Determinants of Post Stock Distribution Volatility of Returns

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Abstract

To explain and provide a direct evidence about the puzzle of persistent increases in volatility of returns after a stock distribution, we use decimalization as a natural experiment. We focus on the role price discreetness plays in volatility of returns and compare two periods with different minimum tick sizes: 1993 to 1997 (Period-1) and 2001 to 2018 (Period-2). We find that Period-1 (Period 2) had an average 26.15% (7.14%) increase in volatility of returns. This shows that a lower minimum tick size has more price quote flexibility allowing for spreads to better represent the change in conditions after a stock distribution.

Introduction

The reasons management of a firm decides to execute a stock distribution (stock split or stock dividend) is still an unresolved and puzzling issue. Many prior studies show evidence that support signaling theory (Millar and Fielitz [1973], Woolridge [1983], Ikenberry et al [1996], McNichols and Dravid (1990), Elgers and Murray (1985), Brennan and Copeland [1988]), trading range and liquidity (Baker and Powell [1993], Muscarella and Vetsuypens [1996], Desai et al [1998], Lakonishok and Lev [1987]), the paid-in capital hypothesis (Adaoglu and Lasfer [2011]), ownership structure (Szewczyk and Tsetsekos [1995], Schultz [2000], Dennis and Strickland [2003], Mukherji et al [1997], Baker and Gallagher [1980]), and executive compensation (Jayaraman and Milbourn [2011], Devos et al [2018]) among many other potential reasons. Within the stock distribution literature there is another puzzling and unresolved empirical anomaly which is the persistent increase in volatility of returns observed after the execution of a stock distribution. This result is bewildering because, economically, stock splits are cosmetic events and just adjust the price of the minimum unit of trade in the stock exchange. Moreover, this is in contrast with the notion that the equity market value of a firm does not depend on the number of shares outstanding which in turn implies that returns on a security should not depend on the number of shares outstanding either. Understanding the causes of the increase in volatility is of importance because of the association with the aforementioned extant stock distribution literature– i.e. liquidity, executive compensation, etc. – and the implications on participants in the financial markets.

Ohlson and Penman (1985) – O&P from here on – investigated the behavior of stock return volatility before and after the execution of a stock distribution. O&P provided evidence that following the stock distribution ex-date there is an increase in the returns' standard deviation of about 30% on average. This "*empirical aberration*" holds for both daily and weekly data, persistent, and not caused by any confounding explanatory variables. Interestingly, the mean returns in O&P behave normally before and after the execution of the stock distribution, and are consistent with prior studies such as Brown and Warner (1985). O&P`s findings come from measuring increases in the volatility of returns based on the square root of the mean squared returns post stock distribution relative to the mean squared returns before the stock distribution. It has been suggested that the bid-ask bounce effect is associated with the volatility of returns (e.g. Amihud and Mendelson, 1987; Lim and Vijh, 1986; Sheikh, 1989; Conroy, 1990; Hwang, 1995;

Park and Krishnamurti, 1995). Other studies also analyzed and suggested a relation between bid-ask spreads, tick size (i.e. price discreteness), and the variance of returns (e.g. Blume and Stambaugh, 1983; Gottlieb and Kalay, 1985, Amihud and Mendelson,1987; Kaul and Nimalendran, 1990). On the other side, Dubofsky and French (1988) and Koski (1998) do not find evidence that supports the notion that bid-ask spreads and tick size are related to increases in variance after a stock distribution. Gottlieb and Kalay (1983) analyze the implications of the discreteness of stock prices on the estimation of standard deviations of returns utilizing simulations which assume that true returns follow a geometric Brownian motion. They conclude that the usual estimator of the standard deviation can be severely biased upwards. The severity of the problem depends (i) on the absolute price and (ii) the standard deviation of the true but unobservable returns. More recently, French and Foster (2002) examines the change from the 1/8 minimum tick size to the 1/16 minimum tick size that took effect in 1997 to directly test price discreetness as a determinant of variance increases after a stock distribution. Based on their results, they state that the post stock distribution increase in variance of returns remains unchanged conclude that price discreteness is not a cause, and declare that this issue remains a puzzle.

Based on the conflicting empirical findings, as well as the differing theoretical explanations in the extant literature, our position is that two market microstructure components; (i) price discreteness (i.e. minimum tick size) in conjunction with (ii) bid-ask spreads may not be the only causes for the post stock distribution increase in volatility. However, these two components are, at least, mainly explain to post stock distribution increase in volatility. We also posit that the change in minimum tick size from 1/8 to 1/16 may not have been large enough to directly test and hence detect a significant relation between price discreetness and the increases in returns volatility after a stock distribution. We address these two points by comparing the 1/8 ($0.125) minimum tick size period (Period 1) with the decimalization period (Period 2) which is when stock prices changed from fraction quotes to the use of decimal places ($0.01 minimum tick size). We apply a method that incorporates quoted prices (CRSP closing prices, variable PRC) and unobserved true prices as defined by Bhardwaj and Brooks (1992) and consistent with Blume & Stambaugh (1983). In addition, we use proportional spreads as per Stoll (1989) and Krinsky and Lee (1996). Besides, we use quoted prices and true prices to calculate and analyze the volatility of realized returns and true returns. Here true returns are calculated from changes in the unobserved true price.

We strive to answer the following empirical questions: Is there a significant relation between price discreteness (i.e. minimum tick size) and bid-ask spreads with the volatility of returns? Are the increases in volatility of returns after a stock distribution are larger during the 1/8 minimum tick period than during the decimalization period?

In our study, we find that spreads decrease after a 100% stock distribution in both periods. However, spreads decrease at a higher percentage in Period 2 than in Period 1. This holds true in the three exchanges we analyze. For NYSE, the decrease goes from an 11.04% decrease in Period 1 to a 33.28% decrease in Period 2, for AMEX is from 22.96% to 40.67%, and for NASDAQ is from 27.90% to a 44.82% decrease in spread. The higher decreases in spread in Period 2 can be attributed to the more flexible minimum tick size of $0.01 in comparison to the 1/8 minimum tick size of Period 1. While some of these decreases in spread are close to 50% (the decrease in price after a 100% stock distribution), they do not reach that percentage resulting in an increase of the spread-price ratio after the stock distribution. We find that the difference in means between pre-stock distribution and post-stock distribution volatility of returns is statistically significant for larger changes in spread-price ratio after the stock distribution, but becomes insignificant for smaller changes in spread-price ratio. These findings are contrary to French and Foster (2002).

When analyzing the three stock exchanges (AMEX, NYSE, and NASDAQ) separately, we compare quoted prices with mid-point prices (a.k.a. true prices). We observe a significant difference in means between the two in most cases. However, in most cases, we do not find sufficient evidence to suggest that there is a difference in mean returns that were calculated with quoted prices and mean returns calculated with true prices (true returns). This is evidence that quoted price movement is affected by price discreetness, but the price movements do not affect the mean realized returns which is consistent with O&P and Brown and Warner (1985). We also find that Period 1 has greater increases in volatility of returns than Period 2 on average which delivers more evidence that the minimum tick size (price discreetness) is responsible for a large portion of the observed post stock distribution changes in volatility of returns.

In our regression models, we show that changes in the spread-price ratio have a positive relation with changes in the volatility of returns, and that a smaller tick size reduces the changes in volatility of returns. Both of these findings are direct evidence that price discreetness does have an effect on the observed increases in volatility. We also find evidence that applying true prices mitigates the differences between the three stock exchanges. In addition to that, consistent with

Schultz (2000) and French and Roll (1986), we also find a significant relationship between trading volume and the volatility of returns. Our trading volume results are similar to French and Foster (2002), but different regarding price discreetness. French and Foster (2002) concluded that price discreetness is not one of the causes of observed increases in stock return variances following a stock distribution when they analyzed the 1/8 minimum tick size period versus the 1/16 minimum tick size period. On the contrary, we find evidence that price discreetness is significantly related to observed increases in stock return variances following a stock distribution when we analyzed the 1/8 minimum tick size period versus the decimalization period. This finding supports our premise that changing from 1/8 to 1/16 may not have been a large enough change to fully capture the effect of price discreetness.

We contribute to the stock volatility literature by examining the relation between price discreteness (minimum tick size) and bid-ask spreads with the volatility of returns by utilizing the change in minimum tick sizes in two periods, and identify the level of that relation. The key differences, among many, in our paper from prior studies are the use of a different determinant variable (changes in spread-price ratio) and providing direct evidence by contrasting two periods with a greater magnitude of change in minimum tick size. Although the announcement of a stock split is a discretionary, for our study this is not a time variant factor.

The rest of this study contains the following sections: Section 2 describes the data and method. Section 3 contains the descriptive statistics and the true price variable calculation. Section 4 investigates the determinants of changes in volatility. Section 5 concludes.

2. Data and Method

In our paper, we first extend the O&P sample to 1997 (before decimalization) which helps verify that the O&P findings were not unique to the time period in their study and that the changes in volatility still continues to exist. We also create reliable subsamples for the 1/8 minimum tick size period (1993-1997) and the decimalization period (2001-2018). For the O&P extension and other subsamples we use NYSE, AMEX, and NASDAQ stock distributions: CRSP stock splits (5523) and stock dividends (5533). We start our analysis with stock distributions that have a 100%, 150%, 200%, 300%, 400%, and 900% factor. The O&P extension dates are from July 2, 1962 to February 1, 1997 for NYSE and AMEX; for NASDAQ, it starts in 1971. The subsamples representing the 1/8th of a dollar minimum tick period and the decimalization period are from May

1, 1993 to February 1, 1997 and from February 1, 2001 to December 31, 2018, respectively. The gap between these dates is to omit the period in which the minimum tick was 1/16th of a dollar. The 1993 start date for the 1/8th period was chosen because of unreliable Bid-Ask data prior to 1993[2].

We collect data for 75 trading days before the execution of the stock distribution and 75 matching trading days after the execution. Following the method in O&P, we apply a day of the week matching process. For each distribution, the squared return for the first trading day following the declaration date (pre-stock distribution) was matched with the squared return for the first same day of the week following the stock distribution date (post stock distribution). Also, the second squared daily return following the declaration date was matched with the squared return of the next same day of the week following the stock distribution date, and so on until the day just prior to the stock distribution execution date. The number of comparisons is therefore basically equivalent to the number of trading days between the declaration and execution dates[3].

The sample's pre-stock distribution volatility was measured as the mean squared returns between declaration date (CRSP: DCLRDT) and execution date (CRSP: PAYDT) – a.k.a. pre-stock distribution. Post stock distribution volatility was measured as the mean squared returns after the execution of the stock distribution and up to the amount of trading days equal to the pre-stock distribution dates. The change in volatility is the square root of post stock distribution mean squared returns divided by the pre-stock distribution mean squared returns minus one.

$$[E(R_2^2)\ /\ E(R_1^2)]^{1/2} - 1$$

[2] As per the statement in the Wharton Research Data Services (WRDS) website: "The Bid (Ask) for the New York Stock Exchange (NYSE) and American Stock Exchange (AMEX) securities is not the inside quotation, but the Bid (Ask) price from the last representative quote before the markets close for each trading date. Due to source limitations, only an unrepresentative quote was available on many days. These unrepresentative quotes showed very large spreads, frequently a Bid of a penny and an Ask of approximately double the price. These were usually posted by a market marker not on the primary listed exchange, who was required to post a quote but not interested in making a trade. From 1992 on, Bid and Ask were set to 0 when CRSP determined that the available quote was unrepresentative of trading activity, pending further research. Bid (Ask) data for NYSE are available from December 31, 1925 through the most currently completed month for securities when no closing price is available. Between December 31, 1925 and February 23, 1942, a continuous series of Bid (Ask) data are available whether or not a closing price is available. Between February 24, 1942 and December 27, 1992, Bid (Ask) is available only in cases when a closing price is missing. Beginning December 28, 1992, a continuous series of Bid (Ask) data are available."

[3] Similar to O&P, the number of comparisons is occasionally less than the total number of trading days between declaration dates and ex-dates because of missing returns on the CRSP Daily Returns File and/or because the requirement to match on days of the week, some days had to be dropped when the exchange was closed on the corresponding day of the week on either side of the post distribution execution date

Where R_i is the daily returns of date range ***i*** which refers to the date range before the stock distribution execution (1) and the date range after the stock distribution execution (2).

3. Descriptive Statistics and True Price

Table 1 presents total stock distributions and volatility of return statistics for our O&P extension and subsamples. Panel A reports the stock distributions by percentage factor in each of the three exchanges (NYSE, AMEX and NASDAQ) for each period. The decline in stock distribution activity observed in the 2000's subsample is consistent with Minnick and Raman (2014). In all three exchanges, 100% stock distributions dominate the sample: about 88% of the entire sample with a low of 85% in the decimalization period (2001-2018) and a high of 90% during the 1993-1997 period.

TABLE 1 HERE

Using the total stock distributions for each period, Panel B of Table 1 reports the mean volatility of returns[4] and the change in volatility after the execution of the stock distribution and also by stock exchange sub-groups. For the O&P extension sample (1/8 minimum tick), we see that all three exchanges (combined and individually) have a significant average increase in volatility of returns. All exchanges combined have a 23.60% increase, NYSE has a 31.87% increase, AMEX has a 22.88% increase, and NASDAQ has a 20.12% increase. In the 1993-1997 subsample also belonging in the 1/8 minimum tick era, we observe similar average increases. We see that our numbers are consistent with the O&P study.

In the 2001-2018 decimalization period subsample, only NYSE has a significant increase. However, NYSE's change in volatility was reduced to a much lower 13.81% change. The data in Panel-B shows that all three exchanges had a large reduction in changes in volatility of returns when the minimum tick size was reduced to \$0.01 from 1/8 of a dollar.

We also report in Table 1 the probability ($\Pr\{R_2^2 > R_1^2\}$) of the post stock distribution volatility of returns (R_2^2) being greater than the pre-stock distribution volatility of returns (R_1^2). We conduct a binomial Z-stat test[5] with a null hypothesis of $\Pr\{R_2^2 > R_1^2\} = 0.5$ and all results are

[4] All calculations done across the entire study were also conducted using returns without cash dividends (CRSP: RETX). Consistent with Ohlson and Penman (1985), there were no significant differences in the results which suggest that cash dividends are not a factor in the changes of volatility after a stock distribution.

[5] Binomial Z-Stat Test = $2\sqrt{n}(\Pr\{R_2^2 > R_1^2\} - 0.5)$

significant indicating that R_2^2 being greater than R_1^2 is significantly more probable. Although we see a similar pattern in the 2001-2018 period, we also observe that there is a reduction in frequency of R_2^2 being greater than R_1^2. This finding indicates that a lower minimum tick size helps reduce incidences in increases of volatility after a stock distribution. Lastly, Table 1 shows that the 1993-1997 sample is very similar to the 1962-1997 sample and a good representation for the 1/8 minimum tick size era, and considering the data reliability issues aforementioned, a preferred sample.

Because our sample is dominated by 100% stock distributions, we proceed to calculate the changes in volatility of returns by the distribution percentage factor. A fundamental part of our method is to examine the spread of a stock and its relationship with its price. The percentage change of a stock price after a stock distribution is different for each one of the distribution percentage factors. We argue that stock distributions with different distribution factors should be analyzed individually in order to control for the differences in price percentage change. Accordingly, we chose to focus our analysis on the 100% factor subsample because of it being the closest representation of the whole, and also it provides the largest sample available. In addition, AMEX sub-sample does not have much data available – in CRSP database – outside the 100% factor subgroup. Accordingly, for the remainder of this study, we will continue with 100% stock distributions only. We will also focus on the 1993-1997 and 2001-2018 sub-periods only. We start at 1993 because of the aforementioned data reliability issues before that year. We feel confident that the 1993-1997 sample is suitable as it delivers results very similar to the larger sample that dates back to 1962. An added benefit is that the 1993-1997 sample has all exchanges present the entire time since NASDAQ began operations in 1971, many years after NYSE and AMEX.

Table 2 reports the change in volatility of returns after a stock distribution. Across all percentage factors, with the exception of a few, we observe a vast majority of our sample's stock distributions have increases in the volatility of returns. Predictably, due to its aforementioned dominant representation in the sample, the values of the 100% factor are the ones that mostly resemble the values in Table 1/Panel B which uses all stock distribution together regardless of the split factor. For example, when comparing the 100% stock distribution values for the 1993-1997 period in Table 2 versus Table 1 values, we see in Table 2 an average increase in volatility in all exchanges of 26.15% versus a 24.39% increase in Table 1. In the same period and group, the probability of an increase of volatility of returns after a stock distribution is also very similar; Table 1 reports a 0.5579 versus a 0.5600 in Table 2.

TABLE 2 HERE

Table 3 reports the mean spreads and mean volume before and after the stock distributions. The mean spreads in the decimalization period (2001-2018) are much lower than in the period with 1/8 minimum tick size (1993-1997). This is observed for mean spreads pre-and post-execution of the stock distributions. This outcome can be attributed mostly to lower price discreetness constraints thanks to a less restrictive minimum tick size.

A key part of our study is the change of the mean spread after the stock distribution. In the 1993-1997 period, the percentage change in stock volatility following 100% stock distributions ranges from an average decrease of 11.04% (NYSE) in the lower end to a 27.90% (NASDAQ) in the upper end. These changes are not close to the 50% decrease a stock price undergoes at the execution of a 100% stock distribution. This results in the spread having a greater value relative to the price. This is also expressed as an increase in the spread-price ratio after the stock distribution. The changes in mean spread during the 2001-2018 decimalization period range from 33.28% to 44.82% which is also less than the 50% change in stock price after the stock distribution. However, it is much closer to 50% which means that the increase in the spread-price is smaller than the 1993-1997 period.

TABLE 3 HERE

Table 2 shows that the differences in spread-price ratio increases across the exchanges and the two periods, when analyzed in conjunction with the changes in volatility of returns. In Table 3, we also notice a trend where the greater the increases in spread-price ratio (or lower percentage change in spread) after a stock distribution are in line with greater increases in volatility of returns after a stock distribution. This pattern, moreover, fits with the frequency in which post stock distribution volatility is greater than pre-stock distribution volatility. In other words, the greater the increases in spread-price ratio after a stock distribution the greater the frequency. While we examine an event that results in a price decrease, the spread-price ratio effect on volatility of returns would also work in the other direction. Namely, price increases can result in a smaller spread-price ratio and in turn contribute to reductions in volatility of returns which is consistent with Black (1976) and Christie (1982) – time series analysis return variances typically decrease as the stock price increases. Unlike the O&P study that by the authors' own admission did not directly relate to Black (1976) and Christie (1982), our method can bridge the gap between these studies. Lastly on Table 3 we present the changes in volume. As expected, volume increases following a stock distribution. These increases in volume could also be a driver of increases in volatility. The notion that increases in trading activity can lead to increases in volatility is also suggested by Schultz (2000) and French and Roll (1986).

In Table 4 we introduce the True Price concept as defined by Bhardwaj and Brooks (1992). They state that when computing returns an estimation of the Bid-Ask bias can be done by using a general Bid-Ask effect model. They extend a model first introduced by Blume and Stambaugh (1983) in which transactions can occur at Bid or Ask prices with different probabilities[6].

TABLE 4 HERE

Panel A in Table 4 compares quoted prices with mid-point prices [(Ask+Bid)/2, a.k.a. true prices] for all exchanges combined and there is a significant difference in means between the two prices. The same seems to be the case in most instances for realized returns versus true returns (returns that were calculated with true prices).

Panel B in Table 4 presents the squared returns as a measure of volatility. We see that during the 1993-1997 period there was a significant difference between the mean squared realized returns and the mean squared true returns after the stock distribution. We observe a similar pattern during the between before the stock distribution sample during the 2001-2018 period. The evidence in Panel B also presents a result in favor of a difference in mean volatility between the two periods (1993-1997 vs. 2001-2018) before and after the stock distribution.

Panel C in Table 4 reports the change in volatility of returns based on quoted values and true values. Using True Prices, which helps control for the effect of constraints imposed by minimum tick size, presents a much lower change in volatility. In the 1993-1997 period, we get an

[6] For the details/assumptions of the model visit the Bhardwaj and Brooks (1992)

increase of volatility of 26.15% with quoted prices while true prices deliver a much lower 11.05% increase in volatility. In the 2001-2018 period, we see a significant change as in volatility. It changes from a 7.14% increase to a 0.56% decrease. The same pattern is observed between the 1/8 minimum tick size period and the decimalization period. Overall, considering the information in Panel B, we can claim that these reductions in volatility are significant. This is additional evidence supporting the idea that price discreetness constraints caused by minimum tick size play a significant role in volatility of returns.

TABLE 5 HERE

Considering that the combined analysis of three exchanges may have different patterns in bid-ask quotes, realized returns, and volatility of returns among many other variables, we repeat the panels in Table 4 but now individually by exchange.

Table 5 presents the results for price and returns pre-and post-stock distribution. The results for price versus true price are consistent with Table 4 / Panel A. However, the same cannot be said about returns and true returns. When analyzing the exchanges individually, a vast majority of results suggest that realized returns and true returns present similar results. This is especially observed after a stock distribution during the decimalization period.

TABLE 6 HERE

In Table 6 we can see how the reduction in volatility of returns from the 1993-1997 period to the 2001-2018 period is consistent with Table 4 / Panel C. However, when comparing between volatility of realized returns and volatility of true returns, the evidence is mixed. We do not always observe a significant difference in means. This contrast in results from Table 4 / Panel B could be caused, at least in part, by the different bid-ask patterns in each exchange. When contrasting the comparable sample found in Table 5 and Table 6 with the O&P results, from the price discreetness perspective, our results are consistent with O&P and Brown and Warner (1985) in that mean returns do not seem to be affected in the same way volatility is affected.

4. Determinants of Changes in Volatility

Considering the results up to this point in our analysis show patterns that indicate a relationship between changes in spread-price ratios and changes in volatility of returns, we calculate a spread price ratio (S/P). Our ratio is similar to Stoll (1989) and Krinsky and Lee (1996): (Ask - Bid) / [(Ask + Bid) / 2] – the denominator is the same as our true price formula. We separate the S/P by pre-stock distribution dates and post execution dates, and then calculate the natural log[7] of the change in S/P [ln ($S/P_{post} \div S/P_{pre}$)]; we label it ln ΔS/P. We then repeat the process with an alternate S/P ratio as (Ask - Bid) / (Quoted Price). The S/P ratios during the pre-stock distribution are matched by day of the week with the S/P ratios in the post execution in the same way the squared mean returns were matched. We also calculate the natural log of the change in trading volume [ln(VOL_{post} / VOL_{pre})] following the same day of the week matching method and we label it ln ΔVolume.

We now use these variables in regression analysis with unrestricted and restricted versions of the models below.

All exchanges combined:

$$ln\Delta VR = \alpha + ln\Delta S/P + ln\Delta VOL + Period + NYSE + AMEX + NASDAQ$$

By each exchange:

$$ln\Delta VR = \alpha + ln\Delta S/P + ln\Delta VOL + Period$$

Where:

*ln*Δ*VR* – natural log of changes in volatility of returns. Two versions are applied in separate models: one based on quoted prices (QP) and another on True Prices (TP). *ln*Δ*S/P* – natural log of changes in spread-price ratio. Two versions are applied in separate models: one based on quoted prices (QP) and another on True Prices (TP). *ln*Δ*VOL* – natural log of changes in volume after a stock distribution. Period – zero (0) for the 1993-1997 period and a one (1) for the 2001-2018 period. NYSE – one (1) for NYSE and zero (0) otherwise. AMEX – one (1) for AMEX and zero (0) otherwise. NASDAQ – one (1) for NASDAQ and zero (0) otherwise

Regression results are reported in Tables 7, 8, and 9. In all models, we use a sample of 2,098 stock distributions using 75 trading days before the execution date and 75 trading days after each stock distribution matched day of the week.

[7] In order to apply regression analysis, variables with a lognormal distribution are converted using natural log.

In Table 7, we run all models with all exchanges combined. The sample used has 918 stock distributions in the 1993-1997 period and 1,180 stock distributions in the 2001-2018 period. The dependent variable is *ln*Δ*VR* using quoted prices (QP) and we run the models with this dependent variable using *ln*Δ*S/P* calculated with quoted prices (QP) and then with *ln*Δ*S/P* calculated with true prices (TP). In all instances, one of our variables of interest – lnΔS/P – shows a significant positive relation with changes in volatility of returns (*ln*Δ*VR, QP*). These results provide evidence that directly supports our claim about the effect of price discreetness affecting the spread and consequently affecting the spread-price ratio which drives changes in volatility of returns. Another variable of interest *Period* is also significant in all models. The difference is the negative relation which indicates that changes in volatility decreased after decimalization was implemented. We interpret this result as evidence that lower price discreetness constraints thanks to a lower minimum tick size allows for spreads that are more appropriate for the changes in conditions after a stock distribution. *Volume* variable is also positive and significant in all models and suggests that changes in trading activity have an effect in volatility of returns.

TABLE 7 HERE

When reviewing the exchange dummy variables, it seems that *NYSE* differentiates itself from the other two exchanges because when *NYSE* dummy is not omitted, both *AMEX* and *NASDAQ* dummy variables are insignificant. The last model is the exception, but it's the model where the intercept in restricted in order to observe all three exchanges included as a robustness check. A possible cause may have to do with *NYSE* consistently showing higher changes in volatility, higher frequency of $\mathrm{R}_2^2 > \mathrm{R}_1^2$, greater changes in spread-price ratio, and greater changes in volume. When using quoted prices as the source for the dependent variable, no material differences are observed in the results between the *ln*Δ*S/P* based on quoted prices and the *ln*Δ*S/P* based on true prices.

In Table 8 we run the models using the true returns: *ln*Δ*VR(TP)* as the dependent variable. We see that results observed for the *S/P*, *Period*, and *Volume* variables all have the same direction of the relation and significance as in the models in Table 7. However, we see notable differences in the exchange dummy variables. It seems that using true prices in the calculation of the dependent variable mitigates the differences between the exchanges. We suspect that this reflects the differences in spread patterns across the exchanges – i.e. quotes biased towards the bid or ask and not exactly centered between them.

TABLE 8 HERE

For Table 9 we consider the potential differences of the exchanges and the influences on each other. We separate the exchanges and run the regressions for each one of them. The NYSE sample has 312 stock distributions in the 1993-1997 period and 584 in the 2001-2018 period. The AMEX sample has 39 stock distributions in the 1993-1997 period and 49 in the 2001-2018 period. The NASDAQ sample has 567 stock distributions in the 1993-1997 period and 547 in the 2001-2018 period. Overall, the *S/P*, *Period*, and *Volume* variables stay consistent with Tables 7 and 8. The exception is AMEX when using quoted prices to calculate the dependent variable; the *Period* variable becomes insignificant. In Tables 7 and 8 the AMEX coefficient does not completely offset the Period coefficient which may suggest conflicting results. However, we suspect that the main issue with AMEX is its much smaller sample size.

TABLE 9 HERE

5. Conclusions

In pursuit of evidence that helps explain the observed increases in volatility of returns after a stock distribution, we analyze NYSE, AMEX, and NASDAQ 100% stock distributions. As we focus on the role price discreetness plays in volatility of returns, we compare two periods with different minimum tick sizes: 1993 to 1997 (Period-1) and 2001 to 2018 (Period-2) which had a 1/8 of a dollar and $0.01 minimum tick size respectively and we analyze changes in spread-price ratio after a stock distribution.

Our results show that Period-1 had an average 26.15% increase in volatility of returns (NYSE: 32.95%, AMEX: 5.21%, NASDAQ: 26.04%) after the execution of a 100% stock distribution. In Period-2 there was an average 7.14% increase in volatility of returns (NYSE: 14.59%, AMEX: 4.35%, NASDAQ: 3.33%) after the execution of a 100% stock distribution. In addition to that, the frequency in which the volatility of returns increased after a 100% stock distribution went down from 56% in Period-1 to 53.67% in Period-2. This supports the concept that a lower minimum tick size has more price quote flexibility allowing for spreads to better represent the change in conditions after a stock distribution, thus reducing the impact of price discreetness on volatility of returns.

When we analyze spreads to see how they affect volatility of returns, the results show that spreads do not change at the same rate as price does after a 100% stock distribution. In Period-1 spreads decreased by an average of 23.45% (NYSE: 11.04%, AMEX: 22.96%, NASDAQ: 27.90%) after the execution of a 100% stock distribution. In Period-2 spreads decreased by an average of 39.90% (NYSE: 33.28%, AMEX: 40.67%, NASDAQ: 44.82%) after the execution of a 100% stock distribution. In both periods the reduction rate of spreads does not reach the 50% price decrease stocks experience at the execution of a 100% stock distribution. That lower decrease rate of spreads causes an increase of the spread-price ratio after a stock distribution. Given the difference in spread numbers between Period-1 and Period-2, it is noted that after a 100% stock distribution the spread-price ratio has a higher increase in Period-1 than in Period-2. This is consistent with the improved pricing flexibility that comes with a lower minimum tick size. When we look at the pattern of the spread-price ratio, the volatility of returns, and the probability of volatility of returns increasing after a 100% stock distribution, it suggests that changes in spread-price ratio have a positive relationship with changes in volatility of returns. The results also indicate that changes in spread-price ratio after a 100% stock distribution are less severe when price discreetness constraints are eased by a lower minimum tick size.

To remove some of the effects of the constraints caused by price discreteness we run our models through the use of midpoint prices (true prices). We compare results using true prices against results using quoted prices. When analyzing all exchanges together, the results show a significant difference between quoted prices and true prices, between realized returns and true returns, and between volatility of realized returns and volatility of true returns. However, when the exchanges are separated, the difference between quoted and true prices stays significant, but the vast majority of realized returns and true returns do not have a significant difference. This contrast in results of each exchange is likely due to differences between the exchanges such as spread patterns (skewed towards ask or bid), firm risk and size in each exchange, broker versus over the counter practices, etc. When calculating changes in volatility of true returns, the results consistently deliver a reduced percentage increase of volatility when compared to the volatility of realized returns. This is more supporting evidence that price discreetness has an effect on volatility of returns since volatility of returns are reduced when price discreetness constraints are partially removed with the use of true prices.

We also examined volume in our study. Consistent with the extant literature we document that volume increased after a stock distribution. The results suggest a positive relation between changes in volume and changes in volatility of returns after a 100% stock distribution. This interpretation is in line with the concept of trading activity impacts volatility.

We bring it all together in a variety of regression models that test all exchanges together and separately. They also have different combinations where quoted prices are used and true prices are used. In all models, we find that changes in spread-price ratio have a significant positive relationship with the dependent variable which is changes in volatility of returns. We also find that the Period with a lower minimum tick size has a negative relationship with changes in volatility of returns. These findings are direct evidence that price discreetness plays a significant role in the volatility of returns. Volume also has a significant positive relation with volatility of returns. It showed in all the regression models in which it was included. These results also deliver direct evidence that trading activity affects the volatility of returns. The significant results and direction of the Volume, spread-price ratio, and the periods independent variables were not affected by the differences between quoted prices and true prices.

The regression results showed that there are differences between the exchanges when using quoted prices in the calculation of the dependent variable. However, when we use true prices to calculate changes in volatility of returns, it mitigates the differences between the exchanges. We again suggest that these could be due to differences in characteristics, patterns, and behaviors between the exchanges. This study was able to capture the portion of the increases in volatility of returns after a stock distribution that is caused by price discreetness, but there seems to be some of that volatility change left unexplained. We believe that the unexplained portion is the main driver of conflicting results in previous studies. This study should serve as a bridge between those conflicting results and promote new research to target the unexplained portion.

References

Adaoglu, Cahit, and Meziane Lasfer. "Why do companies pay stock dividends? The case of bonus distributions in an inflationary environment." *Journal of Business Finance & Accounting* 38, no. 5-6 (2011): 601-627.

Amihud, Yakov, and Haim Mendelson. "Trading mechanisms and stock returns: An empirical investigation." *The Journal of Finance* 42, no. 3 (1987): 533-553.

Baker, H. Kent, and Patricia L. Gallagher. "Management's view of stock splits." *Financial Management* (1980): 73-77.

Baker, H. Kent, and Gary E. Powell. "Further evidence on managerial motives for stock splits." *Quarterly Journal of Business and Economics* (1993): 20-31.

Bhardwaj, Ravinder K., and Leroy D. Brooks. "The January anomaly: Effects of low share price, transaction costs, and bid-ask bias." *The Journal of Finance* 47, no. 2 (1992): 553-575.

Black, Fischer. "Studies of stock price volatility changes." Proceedings of the 1976 meetings of the business and economic statistics section 177-191 in American Statistical association (1976).

Blume, Marshall E., and Robert F. Stambaugh. "Biases in computed returns: An application to the size effect." *Journal of Financial Economics* 12, no. 3 (1983): 387-404.

Brennan, Michael J., and Thomas E. Copeland. "Stock splits, stock prices, and transaction costs." *Journal of financial economics* 22, no. 1 (1988): 83-101.

Brown, Stephen J., and Jerold B. Warner. "Using daily stock returns: The case of event studies." *Journal of financial economics* 14, no. 1 (1985): 3-31.

Christie, Andrew A. "The stochastic behavior of common stock variances: Value, leverage and interest rate effects." Journal of financial Economics 10, no. 4 (1982): 407-432.

Conroy, Robert M., Robert S. Harris, and Bruce A. Benet. "The effects of stock splits on bid-ask spreads." *The Journal of Finance* 45, no. 4 (1990): 1285-1295.

Dennis, Patrick, and Deon Strickland. "The effect of stock splits on liquidity and excess returns: evidence from shareholder ownership composition." *Journal of Financial Research* 26, no. 3 (2003): 355-370.

Desai, Anand S., Mahendrarajah Nimalendran, and Subu Venkataraman. "Changes in trading activity following stock splits and their effect on volatility and the adverse-information component of the bid-ask spread." *Journal of Financial Research* 21, no. 2 (1998): 159-183.

Devos, Erik, William B. Elliott, and Richard S. Warr. "The propensity to split and CEO compensation." *Financial Management* 47, no. 1 (2018): 105-129.

Dubofsky, David A., and Dan W. French. "Share price level and risk: implications for financial management." *Managerial Finance* 14, no. 1 (1988): 6-15.

Elgers, Pieter T., and Dennis Murray. "Financial characteristics related to managements' stock split and stock dividend decisions." *Journal of Business Finance & Accounting* 12, no. 4 (1985): 543-551.

Fama, Eugene F., Lawrence Fisher, Michael C. Jensen, and Richard Roll. "The adjustment of stock prices to new information." *International Economic Review* 10, no. 1 (1969): 1-21.

French, Dan W., and Taylor W. Foster, III. "Does price discreteness affect the increase in return volatility following stock splits?." *Financial Review* 37, no. 2 (2002): 281-293.

French, Kenneth R., and Richard Roll. "Stock return variances: The arrival of information and the reaction of traders." *Journal of Financial Economics* 17, no. 1 (1986): 5-26.

Gottlieb, Gary, and Avner Kalay. "Implications of the discreteness of observed stock prices." *The Journal of Finance* 40, no. 1 (1985): 135-153.

Hwang, Chuan Yang. "Microstructure and reverse stock splits." *Review of Quantitative Finance and Accounting* 5, no. 2 (1995): 169-177.

Ikenberry, David L., Graeme Rankine, and Earl K. Stice. "What do stock splits really signal?." *Journal of Financial and Quantitative Analysis* 31, no. 3 (1996): 357-375.

Jayaraman, Sudarshan, and Todd T. Milbourn. "The role of stock liquidity in executive compensation." *The Accounting Review* 87, no. 2 (2011): 537-563.

Kaul, Gautam, and Mahendrarajah Nimalendran. "Price reversals: Bid-ask errors or market overreaction?." *Journal of Financial Economics* 28, no. 1-2 (1990): 67-93.

Koski, Jennifer Lynch. "Measurement effects and the variance of returns after stock splits and stock dividends." *The Review of Financial Studies* 11, no. 1 (1998): 143-162.

Krinsky, Itzhak, and Jason Lee. "Earnings announcements and the components of the bid-ask spread." *The Journal of Finance* 51, no. 4 (1996): 1523-1535.

Lakonishok, Josef, and Baruch Lev. "Stock splits and stock dividends: Why, who, and when." *the Journal of Finance* 42, no. 4 (1987): 913-932.

Lim, Tee, and Anand Vijh. *The bid-ask spread and the ex-date behavior of stock splits: An investigation using transactions data*. Working Paper, Graduate School of Business, University of California, Berkeley, 1986.

McNichols, Maureen, and Ajay Dravid. "Stock dividends, stock splits, and signaling." *Journal of Finance* 45, no. 3 (1990): 857-879.

Millar, James A., and Bruce D. Fielitz. "Stock-split and stock-dividend decisions." *Financial Management* (1973): 35-45.

Minnick, Kristina, and Kartik Raman. "Why are stock splits declining?." *Financial Management* 43, no. 1 (2014): 29-60.

Mukherji, Sandip, Yong H. Kim, and Michael C. Walker. "The effect of stock splits on the ownership structure of firms." *Journal of Corporate Finance* 3, no. 2 (1997): 167-188.

Muscarella, Chris J., and Michael R. Vetsuypens. "Stock splits: Signaling or liquidity? The case of ADR 'solo-splits'." *Journal of Financial Economics* 42, no. 1 (1996): 3-26.

Ohlson, James A., and Stephen H. Penman. "Volatility increases subsequent to stock splits: An empirical aberration." *Journal of Financial Economics* 14, no. 2 (1985): 251-266.

Park, Jinwoo, and Chandrasekhar Krishnamurti. "Stock splits, bid-ask spreads, and return variances: An empirical investigation of NASDAQ stocks." *Quarterly Journal of Business and Economics* (1995): 39-45.

Schultz, Paul. "Stock splits, tick size, and sponsorship." *The Journal of Finance* 55, no. 1 (2000): 429-450.

Sheikh, Aamir M. "Stock splits, volatility increases, and implied volatilities." *The Journal of Finance* 44, no. 5 (1989): 1361-1372.

Stoll, Hans R. "Inferring the components of the bid-ask spread: Theory and empirical tests." *the Journal of Finance* 44, no. 1 (1989): 115-134.

Szewczyk, Samuel H., and George P. Tsetsekos. "Why Stock Splits? Evidence from Institutional Ownership." *Evidence from Institutional Ownership* (1995).

Wharton Research Data Services. (n.d.). Retrieved May 4, 2019, from https://wrds-web.wharton.upenn.edu/wrds/query_forms/variable_documentation.cfm?vendorCode=CRSP&libraryCode=crspa&fileCode=dsf&id=bid

Woolridge, J. Randall. "Stock dividends as signals." *Journal of Financial Research* 6, no. 1 (1983): 1-12.

TABLE 1 - Total Stock Distributions and Volatility of Returns

Panel A	Stock Distributions						
	100%	150%	200%	300%	400%	900%	Total
'62-'97							
NYSE	2,339	38	193	23	20	3	2,616
AMEX	714	16	78	20	9	3	840
NASDAQ+	2,356	33	216	49	27	8	2,689
Total	5,409	87	487	92	56	14	6,145
'93-'97							
NYSE	312	5	19	5	2	1	344
AMEX	39	-	4	-	1	-	44
NASDAQ	571	4	40	7	5	1	628
Total	922	9	63	12	8	2	1,016
'01-'18							
NYSE	584	8	52	21	18	3	686
AMEX	49	1	22	3	2	1	78
NASDAQ	551	6	50	11	5	4	627
Total	1,184	15	124	35	25	8	1,391

Panel B	Volatility of Returns (%) - Total Distributions (%)						
	$E(R_1^2)$	$E(R_2^2)$	Diff Means		Δ	$Pr\ \{R_2^2 > R_1^2\}$	
'62-'97							
All Exchanges	0.0681	0.1041	0.0359	***	23.60	0.5418	***
NYSE	0.0352	0.0611	0.0260	***	31.87	0.5793	***
AMEX	0.0777	0.1173	0.0396	***	22.88	0.5618	***
NASDAQ+	0.1073	0.1547	0.0475	***	20.12	0.4864	***
'93-'97							
All Exchanges	0.0928	0.1436	0.0508	***	24.39	0.5579	***
NYSE	0.0314	0.0542	0.0228	***	31.43	0.5708	***
AMEX	0.1200	0.1658	0.0458		17.55	0.5623	***
NASDAQ	0.1311	0.2006	0.0695	***	23.69	0.5492	***
'01-'18							
All Exchanges	0.0716	0.0773	0.0057		3.94	0.5372	***
NYSE	0.0413	0.0536	0.0122	***	13.81	0.5344	***
AMEX	0.1519	0.1486	-0.0034		-1.12	0.5261	**
NASDAQ	0.1009	0.0997	-0.0012		-0.61	0.5415	***

Notes: +NASDAQ sample is 1971-1997. $E(R_1^2)$ is pre-stock distribution volatility equal to the mean squared returns between declaration date (CRSP: DCLRDT) and execution date (CRSP: PAYDT). $E(R_2^2)$ is post stock distribution volatility equal to the mean squared returns after the execution date up to the same amount of trading days of the pre-stock distribution dates. Change in volatility is calculated as $[E(R_2^2) / E(R_1^2)]^{1/2} - 1$ which is the square root of post stock distribution mean squared returns divided by the pre-stock distribution mean squared returns minus one. $Pr\{R_2^2 > R_1^2\}$ is the probability of post stock distribution volatility of returns being greater than pre-stock distribution volatility of returns. *, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 2 - Change in Volatility of Returns by Stock Distribution Size

	100%	150%	200%	300%	400%	900%
Δ Ret Volatility (%)						
'62-'97						
All Exchanges	24.47	6.87	26.00	30.29	18.14	-26.80
NYSE	31.90	23.32	30.63	59.06	40.54	20.54
AMEX	27.54	2.97	3.44	8.40	25.98	-21.15
NASDAQ+	20.19	-3.86	31.83	34.45	14.42	-28.71
'93-'97						
All Exchanges	26.15	-7.86	26.09	9.53	-1.98	21.15
NYSE	32.95	6.47	21.45	8.79	37.95	107.71
AMEX	5.21	-	-21.40	-	101.02	-
NASDAQ	26.04	-16.80	32.24	9.67	-31.18	15.29
'01-'18						
All Exchanges	7.14	-9.83	-14.12	5.46	28.02	12.03
NYSE	14.59	-0.99	7.08	7.06	27.15	2.67
AMEX	4.35	-66.48	-16.23	14.65	-8.89	-18.21
NASDAQ	3.33	-2.02	-19.45	3.80	34.34	16.93
Pr $\{R_2^2 > R_1^2\}$						
'62-'97						
All Exchanges	0.5429 ***	0.5325 ***	0.5437 ***	0.5252 ***	0.4890	0.5094
NYSE	0.5791 ***	0.5813 ***	0.5847 ***	0.5366 **	0.5787 ***	0.6571 ***
AMEX	0.5650 ***	0.5447 **	0.5495 ***	0.5473 ***	0.5054	0.5571
NASDAQ+	0.4877 ***	0.4355 ***	0.4871 **	0.5092	0.4347 ***	0.4201 ***
'93-'97						
All Exchanges	0.5600 ***	0.5020	0.5794 ***	0.4912	0.4714	0.2973 ***
NYSE	0.5741 ***	0.5304	0.5801 ***	0.4151 **	0.5490	0.6190
AMEX	0.5584 ***	-	0.6100 **	-	0.5385	-
NASDAQ	0.5510 ***	0.4324	0.5761 ***	0.5452	0.4545	0.1698 ***
'01-'18						
All Exchanges	0.5367 ***	0.5056	0.5438 ***	0.5243	0.5728 ***	0.5350
NYSE	0.5336 ***	0.5079	0.5361 ***	0.5149	0.5981 ***	0.5091
AMEX	0.5310 *	0.2222 **	0.5315	0.5521	0.3750	0.3333
NASDAQ	0.5407 ***	0.5254	0.5545 ***	0.5356	0.5170	0.5588

Notes: +NASDAQ sample is 1971-1997 only. Change in volatility = $[E(R_2^2) / E(R_1^2)]^{1/2} - 1$ which is the square root of post stock distribution mean squared returns divided by the pre-stock distribution mean squared returns minus one. $\Pr\{R_2^2 > R_1^2\}$ is the probability of post stock distribution volatility of returns being greater than pre-stock distribution volatility of returns. *, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 3 - Spread and Volume for 100% Stock Distribution

	Mean Spread					Mean Volume				
	Pre	Post	Diff. in Means		%Δ	Pre	Post	Diff. in Means		%Δ
'93-'97										
All Exchanges	0.7814	0.5982	-0.1832	***	-23.45	297,936	471,933	173,996	***	58.40
NYSE	0.5271	0.4689	-0.0582	***	-11.04	247,281	437,535	190,254	***	76.94
AMEX	0.5460	0.4207	-0.1254	***	-22.96	22,106	38,972	16,867	***	76.30
NASDAQ	0.9629	0.6942	-0.2687	***	-27.90	351,196	526,145	174,950	***	49.82
'01-'18										
All Exchanges	0.1479	0.0889	-0.0590	***	-39.90	948,742	1,591,697	642,955	***	67.77
NYSE	0.1179	0.0786	-0.0392	***	-33.28	1,011,253	1,780,231	768,977	***	76.04
AMEX	0.2956	0.1754	-0.1202	***	-40.67	274,847	385,232	110,385		40.16
NASDAQ	0.1731	0.0955	-0.0776	***	-44.82	916,262	1,441,568	525,306	***	57.33

Notes: Spread is closing ask (CRSP: ASK) minus closing bid (CRSP: BID). *, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 4 - Quoted Price versus True Price - All Exchanges

Panel A	Mean Price		Mean True Price		Diff in Means		Mean Ret (%)		Mean True Ret (%)		Diff in Means	
Pre-Distribution												
'93-'97	47.94	***	51.51	***	-3.58	***	0.279	***	0.207	***	0.072	***
'01-'18	68.46	***	69.01	***	-0.55	**	0.203	***	0.147	***	0.056	***
Diff in Means	-20.53	***	-17.50	***			0.076	***	0.060	**		
Post Distribution												
'93-'97	25.66	***	27.19	***	-1.53	***	0.135	***	0.046	**	0.089	***
'01-'18	35.18	***	35.53	***	-0.35	***	0.022		0.008		0.015	
Diff in Means	-9.51	***	-8.33	***			0.113	***	0.038			

Panel B	$E(R_1^2)$ %		True $E(R_1^2)$ %		Diff in Means		$E(R_2^2)$ %		True $E(R_2^2)$ %		Diff in Means	
'93-'97	0.088	***	0.096	***	-0.009		0.139	***	0.119	***	0.021	***
'01-'18	0.066	***	0.074	***	-0.008	**	0.075	***	0.073	***	0.002	
Diff in Means	0.022	***	0.022				0.064	***	0.046	***		

Panel C	Δ Volatility of Returns (%)	Δ Volatility of True Returns (%)
'93-'97	26.15	11.05
'01-'18	7.14	-0.56

Notes: True Price is (ASK+BID)/2. Mean "true returns" are calculated using True Prices. $E(R_1^2)$ is pre-stock distribution volatility equal to the mean squared returns between declaration date (CRSP: DCLRDT) and execution date (CRSP: PAYDT). $E(R_2^2)$ is post stock distribution volatility equal to the mean squared returns after the execution date up to the same amount of trading days of the pre-stock distribution dates. Change in volatility = $[E(R_2^2) / E(R_1^2)]^{1/2} - 1$ which is the square root of post stock distribution mean squared returns divided by the pre-stock distribution mean squared returns minus one. *, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 5 - Quoted Price versus True Price by Exchange

	Mean Price		Mean True Price		Diff in Means		Mean Ret (%)		Mean True Ret (%)		Diff in Means	
Pre-Distribution												
NYSE												
'93-'97	60.93	***	61.80	***	-0.87	***	0.135	***	0.094	***	0.041	
'01-'18	75.97	***	76.57	***	-0.60	*	0.144	***	0.109	***	0.035	*
Diff in Means	-15.04	***	-14.77	***			-0.009		-0.015			
AMEX												
'93-'97	28.93	***	35.29	***	-6.36	***	0.287	***	0.202	**	0.085	
'01-'18	51.41	***	54.15	***	-2.74		0.356	***	0.189		0.167	
Diff in Means	-22.47	***	-18.86	***			-0.069		0.013			
NASDAQ												
'93-'97	40.87	***	46.05	***	-5.18	***	0.372	***	0.281	***	0.091	**
'01-'18	60.53	***	61.25	***	-0.72	**	0.264	***	0.189	***	0.075	**
Diff in Means	-19.66	***	-15.20	***			0.108	***	0.092	**		
Post Distribution												
NYSE												
'93-'97	31.60	***	31.91	***	-0.31	*	0.0813	***	0.051	**	0.030	
'01-'18	38.74	***	39.12	***	-0.38	**	0.031	*	0.026		0.005	
Diff in Means	-7.14	***	-7.20	***			0.051	*	0.025			
AMEX												
'93-'97	16.26	***	18.93	***	-2.67	***	0.066		-0.017		0.083	
'01-'18	25.28	***	26.50	***	-1.22		-0.077		-0.116		0.039	
Diff in Means	-9.01	***	-7.56	***			0.143		0.099			
NASDAQ												
'93-'97	22.49	***	24.75	***	-2.27	***	0.174	***	0.047		0.127	***
'01-'18	31.53	***	31.85	***	-0.32	*	0.018		-0.006		0.024	
Diff in Means	-9.04	***	-7.09	***			0.156	***	0.053			

Notes: 100% stock distributions only. Sample's mean quoted closing price (from CRSP: PRC) and mean returns (from CRSP: RET). True Price is (ASK+BID)/2. Mean "true returns" are calculated using True Prices. *, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 6 - Returns Volatility by Exchange: Quoted Price vs True Price by Exchange

	$E(R_1^2)$ %		True $E(R_1^2)$ %		Diff in Means		$E(R_2^2)$ %		True $E(R_2^2)$ %		Diff in Means	
NYSE												
'93-'97	0.032	***	0.038	***	-0.006		0.056	***	0.062	***	-0.006	
'01-'18	0.040	***	0.042	***	-0.003		0.052	***	0.051	***	0.001	
Diff in Means	-0.008	***	-0.005				0.004	*	0.011	***		
AMEX												
'93-'97	0.092	***	0.095	***	-0.003		0.102	***	0.115	***	-0.013	
'01-'18	0.178	***	0.162	***	0.016		0.194	***	0.155	***	0.039	
Diff in Means	-0.086	***	-0.067	*			-0.092	***	-0.040			
NASDAQ												
'93-'97	0.124	***	0.134	***	-0.010		0.196	***	0.155	***	0.041	***
'01-'18	0.090	***	0.104	***	-0.015	*	0.096	***	0.094	***	0.002	
Diff in Means	0.034	***	0.030				0.101	***	0.061	***		

	Δ Volatility of Returns (%)	Δ Volatility of True Returns (%)
NYSE		
'93-'97	32.95	27.51
'01-'18	14.59	9.52
AMEX		
'93-'97	5.15	9.91
'01-'18	4.35	-2.38
NASDAQ		
'93-'97	26.04	7.72
'01-'18	3.33	-5.06

Notes: 100% stock distributions only. $E(R_1^2)$ is pre-stock distribution volatility equal to the mean squared returns between declaration date (CRSP: DCLRDT) and execution date (CRSP: PAYDT). $E(R_2^2)$ is post stock distribution volatility equal to the mean squared returns after the execution date up to the same amount of trading days of the pre-stock distribution dates. Change in volatility = $[E(R_2^2) / E(R_1^2)]^{1/2} - 1$ which is the square root of post stock distribution mean squared returns divided by the pre-stock distribution mean squared returns minus one. Change in volatility of returns calculated with CRSP returns. Change in volatility of true returns calculated with "true returns". *, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 7- Determinants of Post Stock Distribution Volatility Changes of Returns (quoted prices on all exchanges)

2,098 Stock Distributions	ln Δ Volatility of Returns (QP)					
α	0.32425 ***	0.08934 ***	0.10113 ***	0.15880 ***	0.06804 ***	Restricted
ln ΔS/P (QP)	0.05203 ***	0.07130 ***	0.07247 ***	0.07247 ***	0.07247 ***	0.07247 ***
ln Δ Volume		0.43105 ***	0.43213 ***	0.43213 ***	0.43213 ***	0.43213 ***
Period	-0.17872 ***	-0.19536 ***	-0.19147 ***	-0.19147 ***	-0.19147 ***	-0.19147 ***
NYSE			-0.03309 **	-0.09076 **		0.06804 ***
AMEX			0.05767		0.09076 **	0.15880 ***
NASDAQ				-0.05767	0.03309 **	0.10113 ***
R^2	0.0053	0.0799	0.0801	0.0801	0.0801	0.1011
α	0.32423 ***	0.08930 ***	0.10109 ***	0.15878 ***	0.06799 ***	Restricted
ln ΔS/P (TP)	0.05205 ***	0.07133 ***	0.07251 ***	0.07251 ***	0.07251 ***	0.07251 ***
ln Δ Volume		0.43106 ***	0.43213 ***	0.43213 ***	0.43213 ***	0.43213 ***
Period	-0.17870 ***	-0.19533 ***	-0.19144 ***	-0.19144 ***	-0.19144 ***	-0.19144 ***
NYSE			-0.03310 **	-0.09079 **		0.06799 ***
AMEX			0.05769		0.09079 **	0.15878 ***
NASDAQ				-0.05769	0.03310 **	0.10109 ***
R^2	0.0053	0.0799	0.0802	0.0802	0.0802	0.1011

Notes: 2,098 total stock distributions with observations 75 trading days before and 75 trading days after the execution. Regressions are changes in returns volatility as the dependent variable calculated with quoted prices (QP) from CRSP: PRC. Change in volatility = $[E(R_2^2) / E(R_1^2)]^{1/2} - 1$. Independent variables are the natural log of changes in the spread-price ratio [calculated with QP and true prices: TP = (ASK+BID)/2] and the natural log of changes in volume before and after the stock distribution. Period is a variable equal to 0 for the 1/8 minimum tick period (1993-1997) and 1 for the decimalization period (2001-2018). NYSE, AMEX, and NASDAQ are dummy variables.*, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 8- Determinants of Post Stock Distribution Volatility Changes of Returns (true prices on all exchanges)

2,098 Stock Distributions	ln Δ Volatility of Returns (TP)					
α	0.32618 ***	0.05944 ***	0.06385 ***	0.12983 ***	0.04711 ***	Restricted
ln ΔS/P (QP)	0.03246 ***	0.05434 ***	0.05492 ***	0.05492 ***	0.05492 ***	0.05492 ***
ln Δ Volume		0.48946 ***	0.49014 ***	0.49014 ***	0.49014 ***	0.49014 ***
Period	-0.21174 ***	-0.23063 ***	-0.22817 ***	-0.22817 ***	-0.22817 ***	-0.22817 ***
NYSE			-0.01674	-0.08272 *		0.04711 ***
AMEX			0.06598		0.08272 *	0.12983 ***
NASDAQ				-0.06598	0.01674	0.06385 ***
R^2	0.0044	0.0780	0.0781	0.0781	0.0781	0.0908
α	0.32615 ***	0.05939 ***	0.06380 ***	0.12979 ***	0.04705 ***	Restricted
ln ΔS/P (TP)	0.03252 ***	0.05441 ***	0.05500 ***	0.05500 ***	0.05500 ***	0.05500 ***
ln Δ Volume		0.48947 ***	0.49015 ***	0.49015 ***	0.49015 ***	0.49015 ***
Period	-0.21171 ***	-0.23060 ***	-0.22813 ***	-0.22813 ***	-0.22813 ***	-0.22813 ***
NYSE			-0.01676	-0.08275 *		0.04705 ***
AMEX			0.06599		0.08275 *	0.12979 ***
NASDAQ				-0.06599	0.01676	0.06380 ***
R^2	0.0044	0.0780	0.0781	0.0781	0.0781	0.0908

Notes: Regressions are changes in returns volatility as the dependent variable calculated with true prices (TP) = (ASK+BID)/2. Change in volatility = $[E(R_2^2) / E(R_1^2)]^{1/2} - 1$. Independent variables are the natural log of changes in the spread-price ratio [calculated with quoted prices (QP) and true prices: TP = (ASK+BID)/2] and the natural log of changes in volume before and after the stock distribution. Period is a variable equal to 0 for the 1/8 minimum tick period (1993-1997) and 1 for the decimalization period (2001-2018). NYSE, AMEX, and NASDAQ are dummy variables.*, **, *** represent 10%, 5%, and 1% confidence levels respectively.

TABLE 9- Determinants of Post Stock Distribution Volatility Changes of Returns (by exchange)

	ln Δ Volatility of Returns (QP)				ln Δ Volatility of Returns (TP)			
NYSE 896 Stock Distributions								
α	0.36817	***	0.06863	***	0.35920	***	0.04127	**
ln ΔS/P (QP)	0.03210	***	0.03621	***	0.02717	***	0.03152	***
ln Δ Volume			0.48506	***			0.51484	***
Period	-0.23039	***	-0.21889	***	-0.24095	***	-0.22874	***
R_2	0.0063		0.0781		0.0055		0.0726	
α	0.36816	***	0.06860	***	0.35917	***	0.04122	**
ln ΔS/P (TP)	0.03211	***	0.03624	***	0.02721	***	0.03160	***
ln Δ Volume			0.48507	***			0.51485	***
Period	-0.23038	***	-0.21888	***	-0.24093	***	-0.22872	***
R_2	0.0063		0.0781		0.0055		0.0726	
AMEX 88 Stock Distributions								
α	0.28133	***	0.08542		0.31599	***	0.08985	
ln ΔS/P (QP)	0.16477	***	0.19330	***	0.14186	***	0.17479	***
ln Δ Volume			0.32985	***			0.38074	***
Period	-0.12457		-0.05416		-0.22573	***	-0.14446	*
R_2	0.0144		0.1086		0.0140		0.1218	
α	0.28152	***	0.08576		0.31591	***	0.08992	
ln ΔS/P (TP)	0.16434	***	0.19265	***	0.14201	***	0.17469	***
ln Δ Volume			0.32977	***			0.38069	***
Period	-0.12455		-0.05420		-0.22560	***	-0.14438	*
R_2	0.0143		0.1085		0.0140		0.1218	
NASDAQ 1,114 Stock Distributions								
α	0.28482	***	0.08870	***	0.29564	***	0.06210	***
ln ΔS/P (QP)	0.07055	***	0.10851	***	0.03110	**	0.07630	***
ln Δ Volume			0.41013	***			0.48839	***
Period	-0.12670	***	-0.16677	***	-0.18424	***	-0.23196	***
R_2	0.0048		0.0843		0.0032		0.0822	
α	0.28477	***	0.08863	***	0.29560	***	0.06204	***
ln ΔS/P (TP)	0.07062	***	0.10859	***	0.03118	**	0.07639	***
ln Δ Volume			0.41015	***			0.48841	***
Period	-0.12665	***	-0.16671	***	-0.18421	***	-0.23191	***
R_2	0.0048		0.0843		0.0032		0.0822	

Notes: Regressions dependent variable = changes in returns volatility calculated with quoted prices (QP, CRSP=PRC) and true prices (TP) = (ASK+BID)/2. Change in volatility = $[E(R_2^2) / E(R_1^2)]^{1/2}$ - 1. Independent variables = natural log of changes in spread-price ratio (calculated with QP and TP) and natural log of changes in volume pre and post stock distribution. Period = 0 for 1/8 tick size period (‘93-‘97) and 1 for $0.01 tick size period (‘01-‘18). *, **, *** represent 10%, 5%, and 1% respectively.