What Drives the Trend and Behavior in Aggregate (Idiosyncratic) Variance? Follow the Bid-Ask Bounce

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Abstract

A number of competing explanations have been offered as a rationale for the trend in idiosyncratic variance that has been experienced over the past four decades. We establish a theoretical model linking a market microstructure bias with the industry-adjusted idiosyncratic variance (Campbell, Lettau, Malkiel, and Xu, 2001) or the risk-adjusted idiosyncratic variance. Using this model's predictions, we empirically show that the bid-ask spread eliminates the time trend in aggregate idiosyncratic variance. These results are robust across various exchanges, across various risk-based measures of idiosyncratic variance, and through time. Two natural experiments demonstrate that an exogenous shock to the bid-ask spread is associated with a subsequent decline in the aggregate idiosyncratic variance. The microstructure hypothesis dominates any of the alternative explanations, including uncertainty about profitability, earnings shocks, or growth options, for the trend in idiosyncratic variance.

Keywords: Aggregate Firm-Level Variance, Trend, Bid-Ask Spread, Decimalization, Odd-Eighth Quotes

1 Introduction

In a seminal paper, Campbell et al. (2001) find that aggregate idiosyncratic variance exhibits an upward time trend through the late 1990s, while market and industry volatilities remain roughly constant during this time. It is well known that the increasing trend in idiosyncratic variance is related to a number of explanatory variables. Idiosyncratic variance is positively correlated with the idiosyncratic cash flow variability (Pástor and Veronesi, 2003; Wei and Zhang, 2006) and with increased product market competition characterized by earnings shocks (Irvine and Pontiff, 2009), exhibits a negative association with firm age (Pástor and Veronesi, 2003), demonstrates a strong correlation with economic business cycles (Brown and Ferreira, 2016), is positively associated with growth options (Cao, Simm, and Zhao, 2008), and demonstrates a positive association with retail trading (Brandt, Brav, Graham, and Kumar, 2010). We propose that a missing feature into the trend analysis is a microstructure bias in firm-level daily returns aggregated to the market level that drives the intertemporal trend in aggregate industry-adjusted idiosyncratic variance identified by Campbell et al. (2001) (hereafter, CLMX).

We argue that market microstructure is crucial in understanding the behavior of aggregate idiosyncratic variance. Blume and Stambaugh (1983) derive a microstructure bias in daily returns arising from the bid-ask bounce in prices. We model this microstructure bias in daily returns and derive a closed-form solution for the liquidity bias. Motivated by our theory, our empirical results show that measurement error in the estimate of aggregate idiosyncratic variance is responsible for the observed time trend and that controlling for the effect of liquidity removes the significance in the observed trend in aggregate industry-adjusted idiosyncratic variance.

While liquidity has been shown to affect the pricing of idiosyncratic volatility (Bali and Cakici, 2008; Han and Lesmond, 2011), liquidity has found little support at the aggregate level explaining the trend. Brandt et al. (2010) argue that microstructure biases are "less able" to explain an episodic spike in idiosyncratic volatility, and they find no evidence that exposure to the Pástor and Stambaugh (2003) liquidity factor captures the increased volatility levels. However, Bandi and Russell (2006, 2008) analyze microstructure noise using the bid-ask spread in relation to realized volatility estimated using squared returns. These papers point out that noise is the dominant characteristic in transaction prices when measured over very small intraday time intervals. Consequently, transaction prices are mainly composed of noise and carry little information about the underlying return volatility. We argue that, for time intervals as short as one day, estimates of volatility run the risk of being affected by the microstructure noise, rather than the underlying return volatility.

Our innovation is to theoretically model a microstructure bias in daily returns and to relate this bias to the CLMX measure of idiosyncratic variance. We propose that the bid-ask bounce causes a microstructure bias in daily returns that is imparted to the monthly estimates of idiosyncratic variance. We place this microstructure bias into the derivation of the CLMX idiosyncratic variance estimate and show that there is a linear relation between the bid-ask spread and the CLMX idiosyncratic variance estimate. In effect, the monthly aggregate volatility estimates contain microstructure noise embodied in the bid-ask bounce consistent with the assertions of Bandi and Russell (2006, 2008). In so doing, our results indicate that the observed trend in idiosyncratic variance ultimately evidences the co-movement in the underlying bid-ask spread. Our model suggests that the bid-ask bounce in security returns is critical to understanding the time trend and behavior of aggregate idiosyncratic volatility.

We initially document that idiosyncratic variance experiences a significant "break" around the decimalization in bid-ask spreads. Before this date, the trend in idiosyncratic variance is positive, while after this date, and continuing to 2015, the trend in idiosyncratic variance is largely negative. We test our microstructure theory by employing a battery of bid-ask spread measures, ranging from the closing bid-ask quotes to low-frequency [1] spread estimators. Consistent with our theoretical predictions, we find that a idiosyncratic variance estimated using quote midpoints, or an estimate of idiosyncratic variance devoid of the bid-ask bounce, shows no association with a time trend up to 2001. We repeat the analysis using low-frequency spread measures and find that the orthogonal component of idiosyncratic variance and the bid-ask spread also displays no significance with a time

[1] We use the bid-ask spread estimator of Corwin and Schultz (2012) and Roll (1984) that are estimable over long time periods. The Corwin and Schultz (2012) estimator avoids a possible mechanical relation between the end-of-day bid and ask quotes and the end-of-day returns used to determine the CLMX estimate. This model uses the intraday lowest bid and highest ask to determine the effective daily bid-ask spread. Corwin and Schultz (2012) show that this estimated bid-ask spread captures the effective spreads much better than other spread estimators.

trend. Directly controlling for the bid-ask spread also reduces the time trend to insignificance with the underlying bid-ask spread explaining more than 81% of the variation in idiosyncratic variance, on average. These results persist for the period after the decimalization in quotes. Controlling for the bid-ask spread is sufficient in explaining the trend in the CLMX measure of aggregate industry-adjusted idiosyncratic variance.

We demonstrate that the bid-ask spread most consistently explains the time trend in idiosyncratic variance. First, consistent with our microstructure theory based specifically on the bid-ask bounce, we show that price impact measures (see, for example, Bali and Cakici (2008); Pástor and Stambaugh (2003)) are ineffective at explaining the time trend. Pástor and Veronesi (2003) relate firm-specific volatility to firm profitability measured by return-on-equity (ROE). They find that idiosyncratic variance tends to be higher for firms experiencing more uncertainty about future profitability and with more volatile profitability, arguing that the number of firms listed at earlier stages is a partial explanation for the trend in idiosyncratic volatility. We find that in the presence of the bid-ask spread, both ROE and firm age are largely insignificant. Cao et al. (2008) focus on growth options using the framework offered by Galai and Masulis (1976) and show that managers of levered firms are motivated to select those investment projects from their menu of growth opportunities that increase the idiosyncratic variance of the firm. However, we find that growth options induce negative and significant time trends in most time periods producing a counter argument concerning a declining aggregate variance. Irvine and Pontiff (2009) argue that increased economic competition, in part, leads to increased volatility in firm-level earnings that is large enough to explain the increase in the market idiosyncratic volatility. Again, earnings volatility falls from significance when tested against the bid-ask spread. Finally, Brandt et al. (2010) offer a behavioral explanation for the upward trend in aggregate firm-level variance, but we find that the bid-ask spread subsumes any relation between retail trading and the CLMX measure. Indeed, we find that in cross-sectional tests the bid-ask spread eclipses a retail trading effect as a possible cross-sectional determinant of future idiosyncratic variance.

The microstructure results are robust across exchanges. It is well known that NASDAQ firms (Bessembinder and Kaufman, 1997; Bessembinder, 1999, 2003; Cao et al., 2008) experience higher bid-ask spreads than do NYSE/Amex firms. Our results show more robust significance in the time trend for NASDAQ firms than for NYSE/Amex consistent with a bid-ask spread explanation. The bid-ask spread can independently explain the trend for NYSE/Amex-listed firms, explaining 76% of the time series variation in idiosyncratic variance, while for NASDAQ firms explaining over 27% of the variation in the idiosyncratic variance. The bid-ask spread, in conjunction with growth options, subsumes the explanatory power of the time trend. We show that growth options cannot explain the time trend for NASDAQ firms.

We address endogeneity concerns in our tests by using two natural experiments that capture exogenous shocks only to the bid-ask spread, but not to idiosyncratic variance. We use the 2001 decimalization in stock quotes as our first natural experiment applicable to NYSE/Amex/NASDAQ markets. Using this exogenous shock, we show that U.S. firms (treatment firms) witnessed a significant decline in quoted bid-ask spreads, but this decline in the bid-ask spread was not experienced by international G6 firms (control firms). This decline in bid-ask spreads induced a large decline in the measured CLMX idiosyncratic variance. We next use a unique natural experiment that utilizes the avoidance of odd-eighth quotes in NASDAQ listed stocks (Christie and Schultz, 1994). This seminal paper illustrates that market-makers in NASDAQ stocks actively avoided odd-eighth quotes thereby artificially inflating the bid-ask spreads. Christie and Schultz (1999) note that market-makers in NASDAQ stocks began altering their quotes after the disclosure of the Christie and Schultz (1994) paper in May of 1994. Using the disclosure of the avoidance in odd-eighth quotes as an exogenous shock, we show that bid-ask spreads declined precipitously for NASDAQ listed stocks (treatment group) subsequent to May of 1994, while NYSE/Amex listed stocks (control group) were unaffected. We show conclusively that the exogenous shock to bid-ask spreads for NASDAQ stocks led to a sharp reduction in idiosyncratic variance. None of the alternative explanations for the trend in idiosyncratic variance are able to explain the time trend across this time period. Only the bid-ask spread is of any consequence when considering the behavior of idiosyncratic variance.

The paper is organized as follows. Section 2 frames our method for estimating each of the risk measures and Section 3 derives the microstructure bias for each of the aggregate idiosyncratic variance measures. Section 4 shows the data sources. Section 5 presents summary statistics.

Section 6 presents the Bai-Perron Break tests, trend tests using quote midpoints to estimate the Campbell et al. (2001) aggregate idiosyncratic variance, and the initial time trend tests. Section 7 examine alternative explanations for the time trend in idiosyncratic variance, as well as alternative risk-adjusted idiosyncratic variance estimates, concluding with an analysis of the determinants of the trend in the bid-ask spread. Section 8 shows the natural experiment around the decimalization in stock quotes, and then a cross-sectional determinant regression for the CLMX idiosyncratic variance. Section 9 illustrates the time trend across separate NASDAQ and NYSE/Amex listed firms as well as a natural experiment centered around the avoidance of odd-eighth quotes for NASDAQ listed firms. Section 10 concludes the paper.

2 Aggregated Firm-Level Volatility Risk Measures

We derive the microstructure bias using two approaches to estimate idiosyncratic variance. First, following, Campbell et al. (2001) we calculate idiosyncratic variance using the residual of daily firm returns from industry returns. Second, we measure idiosyncratic variance from a CAPM model and a measure of idiosyncratic variance from a Fama and French (1993) three-factor model.

2.1 Industry-Adjusted Aggregate Variance Measure

We calculate the industry-adjusted firm-level variance using the following relation as performed in Campbell et al. (2001). The variance term stems from the residual from daily firm-level returns adjusted for value-weighted industry returns

$$\eta_{dt} = r_{dt} - r_{jdt}, \tag{1}$$

where r_d is the daily return for month t. For clarity, we suppress the reporting of subscripts, but all terms represent firm i that belongs to industry j on day d in month t. r_{jd} is the industry daily turn. The difference between the firm-level return and the industry-level return, η_d, is squared [2]

[2] An implicit assumption for calculating variance using squared returns is that the expectation of η is zero. This stems from the definition of variance that is $E(\eta^2) - [E(\eta)]^2$.

and then summed over the weighted average of all firms in the industry, then across all 48 Fama and French (1997) industries and stocks not assigned to any industry are grouped into category 49.

$$Var_{CLMX_t} = \sum_{j=1}^{49}\left[\sum_{i\in j} w_{ijt-1}\sum_{d\in t}(\eta_{dt})^2\right], \tag{2}$$

where w_{ijt-1} is the weight based on the prior month's market capitalization of firm i in industry j. We sum over all days, d, for each month t, then sum over all firms i in industry j. Finally we sum over all 49 industries.

2.2 Risk-Adjusted Aggregate Variance Measure

We calculate the firm-level idiosyncratic variance using the CAPM using daily returns across a month:

$$\tilde{r}_d - r_{f,d} = \alpha + \beta_{mkt}(r_{mkt,d} - r_{f,d}) + \tilde{\gamma}_d, \tag{3}$$

or the Fama and French (1993) three-factor model:

$$\tilde{r}_d - r_{f,d} = \alpha + \beta_{mkt}(r_{mkt,d} - r_{f,d}) + \beta_{smb}r_{smb,d} + \beta_{hml}r_{hml,d} + \tilde{\gamma}_d, \tag{4}$$

where $\tilde{\gamma}_d \sim \mathcal{N}(0, \sigma_\gamma^2)$. r_d refers to the daily return for firm i on day d. $r_{mkt,d}$ is the market daily return, $r_{smb,d}$ is the daily return on the Small–Minus–Big (SMB) factor, $r_{hml,d}$ is the daily return on the High–Minus–Low (HML) factor, and $r_{f,d}$ is the daily risk–free rate.

The idiosyncratic variances are calculated for either the CAPM or the Fama-French based models as follows:

$$Var_{CAPM,FF,t} = \sum_{i=1}^{N_t} w_{it-1}\left[\sum_{d\in t}(\tilde{\gamma}_d)^2\right], \tag{5}$$

where w_{it-1} is the weight based on the prior month's market capitalization of firm i among N possible firms.

3 Microstructure Bias in Aggregate Volatility Measures

Blume and Stambaugh (1983) model a microstructure effect that generates a difference between the observed daily gross return, $\tilde{R}_d$, and the true daily return, R_d, given as:

$$\tilde{R}_d = R_d\left(\frac{1+\delta_d}{1+\delta_{d-1}}\right). \tag{6}$$

The microstructure noise induced by the daily bid–ask spread on day d is represented by δ_d. Blume and Stambaugh (1983) assume that δ_d is a normally distributed random variable, i.e., $\delta_d \sim \mathcal{N}(0, \sigma_\delta^2)$ that is identically distributed across each day within a month, t. Expanding the denominator via Taylor–series expansion, as performed by Blume and Stambaugh (1983), shows:

$$\tilde{R}_d \approx R_d(1+\delta_d)(1-\delta_{d-1}+\delta_{d-1}^2). \tag{7}$$

(7) yields the following relation for the rate of return:

$$\tilde{r}_d = (1+\delta_d)(1-\delta_{d-1}+\delta_{d-1}^2)(r_d+1)-1. \tag{8}$$

Simplifying the expression by eliminating the higher order term, $\delta_d\delta_{d-1}^2$, results in:

$$\tilde{r}_d = r_d[1+(1-\delta_{d-1})(\delta_d-\delta_{d-1})]+[(1-\delta_{d-1})(\delta_d-\delta_{d-1})]. \tag{9}$$

Following Han and Lesmond (2011), a compact representation of the microstructure effect on daily returns is represented as:

$$\tilde{r}_d = r_d(1+\epsilon_d)+\epsilon_d. \tag{10}$$

where:

$$\epsilon_d = (\delta_d-\delta_{d-1}-\delta_d\delta_{d-1}+\delta_{d-1}^2), \tag{11}$$

To derive the microstructure effect on daily returns, we take the expectations of the ϵ_d terms that will be required in the analysis of the microstructure bias for each idiosyncratic variance measure.

The resulting expression drops the crossproducts and sets the expectation of δ_d^4 equal to the fourth moment, which is given by $3\sigma_\delta^4$. Assuming δ_d and δ_{d-1} are independent, and setting the expectation of $\delta_d^2\delta_{d-1}^2$ equal to σ_δ^4 results in:

$$\begin{aligned} E(\epsilon_d) &= E(\delta_d - \delta_{d-1} - \delta_d\delta_{d-1} + \delta_{d-1}^2) = \sigma_\delta^2, \\ Var(\epsilon_d) &= E(\epsilon^2) - [E(\epsilon)]^2 = 2\sigma_\delta^2 + 3\sigma_\delta^4. \end{aligned} \tag{12}$$

σ_δ^2 is the variance of the microstructure noise and, as argued by Blume and Stambaugh (1983), is estimated by the square of the bid-ask spread.

3.1 Microstructure Bias in Industry-Adjusted Variance Measure

We begin by analyzing the microstructure bias for the industry-adjusted variance expressed in equation (2). Substituting equation (10) into equation (1) results in:

$$\begin{aligned} \tilde{r}_d &= (r_{jd} + \eta_d)(1 + \epsilon_d) + \epsilon_d \\ &= r_{jd} + \epsilon_d(1 + r_{jd}) + (1 + \epsilon_d)\eta_d \\ &= r_{jd} + \eta_d^*, \end{aligned} \tag{13}$$

where $\eta_d^* = \epsilon_d(1 + r_{jd}) + (1 + \epsilon_d)\eta_d$. Noting that r_j refers to the industry return, we expand η_d^* as:

$$\eta^* = \epsilon + \eta + \epsilon r_j + \epsilon\eta \tag{14}$$

Taking the variance of each component and assuming the independence of each variable:

$$Var(\eta^*) = Var(\epsilon) + Var(\eta) + Var(\epsilon\eta) + Var(\epsilon r_j) \tag{15}$$

Focusing on $Var(\epsilon\eta)$ term and noting that we can rewrite $\epsilon = e + \sigma_\delta^2$ from equation (12) such that the $E(e)$ equals zero and as we have already noted that $E(\eta)$ equals zero allows for the following representation:

$$
\begin{aligned}
Var(\epsilon\eta) &= Var((e+\sigma_\delta^2)\eta) \\
&= Var(e\eta) + \sigma_\delta^4 Var(\eta) \\
&= Var(e)Var(\eta) + \sigma_\delta^4 Var(\eta) \\
&= (2\sigma_\delta^2 + 4\sigma_\delta^4)Var(\eta)
\end{aligned}
\tag{16}
$$

Finally examining the last term of equation (15) implies that, in expectation, both the daily returns as well as the industry returns are zero resulting in the the following variance representation:

$$Var(\epsilon r_j) = (2\sigma_\delta^2 + 4\sigma_\delta^4)Var(r_j) \tag{17}$$

Combining all terms in equation (15) yields:

$$Var(\eta^*) = 2\sigma_\delta^2 + 3\sigma_\delta^4 + Var(\eta) + (2\sigma_\delta^2 + 4\sigma_\delta^4)(Var(r_j) + Var(\eta)) \tag{18}$$

Simplifying by eliminating higher order terms results in

$$Var(\eta^*) \approx 2\sigma_\delta^2 + Var(\eta). \tag{19}$$

The observed variance estimated using daily firm-level returns is directly proportional to the square of the bid-ask spread leading to a microstructure bias embedded in the calculated industry-adjusted variance.

3.2 Microstructure Bias in Risk-Adjusted Idiosyncratic Variance Measure

Noting that we can state $\epsilon_d = e_d + \sigma_\delta^2$, we can rewrite equation (10) as:

$$\tilde{r}_d = r_d(1 + \sigma_\delta^2 + e_d) + (\sigma_\delta^2 + e_d)) \tag{20}$$

For simplicity, assuming that the true return is generated by a single factor model, $r_d = \alpha + \beta X_d + \nu_d$, with the error term distributed as $\mathcal{N}(0, \sigma_\nu^2)$, and substituting the microstructure effect into the market model representation yields:

$$\tilde{r}_d = \alpha^* + \beta^* X_d + \nu_d^*, \tag{21}$$

where $\alpha^* = \alpha(1 + \sigma_\delta^2) + \sigma_\delta^2$ and $\beta^* = \beta(1 + \sigma_\delta^2)$. Dropping subscripts and setting $\hat{\mu}_d = \alpha + \beta X_d$ allows for a compact representation of the error term stated as:

$$\nu^* = (1 + \hat{\mu})e + \nu(1 + \sigma_\delta^2) + \nu e. \tag{22}$$

Assuming independence between the regression model residual, ν_d, and the random shock, e_d, both of which are zero mean, allows the following representation for the variance of ν_d^*, which is then generally stated as:

$$Var(\nu^*) = (1 + \hat{\mu})^2 Var(e) + (1 + \sigma_\delta^2)^2 Var(\nu) + Var(\nu e). \tag{23}$$

As shown in Han and Lesmond (2011), $Var(\nu e) = Var(\nu)Var(e)$ resulting in:

$$\begin{aligned} Var(\nu^*) &= (1 + \hat{\mu})^2 Var(e) + (1 + \sigma_\delta^2)^2 Var(\nu) + Var(\nu)Var(e) \\ &= [(1 + \hat{\mu})^2 + Var(\nu)](2\sigma_\delta^2 + 3\sigma_\delta^4) + (1 + \sigma_\delta^2)^2 Var(\nu). \end{aligned} \tag{24}$$

For comparative analysis, all the terms in equation (24) are positive, indicating that the bid–ask microstructure effect on the asset return *increases* the resulting residual variance. Simplifying equation (24) by eliminating higher order terms produces a compact form given as:

$$Var(\nu^*) \approx 2\sigma_\delta^2 + Var(\nu). \tag{25}$$

As found with the CLMX measure of idiosyncratic variance , the idiosyncratic variance based on the risk-adjusted CAPM or Fama-French models yields the same microstructure bias, namely the observed idiosyncratic variance estimate is directly proportional to the square of the bid-ask spread.

4 Data

For each stock, we obtain the daily prices using the NYSE/Amex/NASDAQ CRSP database from 1962 to 2015. We exclude American depository receipts, real estate investment trusts, closed–end funds, and primes and scores (or those stocks that do not have a CRSP share code of 10 or 11). We will use the nomenclature year: month to denote the period for our study. Our sample runs from 1962m7 (July 1962) to 2015m12 (December 2015). Using these daily prices, we estimate the Campbell et al. (2001) industry adjusted and the risk-adjusted market model and the three-factor Fama and French (1993) idiosyncratic variance measures. The start date corresponds to the start date used by Campbell et al. (2001).

Our microstructure theory requires the bid-ask spread to estimate the measurement error spanning our entire sample period. Our primary measure of the bid-ask spread estimate is the Corwin and Schultz (2012) estimator. This measure of the bid-ask spread uses the intraday lowest bid and highest ask to provide a daily estimate of the bid-ask spread. Corwin and Schultz (2012) argue that high (low) prices are almost always buyer (seller) initiated. Therefore, the daily price range reflects both the stock's volatility and its bid-ask spread. They build their model on the comparison of one- and two-day price ranges. The latter should reflect twice the variance of the former, but they should have the same bid-ask spread. They calculate the two-day spread as:

$$\text{Bid-Ask Spread} = \frac{2(e^{\alpha} - 1)}{1 + e^{\alpha}}, \tag{26}$$

where,

$$\alpha = \frac{\sqrt{2\beta} - \sqrt{\beta}}{3 - 2\sqrt{2}} - \sqrt{\frac{\gamma}{3 - 2\sqrt{2}}}, \beta = E\left(\sum_{j=0}^{1}\left[ln\left(\frac{H_{t+j}^{0}}{L_{t+j}^{0}}\right)\right]^2\right), \gamma = \left[ln\left(\frac{H_{t+1}^{0}}{L_{t+1}^{0}}\right)\right]^2 \tag{27}$$

The monthly estimates are calculated as the average of the two-day estimates. We set negative bid-ask spread estimates to missing. In robustness checks, we also use the Roll (1984) spread estimator and we use the Amihud (2002) price impact measure as a direct test of our market microstructure model.

The earnings shock is compiled from Compustat and is available from 1963m11 onwards. We estimate the earnings shock [3] in a manner identical to Irvine and Pontiff (2009). For each listed U.S. firm, we compute the market-to-book value of assets using data from Compustat. Market-to-book is the ratio of (Total Assets-Total Common Equity + Price* Common Shares Outstanding)/Total Assets. We value-weight our idiosyncratic variance estimates using the lagged prior month market capitalization. We also use CRSP to develop a measure of firm age. Namely, we construct a proxy for firm age that calculates the proportion of the market comprising firms more than 20 years old. We do not specifically rely on the Initial Public Offering date because requiring this date would eliminate over 2/3 of our sample.

We also use the quoted spreads to obtain an estimate of idiosyncratic variance that is devoid of microstructure noise by using quote midpoints. The quoted spreads are available using both the ISSM (International Study of Security Markets) and TAQ (Trade and Quote) from 1983 to 2015. We also obtain a measure of retail trades from 1983 to 2000 from the TAQ and the ISSM databases, where small-sized trades are used to proxy for retail trades. [4] For our difference-in-difference tests, we use Datastream for the G6 countries as our source for daily transaction prices and closing bid-ask quotes.[5] We calculate the industry-adjusted idiosyncratic volatility measure for the G6 markets using the Compustat - Capital IQ from Standard & Poor's global and North American segments in a manner consistent with that used for U.S. market. Compustat - Capital IQ provide the SIC codes that are similar to those of U.S. based firms. For these tests we use the closing bid-ask quotes

[3] We thank Paul Irvine for providing both his earnings shock estimates as well as his SAS code. This allows us to closely match the earnings shock estimates in the more recent periods

[4] Following Hvidkjaer (2008), we use the $5,000 trade size cutoff to identify small trades. Like Hvidkjaer (2008), we use the ISSM/TAQ data only until 2000 because the assumption that small trades proxy retail trading is less likely to be valid after 2000. In particular, the introduction of decimalized trading in April of 2001 and extensive order-splitting by institutions due to reduced trading costs make small trade size a less reliable proxy for retail trading after 2000.

[5] As noted in Han, Hu, and Lesmond (2015), Datastream and Bloomberg do *not* report the actual closing transaction price for the English market from 1986 to 2008. Rather they report an indicative price that is set to some level within the prevailing quote. Hence, we employ the Thomson Reuters Tick History (TRTH) intra-day data to determine the end-of-day bid and ask quotes as well as the last trade price of the day for the English market. Accurate closing prices from TRTH commence in 1996 for the English market.

for both the US markets and for the G6 markets. We use Datastream for estimates of the closing bid-ask quotes.

We also adopt the data filter that Ince and Porter (2006) advocated when we use daily return data from Datastream. Specifically, we set daily returns to missing if the following condition is satisfied: $(1+R_{i,d})(1+R_{i,d-1}) <= 1.5$, where $R_{i,d}$ and $R_{i,d-1}$ are the stock returns of firm i on day d and $d-1$, respectively, with at least one return greater than 100%. Finally, we convert all returns and local market factors from local currency prices into U.S. dollars for the non-U.S. markets. We accomplish this conversion by using the daily exchange rate for each country as provided by Datastream.

5 Summary Statistics of Idiosyncratic Variance Estimates and Liquidity Measures

Table 1 presents summary statistics for levels in the value-weighted CLMX, CAPM, and Fama and French (1993) risk-factor adjusted idiosyncratic variance measures for the test period comprised in our study. This period spans 1962m7 to 2015m12. These measures span NYSE/Amex and NASDAQ markets. We compliment these measures with the Corwin and Schultz (2012) bid-ask spread estimate and the Amihud (2002) price impact measure. The liquidity cost measures are value-weighted using the market capitalization as of the previous month. It should be noted that we employ the square of the bid-ask spread in all of our tests to be consistent with our microstructure theory.[6]

As shown in Table 1, the CLMX IV measure is demonstrably larger than is the idiosyncratic variance produced by either the CAPM or the Fama and French (1993) risk-adjusted estimate. However, increasing the number of risk factors produces idiosyncratic variance estimates that are consistent between the CAPM and the multi-factor model estimates. Regardless, the higher order moments of the variance, the skewness and kurtosis of all the idiosyncratic variance estimates are virtually identical. We do not find evidence of a unit root process for any measure of idiosyncratic

[6] Our results are robust to using the level for the bid-ask spread.

variance using either the Augmented Dickey-Fuller or the Phillips-Perron unit root test. The liquidity measures also reject unit root concerns.

Turning to the correlation coefficients, we see a high degree of correlation between the various measures of idiosyncratic variance. The bid-ask spread is 90% correlated with all of the measures of aggregate idiosyncratic variance. However, this does not extend to Amihud's measure where we see a negative 8% correlation among the various measure of aggregate idiosyncratic variance.

6 Time Trend Tests

We test for structural breaks in the CLMX idiosyncratic variance time-series using the Bai and Perron (1998) and Bai and Perron (2003) tests. We use the observed end-of-day quotes to estimate quote midpoint returns to estimate the CLMX idiosyncratic variance and then to test for time trends within the periods dictated by the break dates. Finally, we use low frequency bid-ask spread estimate of Corwin and Schultz (2012) and the price impact estimate of Amihud (2002) against closing return estimates of the CLMX idiosyncratic variance.

6.1 Bai-Perron Break Tests

We use the Bai and Perron (1998) and Bai and Perron (2003) multiple breakpoints identification method and estimate the following set of m + 1 time-series models of aggregate variance over the period 1962m7 to 2015m12:

$$\text{CLMX IV}_t = \beta_{j0} + \beta_{j1}\text{CLMX IV}_{t-1} + \epsilon_t, \tag{28}$$

where j estimates the number of breakpoints. While different criteria are available for the search procedure, we use the maximum F-statistic estimated across each sub-period to delineate the breakpoint(s). We estimate m + 1 regressions, one for each of the m + 1 segments defined by the m breakpoints. The breakpoint estimation method identifies the location of the breakpoints by minimizing the total residual sum of squares from the m + 1 linear regression models.

The break date results with the associated F-statistics are presented in Table 2. As is shown, the maximum F-statistic predicts two breaks in the CLMX IV time-series. These occur in 1998m9 and 2001m5. We can attribute the break in 1998m9 to the liquidity crisis induced by the Russian debt default that led to the collapse of LTCM (Long-Term Capital Management). The second date carries particular economic relevance for our microstructure analysis. This is the date whereby the SEC required all firms to report stock quotes in decimals. Given that the decimalization occurred mid-month, we anticipate that May of 2001 is the first month that will experience the full effect of the decimalization in stock quotes.

The trend in CLMX IV and its relation to the bid-ask spread along with the proposed break dates are shown in Figure 1. The break dates are shown in the vertical lines applicable to 1998m9, 2001m5. As is shown, the correlation between the CLMX idiosyncratic variance measure and the bid-ask spread is very high. The first break date witnesses a sudden and sharp upward break in the CLMX idiosyncratic variance measure, but this is matched by an equally sudden and sharp increase in the bid-ask spreads. Also evident in Figure 1 is a sudden and downward break in the CLMX idiosyncratic variance that occurs in 2001m5. Subsequent to the decimalization in April of 2001, we see a decline in idiosyncratic variance consistent with the decline in the reported bid-ask spreads subsequent to quote decimalization. The recession witnessed a resurgence in both the CLMX idiosyncratic variance, but with the bid-ask spreads as well. Subsequently, the aggregate variance is seen to drop precipitously along with the bid-ask spread. It is interesting to note that high frequency (algorithmic trading) begins to dominate the market subsequent to 2009 (Glantz and Kissell, 2013). Algorithmic trading is credited with reducing bid-ask spreads (Hendershott, Jones, and Menkveld, 2011).

6.2 Quote Midpoint Based Idiosyncratic Variance Estimates and Time Trend Tests

We begin our time trend tests by using an estimate of aggregate idiosyncratic variance based on both the closing price and the quote midpoint. It is common practice in the literature to use mid-points of bid-ask quotes as measures of the true prices. While these measures are affected by residual noise in that there is no theoretical guarantee that the mid-points coincide with the underlying efficient prices, they are less noisy measures of the efficient prices than the transaction prices are since they do not suffer from bid-ask bounce effects. This will provide a basis for observing the behavior of idiosyncratic variance that is devoid of the bid-ask bounce. We use data from 1983m1 to 1998m9 and then from 1983m1 to 2001m5. Both of these periods are noted for a positive time trend in the estimate of idiosyncratic variance. The results are presented in Table 3.

As shown in Table 3 for the period 1983m1 to 1998m9, there is a significant time trend associated with the CLMX idiosyncratic variance estimate. The time trend is statistically robust. However, the idiosyncratic variance estimate derived using quote midpoints is not statistically significant. This demonstrates the importance of measurement error on the estimate of idiosyncratic variance.

Turning to the period 1983m1 to 2001m5, we immediately see a strengthening of the time trend that rises from 0.0911 (for the period 1983m1 to 1998m9) to 0.4784 (for the period 1983m1 to 2001m5) indicating that the NASDAQ bubble witnessed a large increase in idiosyncratic variance. The t-statistics show continued statistical robustness in the time trend. But the quote midpoint based estimate of aggregate idiosyncratic variance shows no significant time trend. This evidence is fully consistent with a measurement error bias that is embedded in the Campbell et al. (2001) estimate of idiosyncratic variance. Controlling for the measurement error bias in the estimate of idiosyncratic variance is sufficient at removing any significance for the time trend.

6.3 Time Trend Tests Controlling for the Bid-Ask Spread

We now directly control for the microstructure noise in tests for the time trend. We examine two periods that correspond to our break dates using the periods 1962m7 to 1998m9 and from

1962m7 to 2001m5 wherein we examine a positive time trend and then from 2001m6 to 2007m11 where we examine a negative time trend. For robustness, we also check for a time trend after the Great Recession that begins in 2009m7 and concludes in 2015m12. We primarily use the bid-ask spread estimator of Corwin and Schultz (2012) due to the sample period that precedes the availability of the closing bid-ask quotes. We augment this bid-ask spread measure with Amihud's (2002) measure when testing the alternative explanations of the time trend. The latter of which will provide a comparison between microstructure noise and price impact estimators about the time trend. We test our theoretical model by hypothesizing that microstructure noise should dominate the price impact's effect on the time trend.

The prior quote midpoint results are limited to a relatively short period. It may be the case that a longer time period may evidence a more persistent time trend. We propose two tests to isolate the effect of the bid-ask spread on the time trend exhibited with the CLMX IV measure. The first method is a direct control on the bid-ask spread in a standard regression format. The second method is to regress the CLMX idiosyncratic variance estimate on the bid-ask spread and then using the residual from this regression test whether this residual displays a significant time trend. The residual from this regression is the level of CLMX IV that is orthogonal to the bid-ask spread. We will term this variable the CLMX IV residual. We now examine time trend tests with the following specification

$$\text{CLMX IV}_t = \alpha_0 + \beta_1 Time + \beta_2 Bid - Ask_t + \beta_3 Amihud_t + \epsilon_t, \tag{29}$$

where time represents the trend. CLMX IV is the variance of the CLMX measure. All the liquidity measures are value-weighted to conform to the weighting performed in constructing the CLMX IV measure. We test from 1962m7 to 1998m9 (our first break date) and from 1962m7 to 2001m5 (our second break date). These time spans have been shown to exhibit significant positive time trends. Brown and Ferreira (2016) show that aggregate idiosyncratic variance is highly correlated with economic business cycles. Hence, we also test for time trends from 2001m6 to 2007m11. We choose the end date to correspond to the last month before entering the Great Recession. Using the same reasoning, we also test the period immediately following the recession. This period is 2009m7 to 2015m12. We find that the time trend is negative during these latter two periods. These tests will attempt to address whether a microstructure noise explanation for the time trend found in the CLMX idiosyncratic variance measure is more relevant than is a price impact rationale for the time trend. We specify Newey and West (1987) robust t-statistics with 12 lags.

As shown in Panel A of Table 4, for the period 1962m7 to 1998m9 we see that the time trend is indeed positive and significant, indicating an upward trend in the CLMX aggregate idiosyncratic variance. However, if we test for a time trend using the CLMX IV residual we see clearly that there is little evidence of a time trend. Indeed, the sign of the time trend is now negative, albeit insignificant. This result is reinforced when we include the bid-ask spread. The time trend becomes insignificant and the loading is on the bid-ask spread. The bid-ask spread alone captures 60% (82% minus 22%) of the time-series variation in the CLMX idiosyncratic variance measure. However, the explanatory power of liquidity does not extend to Amihud's measure. As shown in the next regression specification, the regression specification using Amihud's measure shows continued significance in the time trend further exemplifying the importance of the bid-ask spread in relation to the time-trend in the aggregate firm-level variance.

For the period 1962m7 to 2001m5 period, shown in Panel B of Table 4, we see that the time trend is again positive and significant indicating a continuance in the upward trend in the CLMX aggregate idiosyncratic variance continues through 2001. However, using the CLMX IV residual shows an insignificant time trend. Directly including the bid-ask spread eliminates the positive trend. But it should be noted that the bid-ask spread alone explains more than 62% (91% minus 29%) of the time-series variation in the CLMX idiosyncratic variance measure. As found previously, Amihud's measure is unable to explain the positive time trend. This again emphasizes the effectiveness of the microstructure theory that only extends to the bid-ask spread.

We extend the examination of time trends to the period after 2001m5. We examine two time periods. The first is from 2001m6 to 2007m11, and then from 2009m7 to 2015m12. These two periods skip the great recession. The results are shown in Panels C and D, in Table 4.

In Panel C, for the period 2001m6 to 2007m11, we immediately see that now the time trend is negative. The time trend is -0.8913 and significant at the 1% level. We would attribute this decline to the decimalization effect on stock quotes. This conclusion is reinforced when we test for time trends using the CLMX IV residual. Now the time trend is insignificant illustrating the effect of measurement error on the estimate of idiosyncratic variance. The same result is obtained by controlling for the bid-ask spread. The time trend is now marginally negative (recorded at -0.1069).

Finally, in Panel D, for the period 2009m7 to 2015m12, we again see that the time trend is negative and significant at the 10% level. But the residual CLMX IV measure shows no significance in the time trend. This is also observed by directly controlling for the bid-ask spread whereby the time trend is insignificant. Amihud's measure does not completely remove the significance of the time trend, although the significance is marginal (10% level). However, no significance for Amihud's measure is apparent during the 2009m8 to 2015m12 period.

These results clearly indicate that the time-trend in volatility exhibited by the CLMX idiosyncratic variance measure is more reflective of the trend in the underlying aggregate firm-level bid-ask spread, a result that is entirely consistent with a market microstructure effect on the daily returns that form the basis of the aggregate idiosyncratic variance measures.

7 Alternative Models in Time Trend Tests

Past research has shown that a number of variables are related to the CLMX idiosyncratic volatility measure. In this section we benchmark the explanatory power of these variables against that of liquidity. For robustness we use two measures of liquidity, the Roll (1984) bid-ask spread estimator, as well as the Corwin and Schultz (2012) measure. Additional explanatory variables include proxies for growth options Cao et al. (2008), earnings shocks (Wei and Zhang, 2006; Irvine and Pontiff, 2009), firm age and profitability (Pástor and Veronesi, 2003), and retail trading volume (Brandt et al., 2010). Table 5 shows the results of our tests, in which the additional explanatory variables are added into the regression that includes the bid-ask spread liquidity estimators.

It may also be the case that controlling for risk may affect the inferences concerning the time trend in idiosyncratic variance. We control for this by estimating idiosyncratic variance using a Fama-French specification for the return generating process and measuring idiosyncratic variance after estimating the risk parameters.

7.1 Alternative Explanations for the Time Trend

The first three panels of Table 5 focus on a time period ending in 2001m5, corresponding to our estimated break date. The starting dates for each set of explanatory variables are dependent on data availability for each set of explanatory variables. In the last panel of the table we focus on a time period from 2001 to 2007, where the time trend is negative further illustrating the bid-ask bounce effect on the CLMX measure of idiosyncratic variance.

In Panel A of Table 5, which uses data spanning 1963m11 to 2001m5 (given earnings information), we first see that the time trend alone is positive and significant, with a coefficient of 0.1851, and a t-statistic greater than 3. However, once we add the Corwin and Schultz (2012) bid-ask spread estimate, the time trend ceases to be positive and significant. Adding Roll (1984) reduces the level of the time trend considerably, but the time trend remains marginally significant. In each case, the goodness-of-fit measure demonstrably increases from 28% for the trend alone to 85% and 91% for the Roll (1984) or the Corwin and Schultz (2012) bid-ask spread measures, respectively. If we include earnings shocks [7] and firm age in the time trend regression the significance of the trend also disappears. However while firm age remains significant, the earnings shock falls from significance indicating that after controlling for the time trend earnings shocks have no association with the CLMX idiosyncratic variance. However, the goodness of fit of this model only reaches 41%. Adding the bid-ask spread estimates to the other regressors we see that their coefficients are almost identical in size and significance to those observed when they are used on their own, and that the goodness-of-fit of these models is more than doubled in size, attesting to the explanatory power added by the spread.

[7] In unreported results, we also test whether idiosyncratic volatility, as specified in Irvine and Pontiff (2009), is associated with earnings shocks. We find that earnings shocks, in and of itself, can explain the time trend. But adding the bid-ask spread subsumes the significance of the earnings shocks.

In Panel B of Table 5 we add market-to-book as a proxy for growth options and ROE. These models are estimated with data from 1971m9 to 2001m5. As found in Panel A, the trend by itself is positive and significant, but the time trend is insignificant after controlling for the Corwin and Schultz (2012) estimate, but remains marginally significant for the Roll (1984) estimate. Including all the alternative explanatory variables also eliminates the positive trend with significance maintained for book-to-market and firm age. Both are of the expected sign indicating that across this period, the idiosyncratic variance was directed by younger, growth firms. While not reported, we also included each of the variables separately and only the market-to-book growth option proxy was sufficient in removing the significance of the time trend. Combining all four of the alternative explanatory variables, along with the spread estimators, induces a marginally significant negative time trend for the Corwin and Schultz (2012) estimator. Including the bid-ask spreads does affect the loadings on firm age. When the Corwin and Schultz (2012) measure is included in the specification, the coefficient of firm age is reduced from a previous value of -0.0162 to -0.0095, while market-to-book is reduced from 0.0034 to 0.0010 (although both remain significant).

Panel C shows the results of adding a proxy for behavioral explanation of idiosyncratic volatility, in terms of retail trading, to the previous models. This period ranges from 1983m1 to 2001m5. The results are similar to those described previously, in that the trend is significant alone, but ceases to be significant in the presence of the Corwin and Schultz (2012) measure of the bid-ask spread or the time trend is marginally significant for the Roll (1984) bid-ask spread measure. Adding retail trading to the other regressors causes the time trend coefficient to switch sign, becoming negative and significant, with the model attaining an R-square of 73%. Adding the bid-ask spread to this specification absorbs the explanatory power of the retail trading proxy, which ceases to be statistically significant. The retail trading coefficient is reduced from 0.0234 (and significant) in model 6 (that does not contain the spread), to -0.0075 and 0.0059, depending on the spread measure.

As shown in previous results, the time trend becomes negative in the time period after the decimalization period. We study this time period, 2001 to 2007, in Panel D of Table 6, and once again evaluate the relative explanatory power that each variable has on the trend during this period.

The results in the first two models remain qualitatively similar to those in previous panels. The trend alone is negative and significant. Adding the Corwin and Schultz (2012) measure of the bid-ask spread completely subsumes the explanatory power of the trend, rendering its coefficient insignificant. In the case of the Roll (1984) spread measure, the trend coefficient is reduced in size from -0.8913 alone to -0.3366, but it remains marginally significant. Once again, the models with the spread variable explain more than 85% of the variability of the CLMX IV measure, whereas the time trend alone only manages to explain about 39%. In contrast, the specification that includes the trend and all explanatory variables except the spread reaches an R-square of only 55%, and the trend remains large and significant in the presence of these additional regressors. It should be noted that market-to-book is now insignificant in relation to the CLMX idiosyncratic variance measure. While not reported, separately adding each of the additional explanatory variables is insufficient in eliminating the negative trend in the CLMX idiosyncratic variance. Adding the Roll spread to this model increases the R-square to 84%, and subsumes the effect of the trend altogether. More impressively, Roll's (1984)model removes all the significance from the alternative explanations for the trend in the CLMX idiosyncratic variance.

7.2 Alternative Measures of Idiosyncratic Variance

We now repeat these time trend tests using a measure of idiosyncratic variance based on the Fama and French three-factor model (FF IV). [8] This measure of idiosyncratic variance is the dependent variables in regression specifications that include the time trend by itself, as well as the Corwin and Schultz (2012) bid-ask spread measure, and the alternative explanatory variables, which include earnings shocks, ROE, market-to-book, firm age, and retail trading. As in Table 5, we present four panels spanning a different time period. We analyze three periods that begin whenever the relevant data becomes available and end in 2001, and a final post-CLMX period that spans 2001-2007, where previous results show that the time trend of idiosyncratic volatility is reversed. The results of these tests are shown in Table 6

[8] All the results obtained using the three-factor model extend to the CAPM based idiosyncratic variance. For brevity, we do not report these results.

The first model in each panel shows that the time trend is positive in Panels A (model 1), B (model 5), and C (model 9), for those periods prior to 2001, and negative in Panel D (model 13) subsequent to 2001. On its own, the trend is significant, and its explanatory power is relatively high, with an R-squared between 30% and 40%, depending on the time period. However, in every case the addition of the bid-ask spread subsumes the effect of the trend. The addition of the spread to the trend model also elevates the R-squared above 90%.

In Panels A and B we can see that adding four of the alternative explanatory variables, earnings shocks, firm age, market-to-book and ROE, to the trend results in the trend losing significance. While not all of these variables are statistically significant, the overall explanatory power of the model increases, on average, to about 70% when including the market-to-book ratio. However, adding the bid-ask spread to this extended specification retains the main results, but further increases the R-squared. Moreover, while the coefficient of the spread is close in size and significance to the one it attains on its own, those of the other variables see reductions in magnitude and the loss of significance.

In Panel C we add a proxy for retail trading. In conjunction with the rest of the tested variables, we see that this causes the trend coefficient to become negative and significant, reversing the previously reported time trend in idiosyncratic volatility. Adding the spread to this specification does increase the model's R-squared by about 20%, reduces the time trend coefficient to insignificance, and reduces retail trading to insignificance.

Finally, in Panel D we look at a period of time after the one original studied in CLMX where, as we have seen in previous results, the time trend is reversed and its coefficient is now negative. The main results remain unchanged: the trend by itself is negative and significant, and provides a relatively low R-squared (around 39%), but the addition of the spread causes the trend to become insignificant, and the R-squared to increase to 93%. In this case adding the alternative explanatory variables actually increases the size of the trend coefficient, from -0.0508 to -0.2379. Adding the bid-ask spread has a strong effect, reversing the sign of the trend coefficient, which now becomes positive, but marginally significant, and increasing the R-squared of the model to over 94%.

The results indicate that the bid-ask spread fully subsumes the effect of the time trend in explaining the variation in idiosyncratic volatility, and this effect is robust to various measures of IV, and the use of other explanatory variables. These variables in some cases can explain away the trend but are demonstrated to be poor substitutes for the spread in terms of the overall explanatory power of the model, in terms of its R-squared.

7.3 Incremental Content of the Bid-Ask Spread

It is apparent that the bid-ask spread is vital in understanding the trend and behavior in industry-adjusted or risk-adjusted measures of idiosyncratic variance. We first examine the time trends evident in each of the explanations for the CLMX measure and conclude with a principal component analysis. To this end, we first extract the common factors using factor analysis for the correlation across earnings shocks, firm age, market-to-book, return-on-equity, and Amihud's price impact measure. We then extract the common factors by adding the Corwin and Schultz (2012) bid-ask spread. This test will delineate the ability of the bid ask spread to incrementally explain the trend in the CLMX idiosyncratic variance measure using what is common to all the explanations for the trend. We begin the tests using 1971m9 that is the initial date for data availability for growth options across both NYSE/Amex and NASDAQ firms and the end date to correspond to our break dates. This is the period wherein the positive trend is observed. Table 7 presents the initial results.

We begin by examining whether the alternative control variables demonstrate a time trend. The results are shown in Panel A of Table 7. As shown in Panel A, earnings shocks, market-to-book, and return-on-equity, and the bid-ask spread all demonstrate a positive time trend indicating "growth" through time, but firm age demonstrates a negative time trend, indicating that over time the market if composed of younger firms.[9] The last column of Panel A of Table 7, shows that the bid-ask spread and the various control variables are highly associated. As expected, firm age is negatively associated with the bid-ask spread, and firms with greater growth options that

[9] In unreported results, regression tests using the CLMX measure of idiosyncratic variance, a time trend, and adding each alternative control variable separately shows that only the variables demonstrating a positive trend can reduce the time trend to insignificance.

experience increased earnings shocks are positively associated with bid-ask spread. These results indicate that the bid-ask spread reflects the influence of these alternative explanations, but, given our prior results, the bid-ask spread exhibits incremental explanatory power over and above these alternative control variables in explaining the time trend in the CLMX measure of idiosyncratic variance.

We conclude with principal component regression tests of the time trend. Panel B of Table 7 shows that there is a healthy time trend from 1971m9 to 1998m9 (corresponding to our first break) that is significant at the 5% level. Including the first two principal components [10] estimated using only the alternative control variables is unable to explain the time trend that is now even more pronounced remaining significant at the 5% level. The principal components display little association with the trend wherein marginal significance for the second factor is found. However, estimating the principal components by including the bid-ask spread (column 3), shows no significance for the time trend. Now the both principal components load significantly on the CLMX measure of idiosyncratic variance. The goodness of fit also registers a sizable increase in the explanatory power.

Examining the period 1971m9 to 2001m5 shows that the time trend is more pronounced, almost tripling from the prior period (from 0.0704 to 0.2256), but that the first two principal components estimated using only the alternative control variables is incapable of explaining the time trend which remains significant, recorded at 0.1001, at the 5% level. Again, including the bid-ask spread to the factor analysis shows clearly the incremental power of the bid-ask spread. Now the time trend is negative, recorded at -0.1027, but only significant at the 10% level. This incremental power is also demonstrated by a vastly increased goodness of fit. For example, in the base model, the time trend explains 23.2% of the variation in the CLMX idiosyncratic variance, and including the alternative control based principal components now explains 57.3% of the variation in the CLMX measure, but including the bid-ask based principal components now explains 80% of the variation in the CLMX measure of idiosyncratic variance.

[10] In unreported results, the eigenvalues for the first two factors are above one and they represent approximately 60% of the cumulative variation across the included factors. Scree plots show that after the first two eigenvalues, the trend is asymptotically declining. Including the bid-ask spread to the alternative control variables shows the first two factors are again dominant indicating that the commonality among the alternative control variables is also shared by the bid-ask spread.

8 A Natural Experiment and Cross-Sectional Tests

We now provide a natural experiment to control for endogeneity biases, where the bid-ask spread and aggregate variance could be jointly affected by some other factors such as the financial market and macroeconomic conditions or subject to reverse causality concerns. We also perform cross-sectional Fama-MacBeth tests for determinants of the CLMX measure of idiosyncratic variance.

8.1 A Natural Experiment

It may be the case that endogeneity biases may affect our inferences concerning the effect of the bid-ask spread on idiosyncratic variance. To control for any endogeneity bias, we propose a natural experiment to isolate the effect of the bid-ask spread on the CLMX measure of idiosyncratic variance by using an exogenous shock on the bid-ask spread for the U.S. market. This occurred during quote decimalization in the U.S. markets.[11] We use the G6 markets as a control group because these markets employed decimal quotes well before the U.S. market. We use the closing bid-ask quotes [12] for each market as a direct estimate of the spread. The decimalization effect on the bid-ask spread is illustrated in Figure 2. The relatively small bid-ask spread effect noted for April of 2001 is due to timing of the decimalization that occurs mid-month. We estimate the daily average bid-ask spread over a month and given that the decimalization occurs on April 9, 2001 only a portion of the monthly average bid-ask spread is affected by the decimalization. The full effect of the decimalization is most noted for May of 2001.

A critical assumption of the difference-in-difference test is that the U.S. market (treatment group) and the G6 markets (control group) should exhibit the same trend for the period before the exogenous shock. The common trend ensures that the same factors are affecting both the treatment and the control firms.

Figure 3 shows the time-series of both the U.S. and the aggregate G6 idiosyncratic variance

[11]Decimalization across all NYSE quotes occurred in February and this was followed by the decimalization across all stocks as of April 2001.

[12]We use the closing bid-ask spread for both the U.S. and the G6 markets because of data limitations in obtaining the intraday lowest bid and highest ask required to estimate the Corwin and Schultz (2012) model. Using the closing bid-ask spread is an additional robustness check on our results.

measures along with the trend line for each group of countries from 2000m4 to 2002m4. We choose a relatively short time span to better frame the effect of the exogenous shock [13] on the CLMX measure of idiosyncratic variance. As is shown in Figure 3, the CLMX idiosyncratic variance exhibits a downward trend for the period immediately before the decimalization, but the trend is virtually identical between the treatment and the control groups. The parallel trend in the CLMX IV measures between the treatment and control firms ensures test validity for the diff-in-diff specification. The diff-in-diff specification is as follows:

$$
\begin{aligned}
\text{CLMX IV}_{i,t} = \beta_0 + \beta_1&\text{Decimalization Dummy} + \beta_2\text{Treatment Dummy}+ \\
&\beta_3\text{Decimalization Dummy*Treatment Dummy} + \beta_4\text{Amihud's Measure} \\
&+ \beta_5\text{Zero Returns} + \beta_6\text{Skewness} + \beta_7\text{Market-to-Book} + \beta_8\text{Lagged Price} \\
&+ \beta_9\text{Financial Risk} + \epsilon_{i,t},
\end{aligned}
\tag{30}
$$

where the interaction term captures the regulatory effect on the bid-ask spread quotes. We include Amihud's (2002) price impact measure and the percentage of zero returns (Lesmond, Ogden, and Trzcinka, 1999) as alternative liquidity effects. Additional control variables thought to be associated with the CLMX measure as posed in Brandt et al. (2010) include market-to-book, price (lagged by one-month), and return skewness. We also include financial risk (scaled from 1 to 50 where 50 conveys lower financial risk) that is a means of assessing a country's ability to finance its official, commercial, and trade debt obligations. This is obtained from the International Country Risk Guide (ICRG). Uncertainty in financial risk may increase market volatility. The results for the period 2000m4 to 2002m4 are shown in Table 8. We show results for just the diff-in-diff terms and then sequentially add the explanatory variables. We present both pooled and monthly fixed effects model specifications.

As shown in column (1) of Table 8, we see that the base regression indicates that the decimalization event negatively and significantly affects the observed industry-adjusted idiosyncratic volatility for U.S. firms. Controlling for monthly fixed effects only strengthens the relation between

[13] We also run a diff-in-diff test spanning the period 1986 to 2007. We obtain similar inferences concerning the effect of the bid-ask spread on idiosyncratic variance as the shorter time period.

the decimalization event and the behavior of the industry-adjusted idiosyncratic variance. As shown in column (4) the decimalization and treatment interaction term remains negative and significant. Also of note is the robust goodness of fit that shows that the diff-in-diff specification captures a considerable amount of the variation in the CLMX measure of idiosyncratic variance.

Including the firm-specific control variables, shown in column (2), for the pooled regression indicates continued robust significance for the interaction term in its association with the CLMX measure. The positive sign on market-to-book indicates that the CLMX measure is associated with growth firms. The relatively modest increase in the goodness of fit posits that the majority of the explanatory power derives from the diff-in-diff specification. Controlling for systemic financial risk, given in Column (3) does not affect the inferences concerning the effect of the bid-ask spread don the CLMX measure of idiosyncratic variance.

The fixed effects regression, given in column (5) of Table 8, shows the interaction term is significant at the 5% level and the book-to-market effect is significant at the 10% level, but they both remain significantly associated with the CLMX measure of idiosyncratic variance. Including the effect of financial risk, as shown in column (6), shows renewed robustness for the decimalization effect on the CLMX measure and while negative in its association with idiosyncratic variance, it is insignificant.

8.2 Cross-Sectional Behavioral Test

Brandt et al. (2010) argue that the increase in idiosyncratic volatility through the 1990s was not a time trend but, rather, an episodic phenomenon, at least partially associated with retail investors. Results from cross-sectional regressions, conditional trend estimation, stock-split events, and "attention grabbing" events are consistent with a retail trading effect. We directly test whether retail trading can explain the behavior of the idiosyncratic variance measure in light of liquidity as measured by the bid-ask spread and Amihud's price impact measure. Given that we gather information on dollar trade value, we use the closing bid-ask quotes as a basis for the bid-ask spread.

The results are shown in Table 9. We focus on the CLMX measure of idiosyncratic volatility from 1983 to 2000 to correspond to data availability for retail trades. We specify a Fama-MacBeth regression with variables included in Brandt et al. (2010) and separate out each major category. We include and exclude the lagged idiosyncratic variance to control for multicollinearity that would result when we include the bid-ask spread as a regressor. As the results indicate, retail trading is indeed significantly associated with future idiosyncratic volatility, with more weight being placed on low priced stocks, consistent with Brandt et al. (2010). Including Amihud's measure, while positive in its association with the future idiosyncratic variance measure, does not alter the empirical inferences of retail trading. Retail trading remains significant in its association with future idiosyncratic variance.

Including the bid-ask spread also shows a positive cross-sectional association with the one-month ahead idiosyncratic variance measure. But, unlike Amihud's measure, in the presence of the bid-ask spread retail trading falls from significance. The decrease in significance for retail trading is shown by a fall in the t-statistic from 6.13 to a t-statistic of -0.02! The microstructure influence, embodied only in the bid-ask spread, on one-month ahead idiosyncratic variance dominates the behavioral explanation measured by retail trading.

9 Alternative Exchanges and a Natural Experiment

We split our sample into NYSE/Amex and NASDAQ exchanges to better separate out the effect of the bid-ask spread on idiosyncratic variance. Based on this separation, we design an diff-in-diff test to further examine the NASDAQ firms and to control for endogeneity biases.

9.1 Alternative Exhanges

Bessembinder and Kaufman (1997) and Bessembinder (1999, 2003) find NASDAQ firms experience higher bid-ask spreads than do NYSE/Amex firms. Indeed, Christie and Schultz (1994) note that for long periods NASDAQ market makers colluded thereby driving up the bid-ask spread for

NASDAQ listed firms relative to NYSE-listed firms. Motivated by these findings, we investigate the ability of market microstructure to explain the firm-specific idiosyncratic variance of NASDAQ versus NYSE/AMEX firms. One the one hand, it could be argued that higher bid-ask spreads for firms listed on NASDAQ will drive upward the level of the estimated idiosyncratic variance. On the other hand, the larger NYSE/AMEX firms, by experiencing lower bid-ask spread costs, will have lower estimates of idiosyncratic variance. A priori, we would expect the time trend for NASDAQ firms to be more apparent than for NYSE/Amex firms if our microstructure model is correct. This is corroborated by Cao et al. (2008) who note that the idiosyncratic volatility of NASDAQ firms is about four times that of NYSE/Amex firms.

Meanwhile, Schwert (2002) documents unusually high volatility of NASDAQ firms compared with NYSE/AMEX firms over the period between 1995 and 2001. He concludes that the substantial increase in total return volatility of NASDAQ stocks is due to the type of firms (technology firms) that are presumably high growth firms rather than to the firm size or the immaturity of the firm. Motivated by this finding, we also investigate the ability of growth options to explain the idiosyncratic variance of NASDAQ versus NYSE/AMEX firms. We explore these issues by separating firms listed on NASDAQ from those listed on the NYSE and Amex exchanges. We restrict our analysis to the sub-periods dictated by our break dates, as suggested by the breakpoint results in Table 2.

We first investigate whether market microstructure, captured by the bid-ask spread, can explain the time trend in CLMX idiosyncratic variance for NYSE/Amex firms. Panel A of Table 10 reports the results. We begin with earnings and firm age explanations for the trend that begin in 1963m11. Consistent with our previous breakpoint tests, there is an increasing time trend for NYSE/Amex firms before quote decimalization from 1963m11 (column 1) and from 1976m1 (column 5) up to 2001m5. Then after decimalization, the trend tends to be significantly decreasing (column 9). When we introduce the bid-ask spread, idiosyncratic variance does not display any trend for both sub-periods prior to decimalization. The bid-spread alone can explain 76.2% (89.8%-13.6%) during the 1976m1 to 2001m5 period and by 64.5% (92.6%-28.1%) after the decimalization in the time variation of idiosyncratic variance. The growth option variables and firm age can explain the upward time trend before 2001, and they appear to have sufficient power at reduces the level of significance of the time trend. More interestingly, columns 8 and 12 shows that the bid-ask spread not only fully explains the time trend, but also largely subsumes the significance of the growth option variables and firm age. Additionally, when the earnings shock is regressed with the bid-ask spread, it assumes a sign opposite to that predicted by Irvine and Pontiff (2009).

We next examine the NASDAQ firms in Panel B of Table 10. Echoing our breakpoint results in Table 2, we again find strong upward trend before the decimalization in 2001 and downward trend afterwards for NASDAQ firms. We also find that NASDAQ firms overall exhibit more apparent time trend than NYSE/Amex firms, as manifested by the higher magnitude of time trend coefficient and the adjusted R-square. However, the upward time trend cannot be explained by the inclusion of the remaining explanatory variables (i.e growth options, earnings shocks, and firm age). This is shown in column (3). Firm age is negative and, but insignificant in the period prior to 2001m5 indicating that younger firms do not necessarily drive the time trend. Paradoxically, older firms are associated with aggregate variance (rather than younger firms) in the period subsequent to quote decimalization. Market-to-book is significant in both periods. However, these combined variables explain much less time of the variation in idiosyncratic variance than does the bid-ask spread. Adding the bid-ask spread to the additional explanatory variables is sufficient at removing the significance in the time trend.

Overall, we find consistent evidence that the bid-ask spread is critical in better explaining the time trend of idiosyncratic variance for both NYSE/Amex and NASDAQ firms. The cross-exchange evidence demonstrates that the time trend of CLMX idiosyncratic variance indeed embodies the time trend of the bid-ask spread. The liquidity channel provides most robust explanations of the time trend and behavior in aggregate variance than other explanations proposed in the literature.

9.2 Odd-Eighth Avoidance Tests for NASDAQ firms

NASDAQ firms demonstrate a more robust and dominant time trend than do NYSE/Amex firms from 1973m1 to 2001m5. However, endogeneity biases may influence the relation between idiosyncratic variance, the bid-ask spread, and the various alternative explanations in the exchange based tests especially for NASDAQ firms. We control for the endogeneity bias by specifying a diff-in-diff test to reduce possible confounding effects that may cloud the empirical inferences. To this end, we focus on the distinction between NASDAQ firms and NYSE/Amex firms and attempt to delineate an event that affects only the bid-ask spread for NASDAQ firms relative to NYSE/Amex firms. This is evidenced by the exogenous shock on the bid-ask spread for only NASDAQ firms that resulted from the disclosure of the seminal paper by Christie and Schultz (1994).

In this paper, Christie and Schultz (1994) find that market makers in NASDAQ stocks actively avoided odd-eighth quotes. Subsequently, Christie and Schultz (1999) show a dramatic changes in dollar, percentage and effective spreads for 67 (58) NASDAQ stocks whose market makers initiate (withdraw) odd-eighth quotes. Christie and Schultz (1999) note that dealers abruptly adopted odd-eighth quotes for four of the largest NASDAQ stocks when the findings of Christie and Schultz (1994) became public in May of 1994. We use May of 1994 as the date that commences an exogenous shock on bid-ask spreads that is localized to only NASDAQ stocks. Christie and Schultz (1999) examine whether NYSE or Amex stocks of similar size to the NASDAQ sample experience similar shifts in the frequency of odd-eighth quotes, but despite a search of almost 5000 issues over a five-year interval, they did not identify any listed stocks that undergo a similar shift either towards or away from the avoidance of odd-eighth quotes. Thus, the initiation or withdrawal of odd-eighth quotes is a unique feature of NASDAQ stocks from January 1990 to March 1994. We expect this exogenous shock to gradually work out on the bid-ask spreads as market-makers become more inclined to quote tighter bid-ask spreads over time.

To illustrate the disclosure's effect on the bid-ask spread, we show the evolving nature of the bid-ask spread over the interval 1991 to 1995. Figure 4 shows clearly that the increasing likelihood of adoption of odd-eighth quotes by market-makers for NASDAQ stocks subsequent to the initial release of the Christie and Schultz (1994) paper results in a sharp decline in the bid-ask spreads for NASDAQ firms relative to NYSE/Amex firms. We now establish the link between the bid-ask spread and the CLMX measure of idiosyncratic variance.

Figure 5 shows the time-series behavior of NASDAQ and NYSE/Amex idiosyncratic variance along with the trend line for each group of countries from 1991m9 to 1995m9.[14] As is shown in Figure 5, the CLMX idiosyncratic variance exhibits no discernible trend for the period immediately before the disclosure. The time trend for both NASDAQ and NYSE/Amex firms is statistically zero. However, subsequent to the disclosure of the Christie and Schultz (1994) paper, there is a decline in the NASDAQ CLMX idiosyncratic variance that is not observed for the NYSE/Amex CLMX idiosyncratic variance.

For this test, we use NASDAQ firms as the treatment group and NYSE/Amex firms as the control group and we set a dummy variable to one for NASDAQ firms and zero for NYSE/Amex firms. We also set a time dummy to zero before May of 1994 and one thereafter. If our hypothesized relation between the bid-ask spread and idiosyncratic variance is to be supported, then the interaction of the time dummy and the exchange dummy should be negatively related to the disclosure of odd-eighth quotes in the literature. We use the alternative explanations as control variables. Our regression specification is as follows:

$$\begin{aligned}\text{CLMX IV}_{i,t} = \beta_0 + \beta_1\text{Disclosure Time Dummy} + \beta_2\text{Treatment Dummy} +\\ \beta_3\text{Disclosure Time*Treatment Dummy} + \beta_4\text{Firm Age}\\ + \beta_5\text{Log(Earnings Shock)} + \beta_6\text{Market-to-Book} + \beta_7\text{Return-on-Equity}\\ + \beta_9\text{Retail Volume} + \epsilon_{i,t},\end{aligned} \tag{31}$$

where the interaction term captures the disclosure effect of odd-eighth avoidance on the bid-ask spread quotes and consequently the CLMX idiosyncratic variance. Focusing on the regression specification without the control variables, shown in Column (1) of Panel A of Table 11, indicates that the disclosure event negatively and significantly affects the observed industry-adjusted idiosyncratic volatility for NASDAQ firms. Also, as shown in column (3), controlling for monthly fixed effects

[14] We choose 1991 to coincide with the period examined by Christie and Schultz (1999) study and to ensure that we have a parallel trend for both the treatment and control groups. We choose the end date of 1995 to allow for the gradual adoption of odd-eighth quotes. We also choose a relatively short time frame subsequent to the initial release of the Christie and Schultz (1994) paper to better control for extraneous exogenous events that may cloud the inferences surrounding our tests.

only strengthens the relation between the disclosure event and the behavior of NASDAQ based industry-adjusted idiosyncratic variance. This is evident in the robust t-statistic for the interaction term that remains negative and significant. The disclosure of odd-eighth avoidance by NASDAQ market-makers affects the bid-ask spread which in turn affects the CLMX measure of idiosyncratic variance.

Including the firm-specific control variables, shown in column (2), for the pooled regression indicates continued robust significance for the exogenous shocks effect on the CLMX measure. The interaction term is negative and robustly significant as hypothesized by our microstructure theory. It is important to note that only retail volume has any association with the CLMX idiosyncratic variance across this period. It is somewhat surprising that market-to-book is insignificantly different from zero given the prior results that indicated a strong association between market-to-book and the CLMX idiosyncratic variance measure for NASDAQ stocks. These results show that across the disclosure of odd-eighth avoidance, a falling trend in the CLMX measure is not associated with the market-to-book values. This is also true for earnings shocks, and return-on-equity.

The fixed effects regression, given in column (4) of Table 11, shows the interaction term is again significant at the 1% level, but retail volume falls from significance. Indeed, none of the control variables are associated with the behavior of the CLMX idiosyncratic variance measure across this time interval. These results confirm that NASDAQ listed firms experience a time trend that is specifically due to the underlying bid-ask spread and this result persists even after controlling for confounding influences or alternative explanations for the trend.

We now directly test the impact of the disclosure of the NASDAQ avoidance of odd-eighth quotes across the periods dictated by the disclosure date of 1994m5 on the CLMX measure of idiosyncratic variance. We focus only on NASDAQ firms due to the strength of the time trend for these firms. We specifically examine 1976m1 to 1994m4 to capture the period before the disclosure of odd-eighth quote avoidance and then from 1994m5 to 1998m9. Finally we examine the period subsequent to the odd-eighth quote avoidance up to the decimalization in stock quotes, or from 1998m10 to 2001m5 To this end, we only control for market-to-book due to power of growth options in explaining the trend in the CLMX measure of idiosyncratic variance for NASDAQ firms, as shown in Panel B of Table 10. The results are shown in Panel B of Table 11.

As is shown in Panel B of Table 11, for the period 1976m1 to 1994m4, market-to-book fails to control for the time trend. The inclusion of market-to-book marginally reduces the significance of the trend in the CLMX measure, but it is insufficient, in and of itself, to explain the existence of the time trend. However, including the bid-ask spread fully controls for the time trend in the CLMX measure of idiosyncratic variance. Examining the period from 1994m5 to 1998m9 (our first break date) , we see no significance in the time trend for the CLMX measure of idiosyncratic variance. This result indicates that the time trend in NASDAQ firms may have be unduly influenced by market-makers inflating the bid-ask spread. Finally, examining the period after the LTCM and Russian debt collapse up to the decimalization in stock quotes, or from 1998m9 to 2001m5, we see that the time trend is now positive and robustly significant. Controlling for market-to-book is not sufficient at explaining the time trend as shown by the highly robust t-statistic for the trend. There is significance for market-to-book but controlling for this growth option measure cannot explain the time trend across this time period. Including the bid-ask fully explains the time trend as shown in the last column of Panel B of Table 11 where we see no significance for the time trend.

10 Conclusions

We provide evidence that measurement error is a dominant aspect in the behavior and trend of idiosyncratic variance. We theoretically model a bid-ask bounce microstructure bias and empirically show that the principle cause in the observed trend in the Campbell et al. (2001) aggregate idiosyncratic variance is due to the bid-ask spread. After controlling for the bid-ask spread, the trend in idiosyncratic variance disappears. These results are robust to industry-adjusted or risk-adjusted measures of idiosyncratic variance, to alternative definitions of the bid-ask spread, across different exchanges, as well as subsamples. We address endogeneity concerns with a natural experiment that centers around the 2001 regulatory act that required the decimalization of all stock quotes. We find that the bid-ask spread drives the behavior of aggregate idiosyncratic variance.

The results support a microstructure bias argument over the alternative explanations for the trend in idiosyncratic variance. We show that the bid-ask subsumes the behavioral arguments offered by Brandt et al. (2010), while tests concerning firm age or return-on-equity (Pástor and Veronesi, 2003) or earnings shocks (Irvine and Pontiff, 2009) show little power in explaining the time trend. Finally, market-to-book, reflecting firm-level growth options (Cao et al., 2008), appears to provide the most powerful alternative explanation for the time trend. But restricting the sample to NASDAQ firms, or those firms that experience the highest growth options, we find that market-to-book is unable to explain the time trend in the CLMX idiosyncratic variance measure. A natural experiment confirms this conjecture.

This unique natural experiment uses Christie and Schultz's (1994) disclosure that market-makers for NASDAQ listed stocks actively avoided odd-eighth quotes. Using this exogenous shock, we show that the bid-ask spread drives the behavior of aggregate idiosyncratic variance to the exclusion of a growth option explanation. These results raise the possibility that the trend in aggregate industry-adjusted idiosyncratic variance may, in some part, be due to market-makers of NASDAQ stocks avoiding odd-eighth quotes. Once the disclosure of odd-eighth avoidance is made public, there is no evidence of a trend in the CLMX measure of idiosyncratic variance.

The importance of the bid-ask spread in aggregate idiosyncratic variance underscores its application in other areas of finance research. First, Li, Morck, Yang, and Yeung (2004), Durnev, Morck, Yeung, and Zarowin (2003), and Morck, Yeung, and Yu (2000) note that lower market model R-squares are associated with capital market openness. Bartram, Brown, and Stulz (2012) show that U.S. stocks are more volatile than stocks of similar foreign firms. They attribute the increased U.S. stock volatility because it increases with investor protection, stock market development, new patents, and firm-level investment in R&D. Market openness and investor protection has been shown by Lesmond (2005) to be associated with local bid-ask spread costs. Our results are consistent with a microstructure driver for these reported results.

It is increasingly the case that daily returns form the basis for asset pricing studies concerning the pricing of idiosyncratic variance. This is shown in Herskovic, Kelly, Lustig, and Van Nieuwerburgh (2016) who show that firms' idiosyncratic volatility obeys a strong factor structure and that shocks to the common idiosyncratic volatility (CIV) factor are priced. The CIV factor helps to explain a number of asset pricing anomalies. Han and Lesmond (2011) show that idiosyncratic volatility is strongly associated with the underlying bid-ask spread. It is conceivable that the CIV factor is picking a microstructure bias in the daily returns that form the monthly estimates of idiosyncratic volatility.

Finally, the use of daily returns is at the root of estimation for total market volatility as found in Schwert (1989) and, most recently, in Paye (2012). Næs, Skjeltorp, and Ødegaard (2011) find that liquidity and the business cycle are connected. We would argue that our microstructure model linking firm-level liquidity to the aggregate market volatility would provide for a liquidity channel to help in explaining the noted linkages between macro-economic variables and total market volatility as examined by Paye (2012). To this end, Bartram, Brown, and Stulz (2016) argues that from 1963 through 2015, idiosyncratic risk is high when market risk is high. We would argue that these results embed a microstructure bias due to the reliance on daily returns that form the basis for the monthly estimates of idiosyncratic risk.

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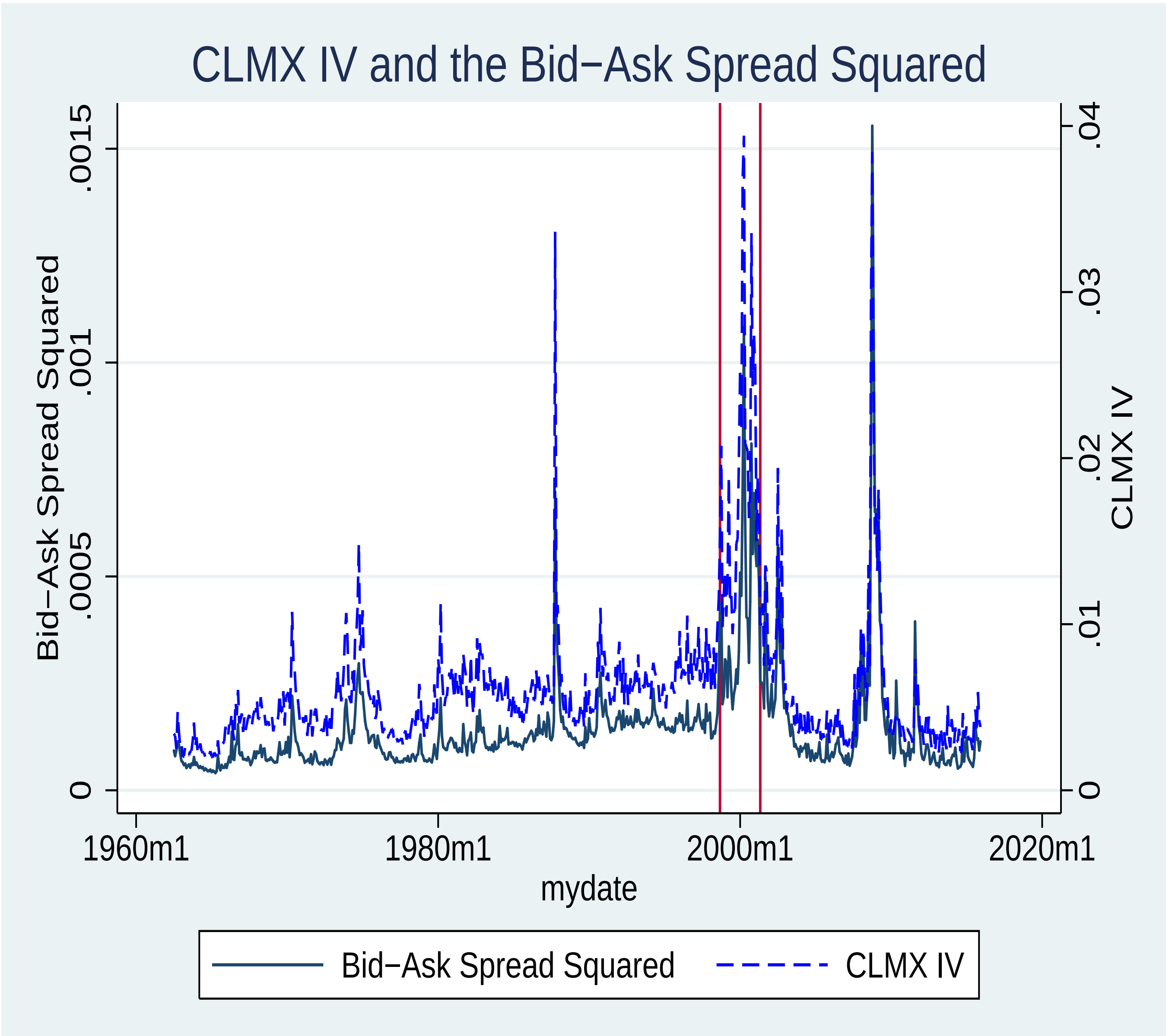

Figure 1: CLMX Industry-Adjusted Idiosyncratic Variance and Bid-Ask Spread This graph depicts the time series behavior of industry-adjusted variance, measured using the Campbell et al. (2001) methodology, and square of the bid-ask spread (estimated using the Corwin and Schultz (2012) methodology) over the period of 1962-2015. We place vertical lines at the proposed break dates, given as 1998m9, 2001m5, suggested by the Bai-Perron break test. Both the industry-adjusted variance and the bid-ask spread are value-weighted.

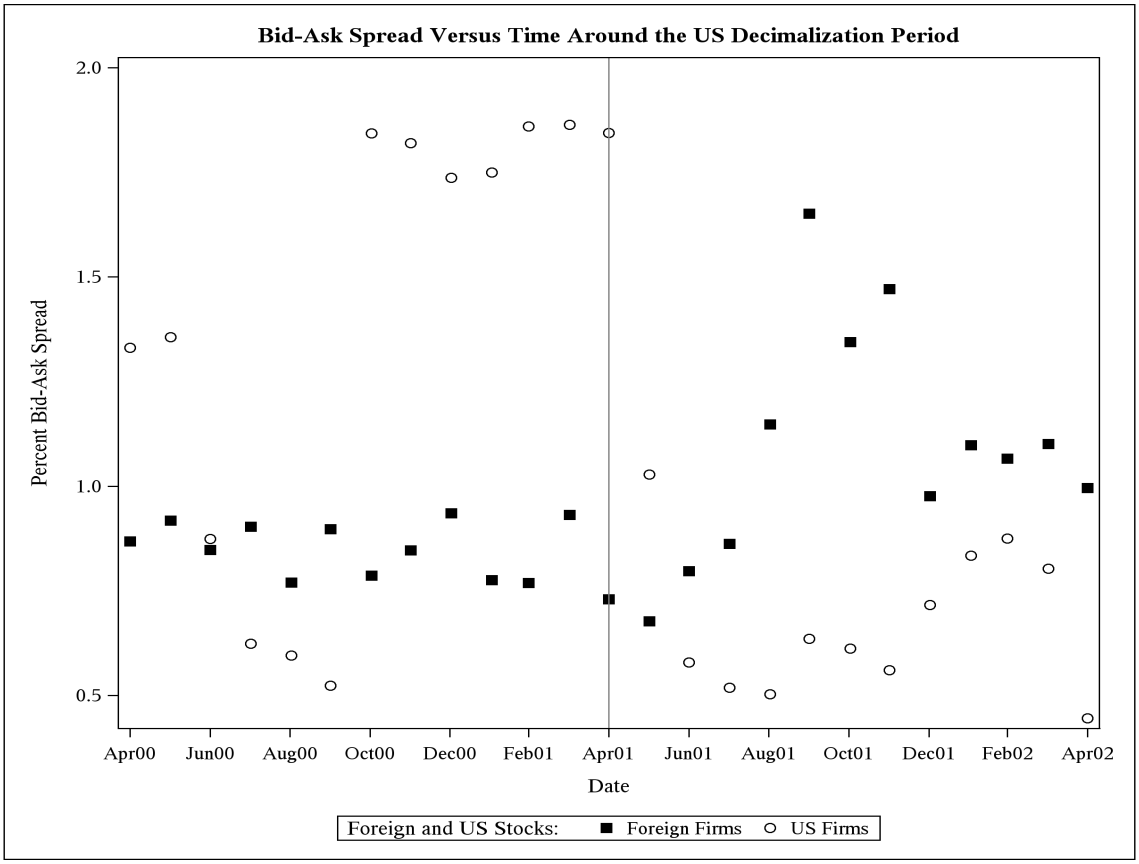

Figure 2: Bid-Ask Spreads Around Quote Decimalization
This graph depicts the time series behavior of the value-weighted bid-ask spread for both U.S. listed firms and for aggregate G6 firms over the period immediately surrounding the decimalization in U.S. stock quotes that is shown as April of 2001. The vertical line represents the mid-month decimalization conversion date.

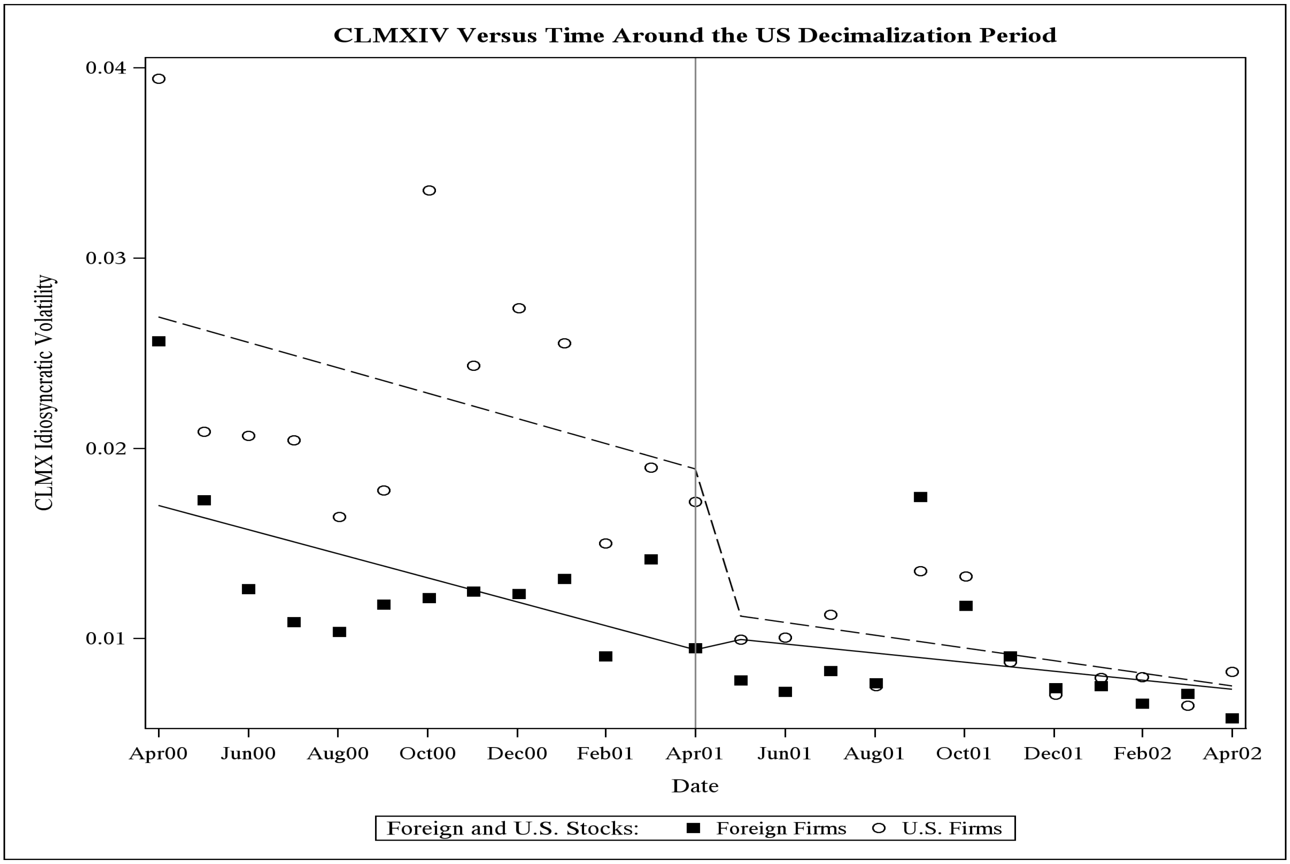

Figure 3: U.S. Versus G6 Markets CLMX Idiosyncratic Volatility: 2000 to 2002
This graph depicts the time series behavior of industry-adjusted idiosyncratic volatility in the United States and G6 countries over the period of 2000m4-2002m4. The solid line represents the trend line for the G6 countries' idiosyncratic variance measure and the dashed line represent the U.S. idiosyncratic variance measure. The vertical line represents the mid-month decimalization conversion date.

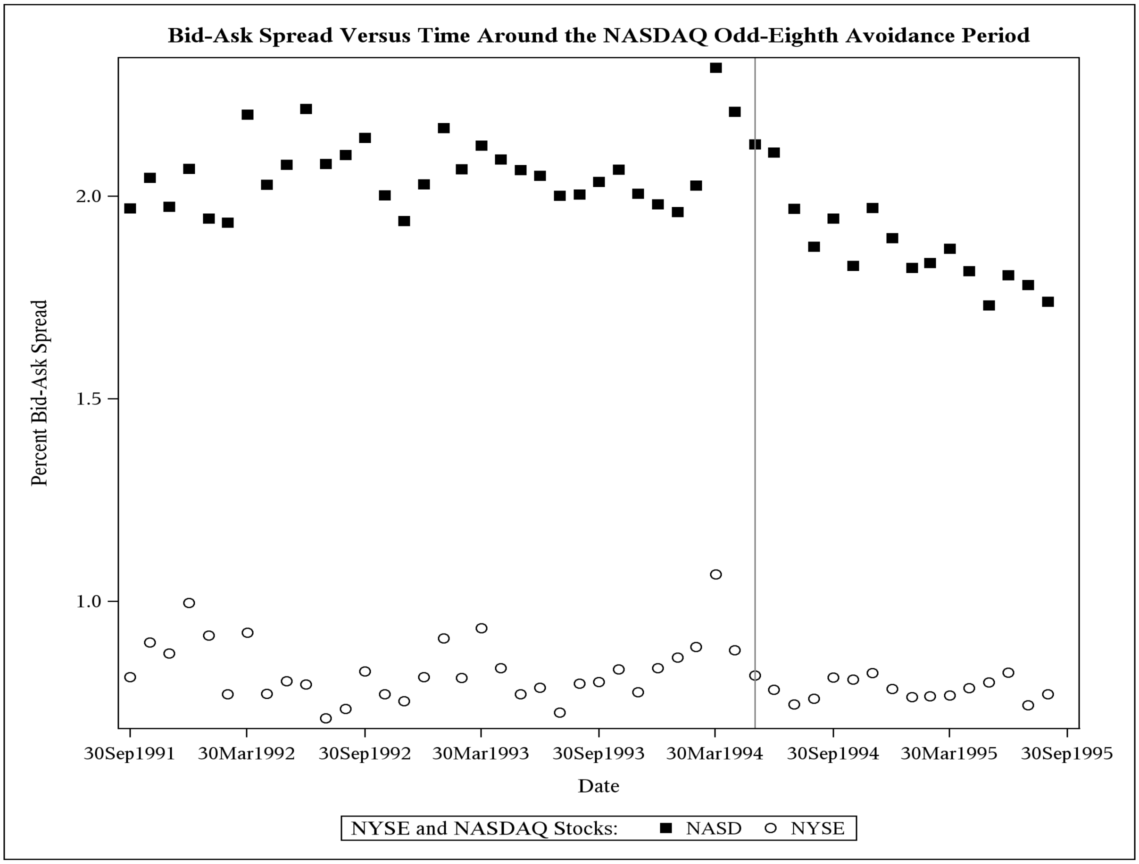

Figure 4: Bid-Ask Spreads Around the NASDAQ Odd-Eighth Avoidance Period This graph depicts the time series behavior of the value-weighted bid-ask spread for both NASDAQ listed firms and for NYSE/Amex listed firms over the period immediately surrounding the release date of the Christie and Schultz (1994) paper. The vertical line represents the May 1994 disclosure date of the Christie and Schultz (1994) paper.

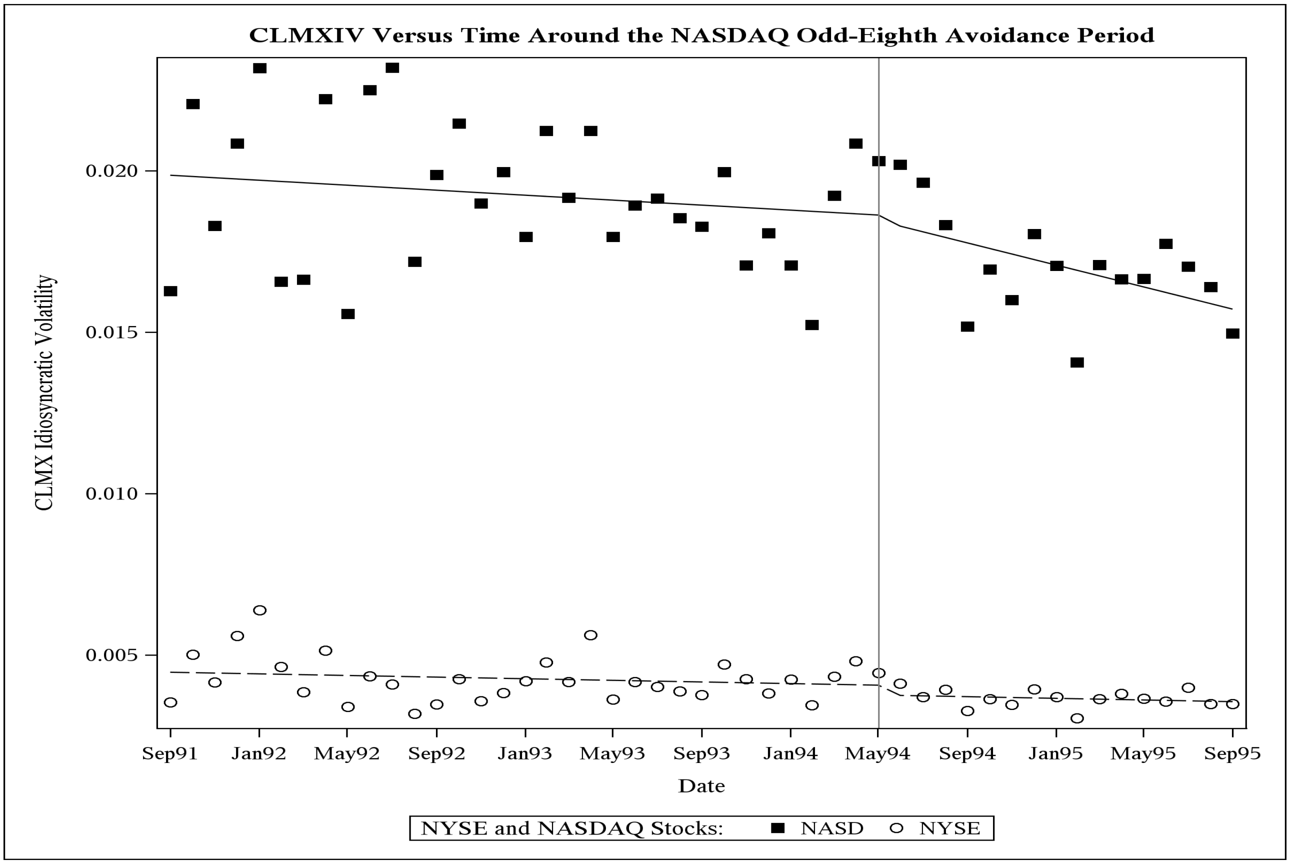

Figure 5: CLMX Idiosyncratic Variance Around the NASDAQ Odd-Eighth Avoidance Period
This graph depicts the time series behavior of industry-adjusted idiosyncratic volatility for NASDAQ firms versus NYSE/Amex firms around the disclosure of the odd-eighth avoidance in NASDAQ quotes over the 1991m9-1995m9 period. The solid line represents the trend line for the NASDAQ firm's idiosyncratic variance measure, and the dashed line represents the NYSE/Amex firm's idiosyncratic variance measure. The vertical line represents the May 1994 disclosure date of the Christie and Schultz (1994) paper.

Table 1: Summary and Correlation Statistics

Panel A reports summary statistics for CRSP firms from 1962 to 2015 for a total of 642 months and Panel B presents the correlation statistics. We compute the value-weighted aggregate idiosyncratic variance using the methodology of Campbell et al. (2001), given as CLMX, and from a risk-adjusted estimate of idiosyncratic variance using the CAPM or the Fama and French (1993) three-factor specification. All of these measures are value-weighted. We present the Corwin and Schultz (2012) bid-ask spread and the price impact estimate of Amihud (2002). These measures are value-weighted. We also present unit root tests based on the Augmented Dickey-Fuller and Phillips-Perron models. Both models use a unit root as the null hypothesis. We also present the first auto-regressive estimate for each variable. The mean, standard deviation, skewness, and kurtosis are given for each variable. Panel B reports correlation coefficients for each of the variables.

	Panel A: Summary Statistics				
	CLMX	CAPM IV	Fama-French IV	Bid-Ask Spread	Amihud Measure
Mean	0.0062	0.0002	0.0002	0.0100	0.1061
Std. Deviation	0.0046	0.0002	0.0002	0.0035	0.0965
Skewness	3.7055	3.7803	3.4563	2.6673	2.0563
Kurtosis	21.1033	21.9593	18.6874	13.6650	9.3265
AR(1)	0.8050	0.8121	0.8486	0.8728	0.9343
Augmented Dickey-Fuller (p-value)	0.0000	0.0000	0.0000	0.0000	0.0001
Phillips-Perron (p-value)	0.0000	0.0000	0.0000	0.0005	0.0000

	Panel B: Correlation Statistics				
	CLMX	CAPM IV	Fama-French IV	Bid-Ask Spread	Amihud Measure
CLMX	1				
CAPM IV	0.9841	1			
Fama-French IV	0.9734	0.9914	1		
Bid-Ask Spread	0.9089	0.9033	0.8958	1	
Amihud Measure	-0.0810	-0.0879	-0.0867	-0.1197	1

Table 2: Bai-Perron Break Tests

Bai-Perron break test results are presented for the Campbell et al. (2001) estimate of industry-adjusted idiosyncratic variance. We test for breaks in the time trend for idiosyncratic variance using the period 1962m7 to 2015m12. The initial date is based on the start date for Campbell et al. (2001). We test for the number of significant breaks in the time trend of the idiosyncratic variance using five possible breaks and employing a maximum scaled F-statistic. We present the break dates that correspond to each of the breaks in the industry-adjusted idiosyncratic variance and the related F-statistic. We denoted the maximum F-statistic that measures the optimal number of breaks with an asterisk.

	Break Dates in CLMX Variance					
Number of Breaks	Break Date(s)					Scaled-F Stat
1	1980M1					49.65
2	1998M9,	2001M5				208.17*
3	1998M9,	2001M5	2009M8			161.37
4	1973M2,	1998M9	2001M5	2009M8		139.82
5	1973M2,	1998M9	2001M5	2007M7	2010M3	127.21

Table 3: Quote Midpoint Trend Regression Tests

We employ two estimates of the idiosyncratic return variance (Campbell et al., 2001) in tests on a time trend. We use two estimates of idiosyncratic return variance. The first is based on returns calculated using closing CRSP-based prices and the second is based on returns using the closing bid-ask quote midpoint price. We term the closing price idiosyncratic return variance estimate CRSP CLMX IV and the quote midpoint-based idiosyncratic return variance estimate Mid-Quote CLMX IV. The time trend is scaled by 10,000. We use both ISSM and TAQ to provide the bid-ask quotes and we use the quote that occurs three seconds prior to the closing price. ISSM begins coverage for NYSE/Amex firms in 1983, while coverage for NASDAQ firms begins in 1987. We analyze two distinct time periods specified by the break tests. These tests span the periods: 1983m1 to 1998m9 and then from 1983m1 to 2001m5. Newey and West (1987) t-statistics with 12 lags are reported in parentheses. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

Model	Time Trend	% Adjusted R^2
Time Period: 1983m1 to 1998m9		
CRSP CLMX IV	0.0911***	4.08
	(2.62)	
Mid-Quote CLMX IV	-0.0561	0.05
	(-0.24)	
Time Period: 1983m1 to 2001m5		
CRSP CLMX IV	0.4784***	29.26
	(2.78)	
Mid-Quote CLMX IV	0.2347	7.76
	(1.60)	

Table 4: Linear Trend Regression Tests

Time-series regressions of Campbell et al. (2001) idiosyncratic return variance on a time trend and liquidity. We estimate the value-weighted Corwin and Schultz (2012) bid-ask spread and the Amihud (2002) price impact measure and take the square of each liquidity estimate. We also estimate the residual of a regression of the (Campbell et al., 2001) variance measure against the bid-ask spread square. The idiosyncratic variance and the liquidity estimates are multiplied by 10,000. We analyze four distinct time periods spanning: 1962m7 to 1998m9, 1962m7 to 2001m5, 2001m6 to 2007m11, and 2009m7 to 2015m12. The first two periods correspond to our break dates, while the last two periods are subsequent to the last break date and include the periods before and after the Great Recession. Newey and West (1987) t-statistics with 12 lags are in parentheses. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

Model	Time Trend	Bid-Ask Spread	Price Impact	% Adjusted R^2
		Panel A: Time Period: 1962m7 to 1998m9		
CLMX	0.0904***			21.9
	(6.86)			
CLMX Residual	-0.0078			0.01
	(-0.83)			
CLMX	-0.0117	40.0727***		82.1
	(-1.07)	(21.38)		
CLMX	0.1053***		1.1903*	27.2
	(7.96)		(1.88)	
		Panel B: Time Period: 1962m7 to 2001m5		
CLMX	0.1825***			29.2
	(3.59)			
CLMX Residual	-0.0015			-0.01
	(-0.13)			
CLMX	-0.0022	39.8906***		91.2
	(-0.19)	(26.81)		
CLMX	0.1975***		1.2048**	30.5
	(3.84)		(2.17)	
		Panel C: Time Period: 2001m6 to 2007m11		
CLMX	-0.8913***			39.3
	(-3.72)			
CLMX Residual	-0.0780			0.02
	(-1.14)			
CLMX	-0.1215	28.4332***		92.2
	(-1.31)	(21.50)		
CLMX	-0.2688*		400.7158***	72.4
	(-1.67)		(8.30)	
		Panel D: Time Period: 2009m7 to 2015m12		
CLMX	-0.1429*			7.9
	(-1.87)			
CLMX Residual	-0.0061			-0.01
	(-0.14)			
CLMX	-0.0071	15.6312***		60.1
	(-0.18)	(9.41)		
CLMX	-0.1326*		5.8540	7.9
	(-1.84)		(0.62)	

Table 5: Alternative Explanations for the Linear Trend Regression Tests

This table reports regressions for the time-trend of value-weighted industry-adjusted idiosyncratic variance against various alternative explanations for the time trend. We use the market-to-book (growth option proxy), firm age, retail trading, and earnings shocks as alternative explanations of the time trend in the Campbell et al. (2001) measure of idiosyncratic variance. All of our tests use the break date of 2001m5 as the critical pre and post decimalization period for the trend in the Campbell et al. (2001) measure of idiosyncratic variance. Panel A spans the period 1964m1 to 2001m5 to correspond to earnings availability, Panel B spans the period 1971m9 to 2001m5 to correspond to growth option availability, and Panel C spans the period 1983m1 to 2001m5 to correspond to retail trading availability. Panel D spans the period 2001m6 to 2007m11 which is the period of declining idiosyncratic variance. The square of the bid-ask spread is estimated following Corwin and Schultz (2012) and Roll (1984) and is value-weighted. Newey and West (1987) t-statistics with 12 lags are reported in parentheses. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

Model	Time Trend	Spread	Roll	Earnings	Firm Age	Market-to-Book	ROE	Retail Trading	$\%Adj-R^2$
Panel A: Time Period: 1963m11 to 2001m5									
model1	0.1851***								29.4
	(3.37)								
model2	-0.0089	40.1270***							90.7
	(-0.78)	(27.28)							
model3	0.0301*		15.9414***						84.0
	(1.80)		(7.92)						
model4	0.0660			0.0002	-0.0388**				69.9
	(1.59)			(1.01)	(-2.48)				
model5	-0.0175	38.3008***		-0.0000	-0.0126***				92.9
	(-1.00)	(22.90)		(-0.43)	(-2.80)				
model6	-0.0049		14.9581***	0.0001	-0.0162***				91.7
	(-0.25)		(9.24)	(0.65)	(-2.99)				
Panel B: Time Period: 1971m9 to 2001m5									
Model7	0.2256***								23.2
	(2.66)								
model8	-0.0174	40.3120***							90.8
	(-1.02)	(28.01)							
model9	0.0388		15.8942***						84.1
	(1.58)		(7.85)						
model10	0.0554			-0.0241***	0.0003	0.0024***	-0.0053*		65.5
	(0.98)			(-3.23)	(1.52)	(5.54)	(-1.66)		
model11	-0.0287	34.8397***		-0.0126***	-0.0000	0.0006***	0.0021		92.7
	(-1.57)	(14.02)		(-2.93)	(-0.16)	(2.91)	(1.60)		
model12	0.0020		12.3133***	-0.0131***	0.0002	0.0011***	-0.0023		90.8
	(0.08)		(13.90)	(-4.14)	(1.25)	(4.27)	(-1.28)		

Model	Time Trend	Spread	Roll	Earnings	Firm Age	Market-to-Book	ROE	Retail Trading	$\%Adj-R^2$
Panel C: Time Period: 1983m1 to 2001m5									
model13	0.4784***								28.9
	(2.78)								
model14	0.0375	39.4423***							91.1
	(0.85)	(25.28)							
model15	0.1342*		15.3577***						83.9
	(1.93)		(7.34)						
model16	-0.3482***			0.0001	0.0150**	0.0052***	0.0037	0.0234**	73.2
	(-3.10)			(0.68)	(1.97)	(9.63)	(1.02)	(2.09)	
model17	-0.0785	34.2276***		-0.0000	-0.0046	0.0013***	0.0015	-0.0075	93.9
	(-0.95)	(9.27)		(-0.37)	(-0.71)	(2.64)	(1.55)	(-1.60)	
model18	-0.1835***		11.9270***	0.0000	0.0041	0.0027***	0.0016	0.0059	92.9
	(-2.84)		(12.78)	(0.05)	(1.05)	(6.88)	(0.74)	(0.88)	
Panel D: Time Period: 2001m6 to 2007m11									
model19	-0.8913***								39.3
	(-3.72)								
model20	-0.1215	28.4332***							92.2
	(-1.31)	(21.50)							
model21	-0.3366*		10.3951***						85.7
	(-1.93)		(6.68)						
model22	-4.0760***			-0.0003	0.0794**	-0.0019	0.0308***		55.1
	(-4.60)			(-1.28)	(2.26)	(-0.59)	(4.98)		
model23	0.0878	29.2573***		-0.0000	-0.0305***	0.0005	-0.0037		90.1
	(0.16)	(7.48)		(-0.08)	(-3.33)	(0.38)	(-1.02)		
model24	-1.0333		9.2918***	-0.0001	-0.0233	-0.0019	-0.0069		83.9
	(-1.05)		(3.37)	(-0.63)	(-1.53)	(-0.75)	(-0.81)		

Table 6: Alternative Idiosyncratic Variance Estimates

We estimate idiosyncratic variance using the residual from a regression of the daily return on the three-factor Fama-French model. We use the market-to-book growth option proxy, ROE, firm age, retail trading, and earnings shocks as alternative explanations of the time trend in the time trend tests of idiosyncratic variance. Panel A presents the earnings shocks and firm age tests that span the period 1963m11 to 2001m5, Panel B presents growth option proxy and ROE from 1971m9 to 2001m5, Panel C reports retail trading tests from 1983m1 to 2001m5, and Panel D reports all the alternative explanations (except for retail trading) spanning the period 2001m6 to 2007m11. The bid-ask spread is estimated following Corwin and Schultz (2012) and is value-weighted. Newey and West (1987) t-statistics with 12 lags are reported in parentheses. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

Model	Time Trend	Bid-Ask Spread	Earnings	Firm Age	Market-to-Book	ROE	Retail Trading	$\%Adj-R^2$
Panel A: Time Period: 1963m11 to 2001m5								
model1	0.0093***							30.6
	(3.36)							
model2	0.0003	1.8565***						89.6
	(0.44)	(17.30)						
model3	0.0033		0.0000	-0.0018**				43.8
	(1.60)		(1.16)	(-2.24)				
model4	-0.0005	1.7621***	0.0000	-0.0006**				90.8
	(-0.55)	(18.37)	(0.07)	(-2.31)				
Panel B: Time Period: 1971m9 to 2001m5								
model5	0.0163***							34.6
	(3.21)							
model6	0.0015	1.8133***						89.1
	(1.05)	(14.94)						
model7	-0.0000		0.0000	-0.0007*	0.0002***	-0.0002		77.7
	(-0.00)		(0.38)	(-1.95)	(8.98)	(-1.03)		
model8	-0.0022	1.3391***	-0.0000	-0.0004	0.0001***	0.0001		93.5
	(-1.29)	(12.27)	(-0.21)	(-1.64)	(4.91)	(0.65)		
Panel C: Time Period: 1983m1 to 2001m5								
model9	0.0249***							34.8
	(2.94)							
model10	0.0052	1.7624***						89.6
	(1.63)	(15.02)						
model11	-0.0142***		0.0000	0.0007***	0.0002***	0.0001	0.0014**	82.2
	(-2.95)		(0.89)	(2.60)	(11.19)	(0.71)	(2.42)	
model12	-0.0043	1.2531***	0.0000	0.0000	0.0001***	0.0000	0.0003	94.4
	(-1.02)	(10.36)	(0.28)	(0.05)	(3.56)	(0.64)	(1.10)	
Panel D: Time Period: 2001m6 to 2007m11								
model13	-0.0508***							39.0
	(-3.91)							
model14	-0.0061	1.6500***						93.5
	(-1.56)	(21.53)						
model15	-0.2379***		-0.0000	0.0064***	0.0000	0.0024***		56.4
	(-5.13)		(-1.36)	(2.71)	(0.16)	(6.03)		
model16	0.0143*	1.7723***	0.0000*	-0.0003	0.0002***	0.0003		93.9
	(1.85)	(27.06)	(1.91)	(-0.50)	(5.62)	(1.25)		

Table 7: Principal Components and Regression Tests

Panel A is a regression test of the trend on each of the alternative control variables spanning the periods 1963m11 to 2001m5 for the earnings shock and firm age, and then from 1971m9 to 2001m5 when examining market-to-book and return-on-equity. Panel B presents the principal component analysis of common factors evident in the alternative control variables and the bid-ask spread. We first use earnings shocks, firm age, market-to-book, return-on-equity, and the Amihud price impact measure. We term these variables the alternative controls. We then augment these variables with the Corwin and Schultz (2012) based estimate of the bid-ask spread. Panel B shows a regression with the CLMX measure of idiosyncratic variance as the dependent variable regressed on the time trend and the first two principal components, where the first two principal components are estimated with and without the bid-ask spread. The tests run from 1971m9 to 1998m9 (our first break) or from 1971m9 to 2001m5 (our second break). Our starting date is the beginning date for book-to-market availability. The time trend is scaled by 10,000 for the regression tests. Newey and West (1987) t-statistics with 12 lags are in parentheses. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

Panel A: Bid-Ask Spread Determinant Tests						
	Earnings	Firm Age	Market-to-Book	ROE	Bid-Ask	Bid-Ask
Time Trend	0.0179***	-0.0199***	0.0050**	0.0004***	0.0048***	0.0013
	(15.39)	(-3.48)	(2.18)	(4.86)	(3.85)	(0.86)
Earnings Shock						0.2024**
						(2.34)
Firm Age						-0.0480***
						(-2.78)
Market-to-Book						0.5239***
						(4.79)
ROE						-2.0217*
						(-1.95)
%Adj - R2	84.2	29.1	23.3	36.5	32.8	62.5

Panel B: Principal Component Time Trend Regression Tests						
	Period: 1971m9 to 1998m9			Period: 1971m9 to 2001m5		
	Base Model	Alternative Controls	Alternative Controls + Bid-Ask	Base Model	Alternative Controls	Alternative Controls + Bid-Ask
Time Trend	0.0704**	0.1079**	0.0156	0.2256***	0.1001**	-0.1027*
	(2.46)	(2.39)	(0.54)	(2.66)	(2.07)	(-1.75)
Principal Component 1		-1.7196	6.7845***		17.2263***	30.9592***
		(-0.63)	(3.08)		(3.21)	(9.32)
Principal Component 2		6.1871*	10.7196***		-15.9605***	-3.7233
		(1.96)	(3.93)		(-5.13)	(-1.33)
Observations	325	325	325	357	357	357
% Adjusted R^2	7.3	12.6	45.5	23.2	57.3	80.0

Table 8: Difference-in-Difference Test: U.S. Stock Quote Decimalization Exogenous Shock

This table presents regression results using a difference-in-difference specification based on monthly observations. SEC Regulation demanded the decimalization in bid-ask spread quotes across all stocks as of April of 2001 and this serves as our exogenous shock affecting only the bid-ask spreads. We test a one-year period immediately surrounding the decimalization date from 2000m4 to 2002m4. The U.S market is the treatment group and the G6 is the control group and the treatment dummy is set to one for U.S. firms and equal to zero for G6 firms. The time dummy is equal to one from 2001m5 to 2002m4 and zero from 200m4 to 2001m4. The interaction of the treatment and time dummy variables tests for the effect of the decimalization in stock quotes on the behavior of idiosyncratic volatility. We include Amihud's price impact measure and the percentage of zero returns to control for other liquidity effects besides the direct effect on the bid-ask spread. End of month stock price and return skewness are lagged by one-month, whereas market-to-book is lagged by six months. These control variables are obtained from Datastream. We also include financial risk (scaled from 1 to 50 where 50 conveys lower financial risk) that is a means of assessing a country's ability to pay its way by financing its official, commercial and trade debt obligations. This is obtained from the International Country Risk Guide (ICRG). We specify pooled and monthly fixed effects regression models with robust t-statistics. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

	Period: 2000m4 to 2002m4					
		Pooled			Monthly Fixed Effects	
Constant	0.0135***	0.0119	0.0550	0.0137***	0.0704	0.1006
	(10.80)	(0.32)	(1.06)	(12.80)	(1.21)	(1.34)
Treatment Dummy	0.0099***	0.0093	0.0009	0.0099***	-0.0120	-0.0139
	(4.07)	(0.75)	(0.06)	(5.54)	(-0.58)	(-0.64)
Time Dummy	-0.0048***	-0.0004	-0.0004	-0.0052**	-0.0028	-0.0012
	(-3.18)	(-0.13)	(-0.14)	(-2.25)	(-0.82)	(-0.35)
Interactive Dummy	-0.0086***	-0.0154**	-0.0135***	-0.0086***	-0.0146**	-0.0129**
	(-3.19)	(-2.48)	(-2.72)	(-4.82)	(-2.19)	(-2.29)
Amihud Measure		0.0125	0.0129		0.0085	0.0035
		(1.40)	(1.53)		(0.48)	(0.23)
Zero Returns		-0.0006	-0.0007		-0.0009	-0.0008
		(-1.22)	(-1.44)		(-1.01)	(-1.09)
Skewness		-0.0012	0.0003		-0.0034	-0.0009
		(-0.28)	(0.05)		(-0.74)	(-0.14)
Market-to-Book		0.0334***	0.0363***		0.0343*	0.0428**
		(3.05)	(3.19)		(2.14)	(2.90)
Lagged Price		0.0100	0.0075		0.0004	0.0014
		(1.43)	(1.03)		(0.04)	(0.13)
Financial Risk			-0.0007			-0.0008
			(-1.09)			(-1.27)
Observations	50	50	50	50	50	50
% Adjusted R^2	59.3	61.2	63.5	66.9	69.1	71.8

Table 9: Cross-Sectional Fama-MacBeth Regression Tests

This table presents monthly Fama-MacBeth cross-sectional regression tests, where the dependent variable is the natural logarithm of industry-adjusted idiosyncratic volatility estimate of Campbell et al. (2001). The independent variables, measured at the end of the previous month, include: stock price, firm size, lagged idiosyncratic volatility, book-to-market ratio, leverage (the ratio of debt value and total assets or market value), past 6-month momentum returns, the level of institutional ownership for the most recent quarter, quarterly change in institutional ownership for the most recent quarter, retail trading proportion (total retail trading volume divided by the market volume from ISSM/TAQ), idiosyncratic skewness, firm age (the number of years since the firm first appears in the CRSP database), the proportional bid-ask spread, Amihud's measure, and volume turnover. Low Price×High RTP (LPHR) is an interaction dummy that is set to one for stocks with high retail trading proportion (top third) and low prices (bottom third). Low Price×Low RTP (LPLR) is defined in an analogous manner. We use the NYSE price breakpoints to form the high and low price categories. All variables are standardized so that each variable has a mean of zero and a standard deviation of one. This procedure allows for direct comparisons among the coefficient estimates within and across specifications. Small-sized trades are used as proxy for retail trades. The 13(f) institutional holdings data are from Thomson Reuters. Monthly average adjusted R^2 statistics are reported. The sample period is from 1983m1-2001m5 spanning 219 months. Newey-West t-statistics are reported in parentheses. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

Dependent Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	0.064***	0.116***	0.067***	0.124***	0.099***	0.174***
	(6.41)	(6.9)	(6.61)	(7.25)	(6.54)	(6.8)
Ln(Price)	-0.399***	-0.701***	-0.397***	-0.686***	-0.366***	-0.576***
	(-22.23)	(-28.5)	(-22.17)	(-28.36)	(-24.87)	(-29.63)
Ln(Firm Size)	-0.019**	-0.065***	-0.020***	-0.067***	-0.016**	-0.044***
	(-2.58)	(-4.56)	(-2.67)	(-4.63)	(-2.36)	(-3.7)
Ln(Lagged Idiosyncratic	0.456***		0.454***		0.416***	
Volatility)	(52.03)		(52.26)		(55.62)	
Retail and Institutional Investors						
Ln(1+Institutional	0.024***	0.032***	0.023***	0.030***	0.023***	0.030***
Holdings)	(13.27)	(11.25)	(12.9)	(10.51)	(13.47)	(11.2)
Δ Institutional	0.011***	0.014***	0.011***	0.014***	0.011***	0.014***
Holdings	(8.66)	(6.93)	(8.67)	(6.94)	(8.98)	(7.35)
LPHR	0.008***	0.019***	0.011***	0.029***	0.018***	0.038***
	(6.06)	(9.42)	(8.69)	(13.97)	(10.94)	(14.83)
LPLR	-0.002	-0.012***	-0.002	-0.012***	-0.003	-0.011***
	(-1)	(-3.44)	(-1.01)	(-3.4)	(-1.12)	(-3.38)
Retail Trading	0.030***	0.063***	0.024***	0.041***	0.003	-0.000
	(5.45)	(6.13)	(4.45)	(4.22)	(0.54)	(-0.02)
Liquidity Costs						
Amihud Measure			0.094***	0.296***		
			(3.71)	(6.64)		
Bid-Ask Spread					0.187***	0.386***
					(9.84)	(11.88)
Firm Characteristics						
Volume Turnover	0.026***	0.133***	0.027***	0.135***	0.039***	0.144***
	(8.54)	(20.49)	(8.85)	(20.67)	(14.42)	(22.91)
Book-to-Market	-0.065***	-0.116***	-0.065***	-0.116***	-0.068***	-0.113***
	(-20.62)	(-26.22)	(-21)	(-26.87)	(-24.5)	(-29.26)
Leverage	-0.018***	-0.035***	-0.019***	-0.036***	-0.021***	-0.038***
	(-6.75)	(-7.65)	(-6.84)	(-7.83)	(-7.73)	(-8.44)
Skewness	0.001	0.001	0.001	0.001	-0.001	-0.001
	(0.18)	(0.33)	(0.16)	(0.25)	(-0.34)	(-0.91)
Firm Age	-0.050***	-0.087***	-0.050***	-0.088***	-0.053***	-0.088***
	(-13.9)	(-13.72)	(-13.97)	(-13.86)	(-14.71)	(-13.96)
6-Momentum Return	0.001	0.003	0.001	0.003	0.003	0.007
	(0.13)	(0.32)	(0.12)	(0.3)	(0.43)	(0.78)
% Adjusted R^2	66.05	58.00	66.08	58.25	66.51	60.47

Table 10: NYSE/Amex and NASDAQ Trend Test

We examine the time trend properties using firms listed on the NYSE/Amex or NASDAQ exchanges. In Panel A, we examine the NYSE/Amex listed firms and in Panel B we examine NASDAQ listed firms. Given earnings shock data availability and firm age, we begin in 1963m11 for NYSE/Amex firms. For both exchanges, we study two periods with a break date at 2001m5 that conforms to the quote decimalization break date. Our first period spans 1976m1 to 2001m5 and our second period spans 2001m6 to 2007m11. We use market-to-book (Cao et al., 2008), a proxy for firm age and return on equity (Pástor and Veronesi, 2003), and earnings volatility (Irvine and Pontiff, 2009) as alternative explanations for the time trend in aggregate industry-adjusted idiosyncratic variance. We use the square of the Corwin and Schultz (2012) bid-ask spread measure. The bid-ask spread, market-to-book, and return-on-equity are value weighted. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, levels respectively.

Panel A: NYSE/Amex Exchanges												
	1963m11-2001m5				1976m1-2001m5				2001m6-2007m11			
Time Trend	0.0609**	-0.0041	0.0301	0.0018	0.1156**	0.0017	-0.0471	0.0212	-0.5837***	-0.0972*	-0.8967	-0.0908
	(2.13)	(-0.74)	(0.94)	(0.24)	(2.22)	(0.14)	(-0.89)	(0.91)	(-3.19)	(-1.80)	(-1.32)	(-1.32)
Bid-Ask Spread		37.5334***		36.2456***		37.4867***		36.3551***		27.5404***		27.5563***
		(31.03)		(29.41)		(28.64)		(26.55)		(18.18)		(11.91)
Earnings			-3.1333	-1.8569**			2.6425	-3.6193*				-1.5322*
			(-0.96)	(-2.09)			(0.99)	(-1.90)			(0.12)	(-1.78)
Firm Age			-2.8034***	-0.5642**			-2.0964***	-0.5617*			3.9936	-0.2583
			(-3.69)	(-2.45)			(-4.08)	(-1.69)			(1.42)	(-0.61)
Market-to-Book							26.8826***	-1.9533			79.2843***	13.8744*
							(3.52)	(-0.61)			(4.45)	(1.85)
ROE							-11.0402	0.1183			341.3313***	23.0837
							(-0.53)	(0.01)			(3.69)	(0.59)
Observations	451	451	451	451	305	305	305	305	78	78	78	78
% Adjusted R^2	9.9	89.4	27.9	90.1	13.6	89.8	46.8	90.7	28.1	92.6	44.3	92.8

Panel B: NASDAQ Exchange								
	1976m1-2001m5				2001m6-2007m11			
Time Trend	0.7506***	0.3223***	0.3881***	0.1701	-1.7533***	-0.0918	0.2012	-0.2656
	(5.22)	(3.96)	(4.36)	(1.48)	(-3.88)	(-0.41)	(0.22)	(-0.56)
Bid-Ask Spread		22.7927***		19.8943***		25.8295***		25.8536***
		(6.27)		(7.35)		(12.74)		(17.25)
Earnings			1.3481	-3.0643			29.0719***	-3.4333
			(0.14)	(-0.98)			(3.10)	(-0.69)
Firm Age			-2.9653	-2.9067**			8.0425***	-1.0213
			(-1.62)	(-2.26)			(4.38)	(-0.71)
Market-to-Book			16.3612***	10.7878***			60.8569***	12.9393**
			(3.68)	(3.28)			(5.18)	(2.23)
ROE			6.7430	2.1236			-16.4009	-1.7518
			(0.28)	(0.19)			(-0.31)	(-0.09)
Observations	305	305	305	305	78	78	78	78
% Adjusted R^2	48.9	75.2	63.3	82.2	48.8	88.4	66.3	89.3

Table 11: Difference-in-Difference Tests: Avoidance of Odd-Eighth Quotes for NASDAQ Listed Firms.

Panel A presents a diff-in-diff test using the initial release of the Christie and Schultz (1994) paper in May of 1994 as an exogenous shock to the bid-ask spread estimated using the Corwin and Schultz (2012) methodology. The time dummy is equal to zero prior to May of 1994 and one thereafter. NASDAQ firms are the treatment group, set to one, and NYSE/Amex firms are the control group, set to zero. The treatment and time dummy interaction tests for the effect of the the avoidance of odd-eighth in stock quotes on the behavior of idiosyncratic volatility. Robust t-statistics are in parentheses. Panel B presents a trend test that focuses on three distinct time periods spanning: 1976m1 to 1994m4, 1994m5 to 1998m9, and from 1998m10 to 2001m5. The first period reflects the period before the exogenous shock date and the last period reflects our break dates. Both the CLMX idiosyncratic variance and the bid-ask spread are scaled by 10,000. Newey and West (1987) t-statistics with 12 lags are in parentheses. The symbols $*$, $**$, $***$ denote significance level at the 10%, 5%, and 1%, respectively.

	Panel A: Diff-in-Diff Test Around Avoidance of Odd-Eighth Quotes			
	Pooled		Monthly Fixed Effects	
Constant	0.0043***	0.0002	0.0043***	0.0032
	(33.27)	(0.03)	(24.08)	(0.55)
Treatment Dummy	0.0149***	0.0147***	0.0149***	0.0148***
	(36.19)	(10.23)	(39.53)	(10.29)
Time Dummy	-0.0006***	0.0004	-0.0006**	0.0002
	(-3.73)	(0.82)	(-2.56)	(0.35)
Treatment Dummy*Time Dummy	-0.0015**	-0.0022***	-0.0015***	-0.0020***
	(-2.46)	(-3.12)	(-3.37)	(-3.97)
Firm Age		0.0040		0.0005
		(0.74)		(0.08)
Log(Earning shock)		0.0002		0.0002
		(1.14)		(1.00)
Market-to-Book		-0.0002		-0.0002
		(-0.18)		(-0.23)
Return-on-Equity		-0.0014		-0.0008
		(-1.04)		(-0.55)
Retail Volume		0.0192**		0.0143
		(2.06)		(1.48)
Observations	98	98	98	98
% Adjusted R^2	95.8	96.0	96.5	96.5

	Panel B:Time Trend Tests Around Avoidance of Odd-Eighth Quotes						
	1976m1 to 1994m4			1994m5 to 1998m9	1998m10 to 2001m5		
Time Trend	0.5979***	0.4658***	0.3194	0.1580	7.0520***	6.9175***	-1.3966
	(9.40)	(2.72)	(1.50)	(0.36)	(3.52)	(3.79)	(-1.08)
Market-to-Book		15.5286				16.4745***	
		(1.02)				(3.14)	
Bid-Ask Spread			12.1952**				28.1497***
			(1.99)				(14.80)
Observations	221	221	221	52	32	32	32
% Adjusted R^2	47.3	47.8	55.6	0.00	20.4	30.6	76.8