passive side of the NASDAQ BBO. Buy orders are re-priced to the bid price, and sell orders are re-priced to the ask price.

**Figure 10: NASDAQ opening volume**

Opening size measured as a percent of 21-day median daily NASDAQ share volume.

Trade Day Type	Liquidity Bucket	Average Open %	Open % MDV Percentile		
			10%	50%	90%
Regular day	4M+	0.8%	0.3%	0.7%	1.4%
	1-4M	1.0%	0.3%	0.7%	1.9%
	.5-1M	1.2%	0.2%	0.8%	2.5%
	<.5M	3.7%	0.0%	0.9%	6.3%
Options expiry	4M+	7.3%	0.5%	4.9%	16.9%
	1-4M	6.9%	0.5%	4.9%	16.8%
	.5-1M	9.0%	0.6%	6.8%	21.1%
	<.5M	18.4%	0.0%	9.4%	47.5%

Most of NASDAQ opening volume forms between 7:00 and 9:28 AM, where traders enter orders with no imbalance information. This is evident in the initial (9:28 AM) paired volume, which accounts for almost all of the volume that will execute in the open (Figure 11).

**Figure 11: Paired volume at initial imbalance as % of open volume**

Paired volume at first imbalance message divided by that day's opening volume.

MDV	Paired Volume as % of Open Volume Percentiles								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
4M+	85%	93%	97%	99%	100%	100%	100%	100%	100%
1-4M	85%	95%	99%	100%	100%	100%	100%	100%	100%
.5-1M	89%	100%	100%	100%	100%	100%	100%	100%	100%
<.5M	0%	51%	100%	100%	100%	100%	100%	100%	100%

From 9:28 to 9:30 AM, little liquidity is added to the auction because there are few imbalances to offset (Figure 12). This happens because the reference price is often set at the equilibrium, the point with minimized imbalance shares. Few imbalances leave the trader in a position where they cannot make up for submitting too little volume in the pre-9:28 AM period. This is another reason why good volume prediction is needed when participating in the NASDAQ auction.

Figure 12: The NASDAQ initial imbalance as % of MDV

MDV	Initial Imbalance % MDV Percentiles								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
4M+	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.07%	0.17%
1-4M	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.16%
.5-1M	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%
<.5M	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

There is evidence of the premarket session “creating” imbalances after 9:28 AM. Pre-market trading can change the BBO, thereby changing the reference price and calculation of imbalance and paired volume. Overall, 6% of the auctions begin with no imbalance but end with an imbalance, though this does vary widely by MDV (as shown in Figure 13). Given a constant reference price, this should not be possible because imbalances can only be offset, but the reference price is more volatile in liquid names because there is more premarket activity (Figure 14). The reference price changing also explains the rare scenarios of imbalance side reversals and growing imbalances, which should also not occur when reference price is constant. Traders working liquid names may benefit from this by offsetting imbalances as they appear.

Figure 13: NASDAQ imbalance scenarios

Imbalance represented as a percent of 21 day median volume. Measured change from initial imbalance at 9:28 AM to final imbalance at 9:30 AM. We counted the number of auctions with each outcome.

Percent of Auctions Occurring in Each Scenario								
MDV	No Initial or Ending Imbalance	No Initial Imbalance then Imbalance Created	Imbalance worsened	Imbalance Side Reversal	Imbalance Stayed Same	Imbalance Partially Offset	Imbalance Completely Offset	Total
4M+	42.21%	17.99%	1.93%	2.40%	0.45%	9.40%	25.62%	100%
1-4M	66.37%	13.93%	1.06%	0.47%	0.16%	4.31%	13.70%	100%
.5-1M	80.41%	7.47%	0.64%	0.12%	0.28%	2.99%	8.10%	100%
<.5M	89.12%	4.32%	0.40%	0.04%	0.96%	1.66%	3.51%	100%
Overall	84.19%	6.12%	0.55%	0.18%	0.79%	2.35%	5.83%	100%

**Figure 14: Liquid names have more and larger reference price changes**

Below are number of reference price change percentiles, and the range of the reference price in bps. Since NASDAQ publishes imbalance snapshots every 5 seconds, there are only 24 possible reference price changes for each auction.

MDV	Number of Reference Price Changes									Avg Reference High Minus Low (in bps)
	10%	20%	30%	40%	50%	60%	70%	80%	90%	
4M+	0	0	1	1	1	2	3	4	5	24.11
1-4M	0	0	0	0	0	1	1	2	4	20.61
.5-1M	0	0	0	0	0	0	0	1	2	15.22
<.5M	0	0	0	0	0	0	0	0	1	12.41

While NASDAQ does hold auctions for NYSE-listed stocks, traders tend to place their orders with the primary exchange. Often there is no buying or selling interest at NASDAQ opening for NYSE-listed names. Coverage is moderate in liquid stocks, holding auctions in 82% of NYSE listings with 4M+ ADV (Figure 15). Non-primary auctions look unappealing as NASDAQ auction volume in NYSE listings are smaller than the corresponding NYSE auction volume (Figure 16). Moreover, there is a high risk of getting an opening price far from that on the primary exchange. Even for a very liquid NYSE stock trading more than four million shares MDV, the NASDAQ opening price is 17 bps from the NYSE opening price (Figure 16). Therefore, traders should generally trade using the NYSE opening auction when trading NYSE-listed stocks.

**Figure 15: NASDAQ auction has moderate coverage of NYSE stocks**

NASDAQ has auctions for NYSE listings. The reverse does not exist. These calculations are based on January 2011 tick data.

MDV	% of NYSE Names with NASDAQ Auctions
4M+	82%
1-4M	66%
.5-1M	44%
<.5M	8%

**Figure 16: NASDAQ auctions of NYSE listings have lower volume and different prices**

We omitted imbalances with no reference prices. These calculations are based on January 2011 tick data.

MDV	% of Observations	Avg NASD Open Size/NYSE Open Size	Avg Difference Between NASD and NYSE Open Price (bps)	Med Difference Between NASD and NYSE Open Price (bps)
4M+	20%	2%	17	11
1-4M	41%	3%	20	13
.5-1M	19%	4%	26	17
<.5M	20%	17%	46	26

## VII. Conclusion

The NYSE and NASDAQ opening auctions play an integral role in the market. They represent an important source of liquidity in equity markets, but can be risky if not used appropriately. In our study of the opening auction processes, we believe the three most important takeaways for traders are:

- Traders should be aware that the published paired and imbalance volume is not representative of all the buying and selling interest in the auction, only the interest at the price the exchange has selected (previous close price at the NYSE, price with minimized imbalance within the best bid/offer at NASDAQ).
- At NASDAQ, because most liquidity forms before any imbalance information is published, traders need to carefully calculate how much can be traded while avoiding impact.
- At NYSE, because opening liquidity can change from orders added and cancelled at any time up to the auction, traders need to actively monitor the published feed to avoid suddenly becoming a larger participant than intended.

Traders and algorithms should try to incorporate this knowledge of auction and real-time pre-auction information to participate effectively in the opening auction. Because participation in the auction requires such careful calculation of auction capacity and attention to pre-auction fluctuations in imbalance information, participation via a smart algorithm may be ideal.

## End Notes

This study was conducted on NYSE and NASDAQ imbalance data from January 2011 to June 2011. Any opinions expressed herein reflect the judgment of the individual author(s) and are not necessarily those of ITG. The information contained herein has been taken from trade and statistical services and other sources we deem reliable but we do not represent that such information is accurate or complete and it should not be relied upon as such. Compliance #110311-24005.

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