Tick Size and Institutional Trading Costs:

Evidence from Mutual Funds

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forthcoming, Journal of Financial and Quantitative Analysis

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The authors thank the Dean's Fund for Research and the Financial Markets Research Center at the Owen Graduate School of Management, Vanderbilt University, for generous research support. The paper has benefited from the comments and suggestions of an anonymous referee, Cliff Ball, Hank Bessembinder, Larry Harris, Craig Lewis, Ron Masulis, Hans Stoll, Russ Wermers, and seminar participants at NYU, the University of Colorado, the University of Washington, Vanderbilt University, and the 2003 Western Finance Association annual meeting.

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Abstract

This paper measures changes in mutual fund trading costs following two reductions in the tick size of U.S. equity markets: the switch from eighths to sixteenths and the subsequent switch to decimals. We estimate trading costs by comparing a mutual fund's daily returns to the daily returns of a synthetic benchmark portfolio that matches the fund's holdings but has zero trading costs by construction. We find that the average change in trading costs of actively managed funds was positive following both reductions in tick size, with a larger and statistically significant increase following decimalization. In contrast, index fund trading costs were unaffected.

In March 1997, Congressman Oxley introduced a bill (H.R. 1053, also know as the Common Cents Stock Pricing Act of 1997) to the U.S. House of Representatives, directing the SEC to adopt a rule requiring stock quotations in dollars and cents. Congress and the SEC supported a smaller tick size, citing projected reductions in trading costs for individual investors. Empirical research shows that bid-ask spreads drop considerably following reductions in tick size, indicating that tick size is often a binding constraint on spreads, and that reducing the tick size benefits small traders who can transact small quantities at quoted prices.[1] However, for small investors the predominant

[1] See, for example, Bacidore (1997), Porter and Weaver (1997), Ahn, Cao, and Choe (1998), Ronen and Weaver (2001), Bacidore, Battalio, and Jennings (2003), Bessembinder (2003), and Chakravarty, Wood, and Van Ness (2004).

method of owning equities is through mutual funds.[2] Therefore, to measure the impact of reducing the tick size on retail investors, one must examine mutual fund trading costs.

We measure changes in mutual fund trading costs over the two recent tick size reductions in U.S. equity markets: the switch from eighths to sixteenths in June 1997, then to pennies over the period August 2000 to April 2001. Trading costs of index funds were unchanged following the two reductions in tick size. In contrast, over the five months following the switch to sixteenths, actively managed funds experienced an increase in trading costs equal to 0.157% of fund assets. Over the five months following the switch to decimals, the increase was 0.502%. Rather than help the individual investor, as decimalization's proponents envisioned, the switch to pennies appears to have levied a burden in the form of lower mutual fund returns.

Academic studies provide three explanations for why shrinking a market's tick size may undermine market quality for mutual funds and other institutional investors. First, Brown, Laux, and Schacter (1991) and Harris (1991) note that a smaller tick size increases the number of possible prices at which to trade, thereby complicating negotiation and presumably decreasing the average speed of execution. Second, and perhaps more important, a smaller tick size may decrease market depth by reducing the profitability of supplying liquidity, as implied by the model of Anshuman and Kalay (1998). Market makers may simply choose to leave the business. Third, Harris (1994), Angel (1997), and Seppi (1997) argue that a smaller tick size may decrease market depth by weakening priority rules in the limit order book. Reducing the tick size lowers the cost

[2] According to the Investment Company Institute (2003), over 80 million U.S. individual investors owned equity mutual fund shares in 2002, collectively owning about 75% of the equity funds' $2.667 trillion in assets.

of jumping ahead of existing orders in the book and gaining priority. This activity would likely discourage investors from placing limit orders. Consistent with these theoretical predictions, the results of numerous empirical studies indicate that drops in market depth accompany tighter spreads following reductions in tick size.[3]

Small, retail orders that can be executed at quoted prices unambiguously benefit from the tighter spreads that follow reductions in tick size without suffering from any contemporaneous reduction in market depth. For the large orders from pension funds, mutual funds, and hedge funds, tighter bid-ask spreads do not necessarily imply lower trading costs since their size often far exceeds the quoted depth—what matters are the prices at which institutional orders execute.[4] To measure the full cost of a mutual fund's trading activity, one could tabulate order-by-order the commissions and execution costs incurred over a given time period. Unfortunately, this approach is infeasible, since mutual fund managers are reluctant to reveal their proprietary trading activity.[5]

We combat the opacity of mutual fund trading activity by using a modified version of Grinblatt and Titman's (1989 and 1993) estimate of trading costs applied to daily returns. The advantage of our approach is that it aggregates all expenses related to trading, including price impact, and covers all possible trading platforms. Our approach

[3] See, for example, Bollen and Whaley (1998), Goldstein and Kavajecz (2000), NYSE (2001), Nasdaq (2001), Bacidore, Battalio, and Jennings (2003), Bessembinder (2003), and Chakravarty, Wood, and Van Ness (2004).

[4] Large institutional orders are sensitive to market depth for at least two reasons. First, as argued by Chan and Lakonishok (1995) and Keim and Madhavan (1997), filling a large order may take several days and multiple transactions; hence a large order likely suffers price concessions as market depth is consumed. Second, information leakage may move prices adversely as the institutional investor attempts to fill the order.

[5] See, for example, "Silence is golden to mutual-fund industry," (Wall Street Journal, July 31, 2002, p.C1). Also, Wermers (2001) concludes that more frequent portfolio disclosure would likely lower fund returns, citing possible front-running by professional investors and speculators.

has two limitations. First, our estimate is based on quarterly snapshots of a portfolio's holdings and therefore includes measurement error. We perform a number of robustness checks to ensure our results are credible. Second, we cannot determine which of the components of total trading costs change following the tick size reductions. However, in the context of our study, an accurate estimate of total mutual fund trading costs is more important than an estimate of the components of costs.

Our paper makes two contributions to the mutual fund performance literature. First, we show how daily mutual fund return data can be used to estimate the impact of changes to the environment in which mutual fund managers operate. Our procedure could be used to study other changes in market microstructure or the regulation of mutual fund activity. Second, our empirical results highlight the importance of tick size for mutual fund trading costs.

The rest of the paper is organized as follows. Section I explains the empirical methodology. Section II describes the data. Section III presents the empirical results, and examines alternative explanations for our findings. Section IV offers concluding remarks.

I. Empirical Methodology

A. Estimating the Change in Trading Costs

As noted by Bessembinder (2003), among others, the trade level data usually analyzed in studies of market quality are not sufficient to infer institutional trading costs. To see this, consider a portfolio manager who releases a large order to an internal trading desk. The trader devises a strategy to fill the order, which often involves splitting the order into smaller pieces, each of which may be routed to different markets and brokers. As each component of the order is executed, prices may move against the portfolio manager. One way to capture the resulting price impact is to analyze the order as far upstream as possible. Some studies of the relation between tick size and trading costs examine particular subsets of institutional orders, and provide insights regarding price impact that are impossible to establish using standard trade and quote data.[6]

The popular press presents anecdotal evidence that competitive pressure has forced institutional order routing strategies to become more sophisticated in recent years, with an increased emphasis on splitting orders across time and alternative trading platforms.[7] For our study, the implication is that existing evidence derived from analysis of individual markets or order types needs to be interpreted with caution when assessing mutual fund trading costs. To estimate trading costs at the mutual fund level, we need to incorporate all trading necessary to fill a fund manager's orders, rather than focus on a particular set of orders or a particular venue.

Grinblatt and Titman (1989 and 1993), Wermers (2000), and Chalmers, Edelen, and Kadlec (2001b) infer trading activity and trading costs at the mutual fund level from changes in portfolio holdings. Most funds report holdings quarterly or semi-annually. Grinblatt and Titman (1989) construct for each mutual fund in their 1975–1984 sample a hypothetical portfolio based on quarterly holdings reports. The authors rebalance portfolio weights monthly between reports. They then compare the CAPM alpha of an equally-weighted portfolio of the actual funds to that of an equally-weighted portfolio of

[6] See, for example, Jones and Lipson (2001), Werner (2003), and Chakravarty, Panchapagesan, and Wood (2004).

[7] See, for example, "The buy side wakes up," (Institutional Investor, April 2002, p.58-68)

the hypothetical funds in order to estimate total average expenses of the actual funds. Chalmers, Edelen, and Kadlec (2001b) estimate fund-by-fund trading costs by calculating bid-ask spread and commission expenses.[8] As Chalmers, Edelen, and Kadlec recognize, this approach ignores the price concessions paid by the mutual fund, which can be substantial and which are central to our study.

Our approach is to create a benchmark portfolio for each fund. We compute the daily returns of a benchmark, r_b, as follows:

$$r_b = \left(1 - w_{p,cash}\right) r_{p,e} + w_{p,cash} r_f - r_{p,exp}, \tag{1}$$

where $w_{p,cash}$ is the estimated cash position of fund *p*, $r_{p,e}$ is the estimated daily return of the equity holdings of fund *p*, r_f is the risk-free rate of interest, and $r_{p,exp}$ is fund *p*'s daily expense ratio. Both the estimated cash position and the estimated equity return are determined daily by linearly interpolating between adjacent portfolio holdings reports, which are generally available quarterly. Since the benchmark portfolio has zero trading costs by construction, but mimics the holdings and expense ratio of the actual fund, the difference between the return of the benchmark and the actual fund is the basis for our measure of trading costs. We define the daily difference between a fund's benchmark return and the fund's actual return as follows:

$$\gamma_{p,t} \equiv r_{b,t} - r_{p,t}. \tag{2}$$

[8] To estimate commissions, Chalmers, Edelen, and Kadlec (2001b) rely on the disclosure of commissions reported by the mutual funds in SEC N-SAR filings. To estimate costs associated with the bid-ask spread, for each stock in a portfolio they multiply the change in the portfolio holding, as measured from consecutive holding reports, by an estimate of the bid-ask spread taken from the ISSM tapes.

Our procedure's benchmarks are similar to the benchmarks developed by Grinblatt and Titman (1989 and 1993).[9] We prefer this approach to that of Chalmers, Edelen, and Kadlec (2001b) because it subsumes all trading costs, including the price impact generated as a mutual fund's orders are filled.[10] Our approach includes several refinements compared to Grinblatt and Titman. First, as mentioned, we linearly interpolate day-by-day between adjacent portfolio holdings reports. This procedure is designed to capture the impact of trading between portfolio snapshots. Second, we adjust our synthetic benchmark returns daily to account for the estimated cash holdings of the actual fund and the actual fund's expense ratio.

Since our estimate of a fund's equity return cannot capture intra-period round-trip trades, and is based on the assumption of linear portfolio revisions, the return of a fund will differ from the return of its benchmark due to trading costs *and* tracking error.[11] We address this issue two ways.

First, we eliminate the difference between actual and benchmark returns caused by differences in their exposures to systematic risk by regressing the daily time series of γ_p on a set of standard factors. Even through the benchmark is formed from actual

[9] Our methodology is also similar in implementation to the procedure used by Barber and Odean (2002) to estimate the net effect of trading by individual investors on their portfolio returns.

[10] Wermers (2000) estimates price impact stock-by-stock by the relation between price impact and trade characteristics estimated in Keim and Madhavan (1997). As pointed out by Chalmers, Edelen, and Kadlec (2001b), this procedure is somewhat imprecise due to the low explanatory power of Keim and Madhavan's model.

[11] The return of actual mutual funds may also differ from their benchmarks because of the dilution of fund assets caused by market timing or late trading of fund shares. Note, though, that unless there is a systematic change in the degree of market timing or late trading, neither will affect our estimate of the change in trading costs. Zitzewitz (2003) presents evidence that for domestic small-cap and mid-cap equity funds, dilution from market timing declined from 17 basis points per year in 1998 to 8 basis points in 2001, suggesting that our approach would be biased towards finding a small reduction in trading costs.

portfolio holdings, slight differences in risk exposures may occur from intra-period trading. Carhart (1997) shows that the excess return of the market portfolio, the Fama and French (1993) size and book-to-market factors, and a momentum factor capture the systematic components of mutual fund returns. We therefore use Carhart's four-factor model to control for any difference between the fund and benchmark risk exposures. For comparison, we also use the standard single-factor CAPM. The factor models we run are:

$$\gamma_{p,t} = \alpha_p + \alpha_{p1} I_{1t} + \sum_{k=1}^{N} \beta_{pk} r_{k,t} + \varepsilon_{p,t}\, , \tag{3}$$

where $\gamma_{p,t}$ is the day t return difference defined in equation (2), $I_{1t} = 0$ in the period before the switch to sixteenths or decimals (the pre-period) and $I_{1t} = 1$ in the period after the switch to sixteenths or decimals (the post-period), N is the number of factors (one or four), and $r_{k,t}$ are the returns of the four factors. In unreported analysis, we use a standard F-test to reject the restriction that the four factor coefficients are jointly zero for over 90% of the funds in our sample, which implies that controlling for tracking error in this manner is important. In equation (3), α_p is our estimate of trading costs during the pre-period and α_{p1} measures the change in trading costs following a tick size reduction.

Second, we conduct a simulation exercise to gauge whether tracking error can generate differences in return large enough to distort our estimates of trading costs. Tracking error can occur two ways. It can be caused by unobservable intra-period round-trip trading that is not captured by the holdings reports we use to construct the benchmark portfolio. It can also be caused by trading patterns that deviate from our assumption of a linear transition between portfolio snapshots. In the simulation, benchmarks are formed by randomly incorporating lumpiness in the total trading inferred from the difference between successive portfolio snapshots, and also by randomly incorporating additional intra-period round-trip trading. The simulation generates a distribution of changes in trading costs that is consistent with our findings; hence our results cannot be explained by tracking error in the benchmark portfolios. Details are presented in the Appendix.

Studies of mutual fund performance, dating back to Jensen (1968), generally use the alpha of factor model regressions related to equation (3) to measure abnormal returns generated from a fund manager's ability to pick stocks that outperform a risk-adjusted benchmark and/or the erosion of asset value caused by trading costs, management fees, and other expenses.[12] In our study, we eliminate the impact of management fees and other non-trading expenses by reducing the benchmark portfolio's return by the actual fund's expense ratio. We also address the impact of managerial ability by adjusting the benchmark portfolio holdings daily. As discussed above, intra-period round-trip trading is unobservable, and could affect our estimate of trading costs, though simulation evidence suggests otherwise. Nonetheless, our estimate of the change in trading costs, α_{p1}, might be affected by a change in a fund manager's ability to generate abnormal returns by intra-period round-trip trading. However, this possibility will likely play a small role in our results. If a particular fund manager can generate substantial abnormal returns from intra-period trading, α_{p1} will still equal zero provided that short-term trading skill persists across the pre- and post-periods.[13] Even if short-term trading skill does not persist, skill

[12] Blake, Elton, and Gruber (1993) provide empirical evidence supporting this view. They run cross-sectional regressions of alpha against expenses and find a statistically significant coefficient of approximately –1 on the expense ratio. Similarly, Carhart (1997) finds significantly negative relations between four-factor alpha and the expense ratio, and between the four-factor alpha and turnover.

[13] See Bollen and Busse (2005) for evidence that skill persists at a quarterly horizon.

should average zero across the universe of funds in a semi-strong form efficient market, and, across funds, the average α_{p1} should reflect the average change in trading costs.

Characteristics of individual mutual funds may predict changes in trading costs. Jones and Lipson (2001) sort institutional orders into three categories based on management style: momentum, value, and index. Momentum traders desire speed of execution and accordingly pay a penalty to establish their positions as they consume available liquidity. Value and index traders hurry less to meet their objectives and can act strategically to minimize price penalties. We adopt a simpler classification scheme: we designate funds as either index funds or actively managed funds. We report the change in trading costs for these categories separately.

B. Measurement Windows

In selecting measurement windows, we consider three issues. First, to avoid contaminating our estimates of trading costs, the measurement windows should not contain any dates during the conversion to smaller tick sizes. We therefore select time periods during which all stocks traded in eighths, sixteenths, or decimals. Second, the measurement windows should ideally be identical in calendar time to ensure that seasonal effects do not influence changes in measured trading costs. Brown, Harlow, and Starks (1996) and Carhart, Kaniel, Musto, and Reed (2002), for example, suggest that fund managers, depending on their year-to-date performance, may change investing strategies over the calendar year in order to game compensation schemes. Third, defining short measurement windows close to the conversion periods reduces the probability of observing some other market-wide event that might affect trading costs.

Figure 1 displays the relevant dates for our study. As listed in Figure 1A, Nasdaq switched from quoting stocks in eighths of a dollar to sixteenths on June 2, 1997. NYSE followed suit on June 24, 1997. We define our pre-period beginning January 1, 1997, and ending May 30, 1997. We define our post-period beginning July 1, 1997, and ending November 30, 1997. The pre- and post-periods are obviously not identical calendar periods, but they meet all of the other criteria. In Figure 1B, note that the conversion to decimals is dispersed over a longer period of time, beginning with the NYSE on August 28, 2000, and ending with Nasdaq on April 9, 2001. We therefore define the decimals pre-period beginning April 17, 2000, and ending August 25, 2000, and the post-period beginning April 16, 2001, and ending August 24, 2001. In the case of decimals, we are able to align the pre- and post-periods in calendar time.

II. Data

We construct two fund samples: one associated with the switch from eighths to sixteenths (the sixteenths sample) and one associated with the switch from sixteenths to decimals (the decimals sample). To construct the sixteenths sample, we begin with the April 1997 and October 1997 versions of Morningstar's *Principia Plus*. To focus on funds that invest predominantly in U.S. equities, we select from each Morningstar disk domestic equity funds that allocate at least 90% of their assets to stocks and no more than 10% to cash. We eliminate "fund of funds" to focus on individual funds. We also include only the oldest share class of any particular fund since multiple classes hold the same portfolio of stocks. We select funds for which Morningstar provides portfolio holding dates of December 31, 1996 (on the April disk), and June 30, 1997 (on the October disk), which represent portfolio holding dates at the beginning of the sixteenths pre- and post-periods respectively. These search criteria produce two sets of mutual funds, one for each disk. The sixteenths sample consists of those funds that exist in both sets. For the decimals sample, we repeat the procedure using the July 2000 and July 2001 Morningstar *Principia Pro Plus* disks and searching for portfolio holding dates of March 31, 2000, and March 31, 2001.

For each sixteenths sample fund, we take from Morningstar the complete set of equity portfolio holdings (including company name, stock ticker symbol, and number of shares owned) for the December 31, 1996 and June 30, 1997 portfolio holding dates. These provide the portfolio holdings at the beginning of the pre- and post-periods, respectively. We use additional Morningstar disks to collect for each fund the first available equity portfolio holdings after the end of the pre- and post-periods. Approximately 80% of funds during this time period report quarterly portfolio holdings to Morningstar, and for these funds we collect an additional portfolio holding snapshot midway through the measurement window. We similarly collect complete sets of equity portfolio holdings for the decimals sample at the beginning, middle (for about 90% of the funds), and end of the pre- and post-periods. Also from Morningstar we take for each fund the percentage of assets allocated to cash (typically updated at the same frequency as the portfolio holdings), mutual fund ticker symbol, the fund family total net assets, and a classification of either actively managed or index.

Next, for each sample fund, we extract the daily fund returns (which are net of trading costs and other expenses) from a database purchased from Standard & Poors.[14] We use the CRSP Mutual Funds Database to collect the annual expense ratio, turnover rate, and total net assets of the sample funds. We match funds on the Morningstar and CRSP databases via fund names and ticker symbols.

We use each fund's portfolio holdings to construct daily zero-cost benchmark equity returns. We match each stock holding (from Morningstar) to the CRSP stock return database via the ticker symbol. The sixteenths sample entails 122,167 matches (e.g., 600 matches for a 100-equity fund with three portfolio snapshots during the pre-period and three snapshots during the post-period). The decimals sample requires 229,890 matches. We verify the match by comparing the company names given on CRSP with those provided in the Morningstar holdings data.[15] We compute the daily benchmark equity returns by taking the sum of the portfolio weighted stock returns. Portfolio weights are adjusted daily to reflect a linear transition between each pair of adjacent sets of portfolio holdings, accounting for stock splits and stock dividends. To mimic the cash portion of the fund portfolios, we take the monthly CRSP *T30RET* 30-day t-bill return divided by the number of days in the month.

In addition to the funds for which Morningstar has portfolio holdings on the appropriate dates, we also include in the sample the entire set of S&P 500 index funds in

[14] Visual inspection of the sample fund return data does not indicate obvious instances of data-entry error. However, as a robustness check, we use the filtering approach recommended by Chalmers, Edelen, and Kadlec (2001a), and we discard any return with absolute value exceeding five times the standard deviation of daily S&P 500 returns. Our reported results reflect the unfiltered data; the results associated with the filtered data are nearly identical.

[15] We match 99.4% of total asset value. We remove non-matched holdings from the fund benchmark and re-weight the matched holdings. Holdings that we are unable to match mainly consist of foreign stocks that do not have a corresponding U.S.-traded ADR and small capitalization stocks.

the Standard & Poors database, regardless of whether Morningstar includes portfolio holdings on the appropriate dates. We can include S&P 500 funds without portfolio holdings because the returns on the S&P 500 index can serve as the equity portion of their benchmark portfolio. We use the CRSP S&P 500 index returns series including dividends as the equity portion of the benchmark portfolio for these funds.

The sample includes funds with Morningstar prospectus objectives of aggressive growth, growth, growth and income, equity income, and income. The sixteenths sample consists of 175 funds, and the decimals sample 265 funds, as shown in Panel A of Table 1. Panel B lists summary statistics of the funds for the pre- and post-periods of the two tick size changes. Fund returns were high before and after the switch to sixteenths: the median annualized return for actively managed funds was 26% in the pre-period and 24% in the post-period. In contrast, the median annualized return for actively managed funds in the decimals pre-period was 46% but only 7% in the post-period. In our empirical analysis, we assess whether the difference in returns across the decimals pre- and post-periods affects our estimates of trading costs.

Other fund statistics listed in Panel B of Table 1 are relatively stable across the pre- and post-periods, so we report here the pre-period medians. The typical actively managed fund has a much higher expense ratio than the typical index fund. The median expense ratios are 1.14% and 0.25% respectively for the two categories in the sixteenths sample, and 1.16% and 0.30% in the decimals sample. Although interesting, these facts do not play a direct role in our analysis since we adjust each fund's benchmark to reflect the actual fund's expense ratio. The difference between the active and index funds' turnover is more important, since trading costs are naturally a direct function of turnover.

The median turnover is 65% (59%) for the actively managed funds in the sixteenths (decimals) sample, versus 6% (13%) for the index funds.[16] The disparity in turnover suggests that if a reduction in tick size increases trading costs, then actively managed funds should feel the effect substantially more than index funds. Index funds are also from larger fund families, suggesting that index funds may have more opportunity to cross trades within the family and thereby avoid any increase in trading costs resulting from a reduced tick size. Note, however, that the typical index fund is several times as large as the typical actively managed fund. The median total net assets of the index funds are $447 million ($883 million) in the sixteenths (decimals) sample, versus $248 million ($170 million) for the actively managed funds. To the extent that larger funds trade larger quantities of stock to affect the same degree of portfolio rebalancing, the index funds will be at a disadvantage if only very large orders are subject to higher trading costs.

We gauge the effectiveness of the benchmark procedure by measuring the time series correlation between each actual fund's daily returns and the corresponding benchmark returns. Medians are above 0.99 for all time periods studied. In Figures 2A and 2B, we illustrate the tight match between funds and their benchmarks by plotting the time series of the cross-sectional average fund return and benchmark return in the decimalization pre- and post-periods, respectively. The figures suggest that the match between benchmark and fund returns is consistently quite close. A small number of funds exist, however, for which the benchmark procedure does not accurately match the actual returns. For example, the lowest correlations for the sixteenths and decimals sample

[16] According to Beneish and Whaley (2002), Standard & Poors made only three voluntary changes to the S&P 500 index in 1997, but made 19 in 2000 and nine in 2001. The more frequent changes in the decimals period would require more trading by index fund managers in order to maintain a match to the index.

periods are 0.62 and 0.59 respectively.[17] Since a tight match between the actual fund and the benchmark fund is essential to our estimate of trading costs, we only report results in Tables 2 through 4 for a subset of funds with correlation greater than 0.97 in both pre- and post-periods. Although our choice of a correlation constraint of 0.97 is somewhat arbitrary, our inference is not sensitive to this specific constraint. The correlation constraint reduces the number of index funds in our sample from 39 to 38 in the sixteenths sample and from 59 to 58 in the decimals sample. The number of actively managed funds decreases from 136 to 121 in the sixteenths sample and from 206 to 190 in the decimals sample.

Our sample of actively managed funds following the switch to sixteenths may be affected by Nasdaq's implementation of the order handling rules during 1997. In an effort to isolate the impact of the tick size change, we sort the sixteenths sample of actively managed funds by turnover of NYSE listed stocks. We report results in the following section only for the 60 funds above the median.

III. Results

A. Main Results

Table 2 shows the cross-sectional mean of the pre-period trading costs α_p and change in trading costs α_{p1} following the switches to sixteenths and decimals. Consider

[17] There are a variety of causes for low correlations between funds and benchmarks, most associated with data errors by vendors. For example, some funds had one or more outlier returns, typically involving a large positive return one day followed by a reversal the next day, suggesting an NAV error. Others had Morningstar portfolio holdings data that did not mach those from another vendor (Thomson Financial). Finally, other funds had unusually high turnover. Given the low frequency of portfolio holding snapshots, our procedure is unable to precisely track high-turnover portfolios.

the results for actively managed funds. Using the four-factor model, trading costs were 1.243% of fund assets in the five months leading up to the switch to sixteenths, as listed in Panel A. Trading costs increased over the five months following the switch to sixteenths by 15.7 basis points, statistically insignificant at the 5% level using the standard *t*-test. The results from the single-factor model provide the same qualitative inference.

The results for decimalization are stronger. In the five months leading up to the switch to decimals, trading costs for actively managed funds were insignificantly different from zero, as listed in Panel B. This result is consistent with anecdotal evidence regarding the evolution of institutional trading. Current practices include dynamic order routing in response to pre-trade cost estimators, "capital markets" desks linking institutional investors directly with companies willing to transact in their own shares, and pressuring brokers to accept the risk of trading losses while orders are being filled.[18] Following the switch to decimals, however, the actively managed funds appear to have suffered a statistically significant and economically large increase in trading costs. The mean increase is 36.1 basis points using the single-factor model and 50.2 basis points using the four-factor model.[19] Our estimates are statistically significant at the 5% level

[18] See, for example, "The buy side wakes up," (Institutional Investor, April 2002, p.58-68) and "Tough customer: How Fidelity's trading chief pinches pennies on Wall Street," (Wall Street Journal, 12 October 2004, p.A1).

[19] Coefficients are estimated using OLS. Residuals in equation (3) may have a time-dependence, however, which would render OLS estimates inefficient, possibly biased, but still consistent. To ensure that our results are reliable, we also estimate coefficients using a two-step GLS procedure to eliminate serial correlation in residuals. We find significant negative serial correlation in approximately one-third of the funds, which is consistent with lumpiness in actual portfolio revisions relative to the smooth linear interpolation in the benchmark portfolios. The cross-sectional means of the trading costs and change in trading costs are quite close using the GLS procedure; the qualitative inference is identical.

using a standard *t*-test.[20] The two nonparametric statistics also indicate a significant change: the Wilcoxon signed rank test, which is the value of a standard normal under the null, has a value greater than 2.75 for both factor models, and about 60% of funds show a cost increase, which is statistically significantly different from the 50% expected under the null.

To put these estimates of the increase in trading costs in perspective, we compare them to estimates of institutional trading costs from existing studies. Grinblatt and Titman (1989) estimate annual total trading costs between 1% and 2.5% of fund assets, depending on the benchmark used. Chalmers, Edelen, and Kadlec (2001b) estimate an average annual spread and commission expense for funds in their 1984–1991 sample of 0.75%. This excludes the price impact of mutual fund trades. They cite Chan and Lakonishok (1995), who estimate a price impact of 1% for institutional purchases and 0.35% for institutional sales. A fund with 100% annual turnover, which is at about the 75th percentile of our sample, would thus incur an annual price impact cost of 1.35% of fund assets. Combining the spread and commissions from Chalmers, Edelen, and Kadlec with the price impact from Chan and Lakonishok yields a total trading cost estimate of 2.1% of fund assets. Therefore, our estimate of an increase in trading costs of 0.36% to 0.50% of fund assets over a five-month period is quite large compared to these prior studies. We conduct a series of robustness tests in the following subsection to seek alternative explanations for the estimated increase in trading costs.

[20] We also find significance using a bootstrap standard error based on the empirical distribution using three sets of event windows outside the switch to decimals. Details are available from the authors.

Our results are consistent with numerous complaints from institutional traders regarding increased trading costs from the reduction in depth following decimalization.[21] It is possible that the impact of a new tick size diminishes over time as market participants adjust; we measure the time trend following the switch to decimals in subsection C.

For the index funds, our estimates of trading costs using the four-factor model are 6.3 basis points during the sixteenths pre-period and 10.6 basis points during the decimals pre-period, consistent with the low turnover of index funds. Changes in trading costs are statistically insignificant for the index funds, again consistent with their low turnover. As listed in Table 1, however, the median index fund was approximately five times as large as the median actively managed fund around the switch to decimals, so one might wonder how index funds can avoid the increase in trading costs experienced by actively managed funds post-decimalization. Jones and Lipson (2001) provide some guidance, as they report trading costs for momentum, value, and index funds separately. They find that, per order, index fund trading costs are approximately one-third that of momentum funds following the switch to sixteenths. Index fund managers do not require the same speed of execution, and may be able to use index futures to more efficiently manage trading demands.

B. Robustness Tests

Perhaps other phenomena affecting our measure of trading costs—unrelated to the tick size—cause time series variation in the cross-sectional mean of trading cost

[21] See, for example, "Decimal move brings points of contention from traders," (Wall Street Journal, February 12, 2001, p.C1) and "How penny pricing is pounding investors," (Business Week, January 15, 2001, p.74).

changes.[22] We consider three alternative explanations of our results: systematic changes in fund turnover, systematic changes in fund strategy, and changes in the distribution of market returns. We test these alternatives around the switch to decimals.

Our measure of trading costs is a function of both the per-share trading costs incurred by fund managers as well as the quantity of shares traded. We argue that per-share trading costs increased following decimalization, likely the result of decreased depth, and this drives the increase in trading costs we document. However, perhaps per-share trading costs actually declined as a result of tighter spreads, and fund managers as a result increased their trading activity. This could also generate an increase in total trading costs, but would have vastly different implications. To test this alternative explanation, we compute the turnover in each fund in the decimalization pre- and post-periods directly from the change in the portfolio holdings. We estimate pre- (post-) period turnover as the average of stock purchases and stock sales (estimated from the portfolio holdings snapshots) during the pre- (post-) period divided by the average fund TNA during the pre- (post-) period. We find average turnover of 68.1% during the pre-period and 68.3% during the post-period and fail to reject the null hypothesis that the average turnover rates are the same. Thus a systematic change in fund turnover does not appear to be a viable alternative explanation for our results.

Suppose that fund managers in aggregate changed their risk exposure in the post-period relative to the pre-period. Our methodology in equation (3) estimates risk exposures using data from both periods. This would distort our estimate of the change in trading costs; for example, the market beta could be over- or under-estimated in the post-

[22] This problem is analogous to clustering in event studies.

period. To address this concern, we modify equation (3) to allow the market beta to shift from the pre-period to the post-period. Our estimate of trading cost changes is unaffected. We find that the median market beta decreases by 0.0097 during the decimals post-period. A systematic change in fund strategy, therefore, does not appear to be a viable alternative explanation of our findings.

An alternative explanation of our results is that equity markets were different in some other way that affected trading costs in the pre- and post-periods. Of all the market characteristics we could consider, the distribution of equity returns is arguably the most important, because it is integral to the cost structure of equity dealers. The literature on the dealership function in equity markets specifies three types of costs incurred by dealers in supplying liquidity: overhead costs, asymmetric information costs, and inventory-holding costs.[23] Inventory-holding costs refer to the risk borne by dealers in maintaining inventory. The cost of managing risk is generally directionless; however, managing risk is more costly when the value of the asset held in inventory is more volatile. Thus, if volatility in the market were higher in the post-period, we might expect an increase in dealer costs which would be passed on to traders.

To test this alternative explanation, we use the Chicago Board Options Exchange Volatility Index (VIX) as a proxy for stock market volatility. It is a daily series constructed from implied volatilities of at-the-money put and call options on the S&P 100 index. The VIX can be interpreted as the market's expectation of volatility over the next 30 days, and is expressed as the annual return volatility of the underlying assets. The average levels of the VIX in the decimalization sample's pre- and post-periods were

[23] See Stoll (2002) for a review.

24.94% and 25.17% respectively. We fail to reject the hypothesis that they are the same. We also rerun our analysis with the daily VIX as an additional explanatory variable in equation (3), and the decimals cost change estimate is again unaffected. Thus it appears that a change in market volatility is not a viable alternative explanation for our results.

One might also expect that trading costs could increase in periods of negative returns if liquidity were to decline, and price impact were to rise, as a result. If the post-period features more frequent, severe drops in market prices, then one might expect an increase in trading costs in the post-period. To test this hypothesis, we separate our daily observations into days on which the market return was positive and negative. In the decimalization pre-period, 42 of the 92 trading days have negative market returns, with an average (median) return of –1.036% (–1.023%). In the post-period, 46 of the 93 trading days have negative market returns, with an average (median) return of –0.861% (–0.886%). Thus it does not appear that an increase in the frequency or magnitude of market drops in the post-period is the cause of our decimalization result. For completeness, we run the following version of our main four-factor regression:

$$\gamma_{p,t} = \alpha_p + \alpha_{p2} I_{2t} + \alpha_{p3} I_{3t} + \alpha_{p4} I_{4t} + \sum_{k=1}^{4} \beta_{pk} r_{k,t} + \varepsilon_{p,t} \tag{4}$$

where $I_{2t} = 1$ for observations in the pre-period with negative market returns and $I_{2t} = 0$ otherwise, $I_{3t} = 1$ for observations in the post-period with positive market returns and $I_{3t} = 0$ otherwise, $I_{4t} = 1$ for observations in the post-period with negative market returns and $I_{4t} = 0$ otherwise, and the four factors are the same as in equation (3). We find that

α_{p2} equals 0.747% on a five-month basis and is significant at the 5% level, α_{p3} is not significantly different from zero, and α_{p4} equals 1.594%, significant at the 1% level.

We interpret these findings as follows. First, in the pre-period, trading costs are significantly higher on days with negative market returns, as indicated by the positive α_{p2} coefficient. Second, in the post-period, trading costs are again significantly higher on days with negative market returns, as indicated by the difference between the α_{p3} and α_{p4} coefficients. These results are related to evidence in Chiyachantana, Jain, Jiang, and Wood (2004) that institutional sales in the U.S. had higher price impact than purchases during 2001, presumably the result of an increased cost of liquidity in falling markets. Third, there is no difference in trading costs pre- and post-decimalization when comparing trading costs only on positive market return days, as indicated by the insignificant α_{p3} coefficient. Fourth, when comparing trading costs only on negative market return days in the pre- and post-periods, we find an increase in trading costs following decimalization, as indicated by the difference between the α_{p2} and α_{p4} coefficients. This result is consistent with our conjecture that decimalization has raised institutional trading costs by reducing liquidity. Since mutual fund trading costs appear to be higher on negative market return days in general, decimalization's impact on depth is likely to be more binding, and will therefore be reflected in higher trading costs, when the market return is negative.

C. Cross-Sectional and Time-Series Variation in Trading Cost Changes

Although in the previous subsection we have identified and tested alternative explanations for why we might find that trading costs increase following decimalization, there may be others we have not considered. Another approach to support our contention of causation is to develop cross-sectional predictions consistent with our explanation that decimalization caused a drop in liquidity, which in turn increased mutual fund trading costs. If these cross-sectional predictions are borne out by the data, then we raise the hurdle for other unspecified alternative explanations for the trading cost increase. Four fund characteristics that predict cross-sectional variation in the change in trading costs are turnover, correlation with benchmark, fund size, and the fraction of trading volume consisting of low-priced stocks. The reasoning is as follows. Funds with higher turnover would realize a greater impact on returns for a given change in per-share trading costs. Funds with low correlation with their benchmarks would tend to have more intra-period round-trip trading, which could increase trading costs since this trading activity is fast-paced. A large fund will consume more liquidity than a small fund for a given portfolio reallocation, hence if decimalization has increased trading costs by reducing depth in the market, the impact is likely to be greater for large funds. For low-priced stocks, a tick size of a sixteenth is more likely to be a binding constraint on the spread than for high-priced stocks. Low-priced stocks, then, are likely to be affected more by decimalization and “penny-jumping” than high-priced stocks. We might expect a fund with high turnover in low-priced stocks to suffer a greater increase in trading costs than other funds as a result.

Table 3 reports average changes in estimated trading costs following decimalization for sub-samples of actively managed funds organized by turnover, correlation with benchmark, fund size, and turnover in low-priced stocks. Panel A shows that funds with high turnover experienced a larger increase in trading costs following decimalization than did funds with low turnover, 0.615% compared to 0.390%. To the extent that trading costs were higher following the switch to decimals, funds that traded more, suffered more.

Recall that our estimate of trading costs relies on the difference between a mutual fund's return and the return of a synthetic benchmark derived from portfolio holdings snapshots. Funds with lower correlation with their benchmark are likely engaging in more intra-period trading than funds with higher correlation with their benchmark. Panel B confirms this, and shows that funds with lower correlation with their benchmark experienced an increase of trading costs equal to 0.610% of fund assets, compared to 0.395% for funds with higher correlation.

Panel C shows that smaller funds suffered a larger increase in trading costs than larger funds, 0.629% compared to 0.376%. This result is somewhat counterintuitive, as we expect that the larger the fund, the greater the price impact of trading. Thus, an increase in per-share trading costs would affect a larger fund more, all else equal. Large funds, however, may be more likely to be part of a large fund family which would facilitate internal crossing of trades. Also, large funds may be managed by more sophisticated managers, with more effective traders. Thus they may be more able to mitigate any deleterious change in market quality.

Panel D shows the average trading cost increase for funds separated by turnover in low-priced stocks. We compute this measure by weighting each stock's contribution to turnover by the inverse of price, thereby putting more weight on those stocks with low prices.[24] We find that the high turnover category has an average increase of 0.661% versus an increase of 0.344% for the low turnover category, significant at the 5% and 1% level respectively. Although a *t*-test for a significant difference fails, the magnitudes are consistent with our conjecture that decimalization caused the increase in trading costs.

To determine which of the variables studied in Table 3 are more important, we run a cross-sectional regression of the changes in trading costs on the four fund characteristics estimated in the post-period. We transform the independent variables to conform to OLS assumptions in several ways. First, we take the natural logarithm of fund size. Second, we replace the benchmark correlation by an indicator variable that equals one if the fund is above the median and zero otherwise. Third, we replace turnover by the residuals of a regression of turnover on turnover in low-priced stocks, since the correlation of these two variables is 0.85 in the post-period. The only variable with a statistically significant coefficient is turnover in low-priced stocks. We drop the three insignificant variables and re-run the regression. The positive coefficient on low-priced stocks remains significant, with a *p*-value of 0.054, and we are unable to reject the restrictions that the other coefficients are zero. Thus it appears that the most important cross-sectional predictor of an increase in trading costs is the turnover in low-priced stocks.

The question of whether the increase in trading costs is permanent or transitory matters greatly from a policy perspective. If the increase is permanent, then exchange officials and the SEC may wish to reconsider the move to decimal pricing. If it is

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[24] When each stock's contribution to turnover is scaled by inverse price, the standard expression for turnover (the average of the dollar value of purchases and the dollar value of sales, divided by total net assets) collapses to the average of the shares purchased and the shares sold, divided by total net assets. This ratio will be high when low-priced stocks are traded heavily, since this will involve many shares.

transitory, then there would be less impetus to invest the capital necessary to reverse course. To provide some insight, we estimate the change in trading costs in the first half of the post-period, relative to the pre-period, and the change in trading costs in the second half of the post-period, again relative to the pre-period:

$$\gamma_{p,t} = \alpha_p + \alpha_{p5} I_{5t} + \alpha_{p6} I_{6t} + \sum_{k=1}^{4} \beta_{pk} r_{k,t} + \varepsilon_{p,t}\,, \tag{5}$$

where $I_{5t} = 1$ ($I_{6t} = 1$) during the first (second) half of the post-period and zero otherwise, and the four factors are the same as in our equation (3). Thus, α_{p5} indicates the change in trading costs in the first half of the post-period, and α_{p6} indicates the change in trading costs in the second half of the post-period.

Table 4 shows the results. Neither of the sub periods in the sixteenths sample displays any statistically significant change in trading costs. For the decimals results, there is little evidence to suggest that the increase in trading costs suffered by actively managed funds diminished over the post-period. Trading costs increase by 0.535% in the first half of the post-period, and by 0.470% in the second half. In the first half of the post-period, 58% of funds show an increase in trading costs, whereas 60% of funds show an increase in the second half. In summary, our results in Table 4 suggest that the increase in trading costs post-decimalization is constant across the post-period for actively managed funds.

IV. Conclusions

This study analyzes changes in equity mutual fund trading costs following two reductions in tick size in the U.S. equity markets. For actively managed funds with above median turnover in NYSE stocks, we find an increase in trading costs following the switch to sixteenths, consistent with the results of Jones and Lipson (2001). Over the five months following the switch to decimals, we find an economically and statistically significant increase in trading costs between 0.361% and 0.502% of fund assets for actively managed funds.

Proving a causal relation between changes in tick size and trading costs is difficult because institutional investors operate in a dynamic environment. This limits our ability to compare trading costs in different time periods. We therefore emphasize the degree to which our estimates of trading cost changes vary cross-sectionally in ways predicted by our explanation that smaller tick sizes lower depth, thereby penalizing institutional investors. We find that trading costs increase more following decimalization for those funds with large quantities of trade in low-priced stocks, consistent with a causal relation between changes in tick size and institutional trading costs.

Our results suggest that the move to decimal pricing preceded increased trading costs for some actively managed mutual funds. These costs are ultimately borne by individual fund shareholders. The objective of reducing costs for retail investors therefore has only been partially achieved by decimalization. Investors who trade small quantities of individual equities benefit from the tighter spreads following the switch to decimal pricing, and are largely unaffected by any decline in depth. Investors in some equity mutual funds, however, appear to have suffered in the five months following decimalization. We leave analysis of the longer-term impacts of decimalization for future research.

Appendix

This Appendix describes our simulation procedure for constructing benchmark portfolios that feature randomized quantity and timing of daily trading consistent with the total quantity of observed portfolio changes from successive snapshots, as well as the total quantity of inferred but unobservable intra-period trading.

To randomize the trading representing observed changes in portfolio composition from successive holdings snapshots, we first compute the average daily trading volume *M* of each stock in each fund. We do this by taking the difference between the holdings on the successive portfolio snapshots, then dividing by the number of trading days in the period. We randomize the quantity traded each day by defining a random variable $\tilde{x}$ where $\tilde{x} = Me^{\tilde{z}}$ and $\tilde{z} \sim N\left(-\sigma^2/2, \sigma^2\right)$. The daily trading quantity has a lognormal distribution, and some algebra shows that $\tilde{x}$ has mean *M* and standard deviation $M\sqrt{e^{\sigma^2} - 1}$. We compute five levels of daily standard deviation *S* corresponding to one through five tenths of the daily average *M*. These values encompass the observed range of standard deviation of daily trading volume of a random selection of growth and value stocks. We set $\sigma^2 = \ln\left[\left(S/M\right)^2 - 1\right]$ in order to simulate the appropriate level of standard deviation.

In each of 250 simulations, we loop through the days in a period for each fund, randomly drawing shares of each stock to be traded based on this procedure. At the end of the period, for a given stock in a given fund, each day's random trade quantity is rescaled by a common scalar so that the total quantity traded is equal to the actual amount traded over the period as given by the change in the successive holdings reports.

To randomize intra-period trading for each mutual fund, we combine the fund's successive portfolio holdings to construct a list of *N* candidate stocks. We estimate total intra-period trading by comparing the fund turnover as reported on CRSP to the fund turnover observed in the successive holdings reports. We allocate total intra-period trading among the *N* stocks by first randomly drawing a number *n* from a uniform distribution over the range zero to *N*. We then draw *n* standard uniform variates ε, and, for stock *i*, compute its share of total intra-period trading as

$$\varepsilon_i \Big/ \sum_{j=1}^{n} \varepsilon_j \; . \tag{A1}$$

Finally, we randomly chose two dates between portfolio snapshots, and randomly buy or sell the stock on the first and reverse the position on the second. If the fund did not own the stock on the first day, and a sell was chosen, it is converted to a buy to avoid short selling.

Figure 3 displays a histogram of the distribution of average trading cost change estimates from the simulations using the four-factor model. The mean trading cost increase is 0.407% across the simulations, slightly below our estimate assuming linear interpolation. More importantly, the range of the cost changes is 0.241% to 0.592%, with an inter-quartile range of 0.367% to 0.449%.

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Table 1. Summary Statistics

Panel A lists the number of mutual funds in our sample for the switches to sixteenths and decimals. Panel B lists characteristics of the funds. The sixteenths sample pre- (post-) period is from January 1, 1997, to May 30, 1997 (July 1, 1997, to November 30, 1997). The decimals sample pre- (post-) period is from April 17, 2000, to August 25, 2000 (April 16, 2001, to August 24, 2001). The total return, expense ratio, and turnover statistics are annualized.

Panel A. Number

	Sixteenths	Decimals
Total	175	265
Actively Managed	136	206
Index	39	59
S&P 500	31	42
Other	8	17

Panel B. Characteristics

B1. Sixteenths	Active Pre			Active Post			Index Pre			Index Post		
	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th
Total Return (%)	14.83	25.57	35.15	20.65	24.21	30.71	42.17	42.61	42.89	23.96	24.47	24.67
Expense Ratio (%)	0.91	1.14	1.45	0.91	1.14	1.45	0.20	0.25	0.40	0.20	0.25	0.40
Number of Holdings	53	79	109	54	77	109	500	501	506	499	501	504
Median Mkt Cap ($M)	1,106	4,965	14,505	1,693	6,332	18,559	24,485	25,823	26,148	32,767	34,752	35,190
Turnover (%)	33	65	104	33	65	104	3	6	15	3	6	15
Net Assets ($M)	99	248	677	117	342	890	178	447	953	283	686	1,416
Family Net Assets ($M)	459	1,561	8,377	441	2,623	8,533	1,344	3,401	10,766	1,761	4,226	13,312

B2. Decimals	Active Pre			Active Post			Index Pre			Index Post		
	25th	Median	75th	25th	Median	75th	25th	Median	75th	25th	Median	75th
Total Return (%)	32.36	45.93	72.04	-1.67	6.75	18.83	36.66	37.07	38.09	2.72	2.94	3.36
Expense Ratio (%)	0.96	1.16	1.34	0.96	1.18	1.35	0.20	0.30	0.45	0.22	0.35	0.47
Number of Holdings	52	80	123	50	80	121	500	502	505	500	501	504
Median Mkt Cap ($M)	2,677	22,782	63,420	2,342	24,133	52,503	46,818	88,115	90,336	36,848	59,850	60,657
Turnover (%)	33	59	96	33	64	110	7	13	30	8	11	33
Net Assets ($M)	54	170	756	49	171	545	184	883	2,767	184	748	2,018
Family Net Assets ($M)	420	3,552	15,286	496	3,254	14,640	3,417	15,715	41,386	3,620	13,844	39,071

Table 2. Estimates of Trading Costs and Trading Cost Changes following the Switches to Sixteenths and Decimals

Listed are estimates of the trading costs and change in trading costs over the five-month periods prior to and following the switches to sixteenths (Panel A) and decimals (Panel B) for actively managed funds and index funds. The estimates are expressed as a percentage of fund assets. The estimated trading cost α_p and change in trading cost α_{p1} are computed in the regression,

$$r_{p,benchmark,t} - r_{p,actual,t} = \alpha_p + \alpha_{p1} I_{1t} + \sum_{k=1}^{N} \beta_{pk} r_{k,t} + \varepsilon_{p,t},$$

where $I_{1t} = 0$ before the switch to sixteenths or decimals (the pre-period) and $I_{1t} = 1$ after the switch to sixteenths or decimals (the post-period), and N = 1 or 4. We report in the table the value of the cross-sectional means of α_p and α_{p1} on a five-month basis. The t-statistics are the ratio of the mean of α_p or α_{p1} to the corresponding cross-sectional standard error. We compute the z-statistics using the Wilcoxon signed ranks test. The t-statistic for the fraction of positive estimates tests whether the fraction is different than 0.5. * and ** indicate two-tailed significance at the 5% and 1% level respectively. The sixteenths sample consists of 60 actively managed and 38 index funds. The decimals sample consists of 190 actively managed and 58 index funds. The sixteenths sample pre- (post-) period is from January 1, 1997, to May 30, 1997 (July 1, 1997, to November 30, 1997). The decimals sample pre- (post-) period is from April 17, 2000, to August 25, 2000 (April 16, 2001, to August 24, 2001).

	Panel A. Sixteenths			
	Single-Factor		Four-Factor	
	Active	Index	Active	Index
α_p	1.266%**	0.068%	1.243%**	0.063%
t-statistic	(3.740)	(1.533)	(3.750)	(1.744)
z-statistic	(3.283)	(1.849)	(3.438)	(1.965)
Fraction α_p Positive	0.650*	0.632	0.650*	0.658
t-statistic	(2.324)	(1.622)	(2.324)	(1.947)
α_{p1}	0.025%	0.056%	0.157%	-0.001%
t-statistic	(0.105)	(1.237)	(0.651)	(-0.029)
z-statistic	(0.898)	(1.109)	(1.256)	(0.051)
Fraction α_{p1} Positive	0.617	0.579	0.633*	0.500
t-statistic	(1.807)	(0.973)	(2.066)	(0.000)

	Panel B. Decimals			
	Single-Factor		Four-Factor	
	Active	Index	Active	Index
α_p	0.101%	0.044%	-0.159%	0.106%
t-statistic	(0.528)	(0.621)	(-0.858)	(1.589)
z-statistic	(0.302)	(1.847)	(-2.393)	(3.550)
Fraction α_p Positive	0.526	0.638*	0.426*	0.759**
t-statistic	(0.725)	(2.101)	(-2.031)	(3.939)
α_{p1}	0.361%*	0.076%	0.502%**	0.041%
t-statistic	(2.220)	(0.948)	(3.044)	(0.551)
z-statistic	(2.856)	(0.283)	(3.957)	(-1.018)
Fraction α_{p1} Positive	0.584*	0.534	0.626**	0.466
t-statistic	(2.322)	(0.525)	(3.482)	(-0.525)

Table 3. Estimates of Trading Cost Changes following the Switch to Decimals Sorted by Fund Characteristics

Listed are estimates of the change in trading costs over the five-month period following the switch to decimals for actively managed funds grouped according to turnover (Panel A), correlation with benchmark (Panel B), size (Panel C), and turnover in low-priced stocks (Panel D). The estimated trading cost change is α_{p1} in the regression,

$$r_{p,benchmark,t} - r_{p,actual,t} = \alpha_p + \alpha_{p1} I_{1t} + \sum_{k=1}^{4} \beta_{pk} r_{k,t} + \varepsilon_{p,t},$$

where $I_{1t} = 0$ before the switch to decimals (the pre-period) and $I_{1t} = 1$ after the switch to decimals (the post-period). We report in the table the value of the cross-sectional mean α_{p1} on a five-month basis. The *t*-statistic in parenthesis is the ratio of the mean α_{p1} to the standard error of the mean α_{p1}. "High" ("Low") turnover funds have turnover that is higher (lower) than the median fund turnover. "High" ("Low") correlation funds have correlation with their respective benchmark that is higher (lower) than the median fund correlation. "Big" ("Small") funds are greater (less) than the median fund size. "High" ("Low") turnover in low-priced stocks have turnover of low-priced stocks that is higher (lower) than the median. * and ** indicate two-tailed significance at the 5% and 1% level respectively. The sample consists of 190 actively managed funds. The pre- (post-) period is from April 17, 2000, to August 25, 2000 (April 16, 2001, to August 24, 2001).

Panel A. Turnover

	# Funds	α_{p1}
High	95	0.615%*
		(1.976)
Low	95	0.390%**
		(3.481)

Panel B. Correlation with Benchmark

	# Funds	α_{p1}
High	95	0.395%**
		(3.313)
Low	95	0.610%*
		(1.978)

Panel C. Fund Size

	# Funds	α_{p1}
Big	95	0.376%
		(1.553)
Small	95	0.629%**
		(2.797)

Panel D. Turnover in Low-Priced Stocks

	# Funds	α_{p1}
High	95	0.661%*
		(2.102)
Low	95	0.344%**
		(3.388)

Table 4. Estimates of Trading Cost Changes following the Switches to Sixteenths and Decimals by Subperiod

Listed are estimates of the change in trading costs during two subperiods following the switches to sixteenths and decimals for actively managed funds. The estimated trading cost changes are α_{p5} and α_{p6} in the regression,

$$r_{p,benchmark,t} - r_{p,actual,t} = \alpha_p + \alpha_{p5} I_{5t} + \alpha_{p6} I_{6t} + \sum_{k=1}^{4} \beta_{pk} r_{k,t} + \varepsilon_{p,t} \,,$$

where I_{5t} = 1 (I_{6t} = 1) during the first (second) half of the period after the switch to sixteenths or decimals and both equal zero before the switch to sixteenths or decimals. We report in the table the value of the cross-sectional mean α_{p5} or α_{p6} on a five-month basis. The *t*-statistic for the change in trading costs is the ratio of the mean α_{p5} or α_{p6} to the standard error of the mean α_{p5} or α_{p6}. We compute the *z*-statistic using the Wilcoxon signed ranks test. The *t*-statistic for the fraction of positive estimates tests whether the fraction is different than 0.5. * and ** indicate two-tailed significance at the 5% and 1% level respectively based on the *t*-statistic. The sixteenths sample consists of 60 actively managed and 38 index funds. The decimals sample consists of 190 actively managed and 58 index funds. The sixteenths (decimals) sample pre-period is from January 1, 1997, to May 30, 1997 (April 17, 2000, to August 25, 2000). The first (second) half of the sixteenths sample post-period is from July 1, 1997, to September 15, 1997 (September 16, 1997, to November 30, 1997). The first (second) half of the decimals sample post-period is from April 16, 2001, to June 20, 2001 (June 21, 2001, to August 24, 2001).

	Sixteenths		Decimals	
	First Half	Second Half	First Half	Second Half
α_{p5} or α_{p6}	0.163%	0.150%	0.535%**	0.470%*
t-statistic	(0.500)	(0.649)	(3.160)	(2.456)
z-statistic	(0.847)	(1.178)	(3.483)	(3.417)
Fraction α_{p5} or α_{p6} Positive	0.600	0.650*	0.584*	0.600**
t-statistic	(1.549)	(2.324)	(2.322)	(2.757)

Figure 1. Event Dates

Displayed are the dates defining the estimation periods used to measure mutual fund trading costs before and after the switch to sixteenths on the NYSE and Nasdaq, as well as the estimation periods before and after the switch to decimals.

Figure 1A. Sixteenths

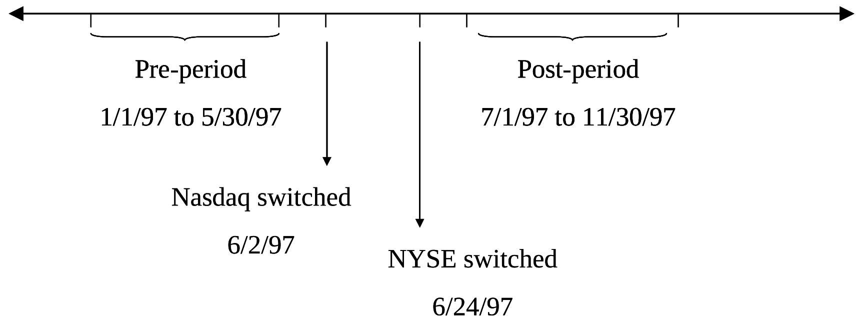

Figure 1B. Decimals

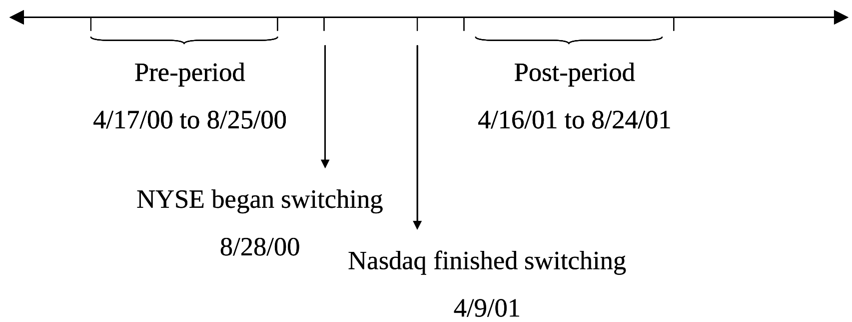

Figure 2. Comparison of Benchmark and Actual Fund Returns

Displayed are daily cross-sectional average returns of actual funds and their benchmarks before and after the switch to decimals. The sample consists of 190 actively managed and 58 index funds. The pre-period is from April 17, 2000, to August 25, 2000 and is depicted in Figure 2A; the post-period is April 16, 2001, to August 24, 2001 and is depicted in Figure 2B.

Figure 2A. Pre-Period

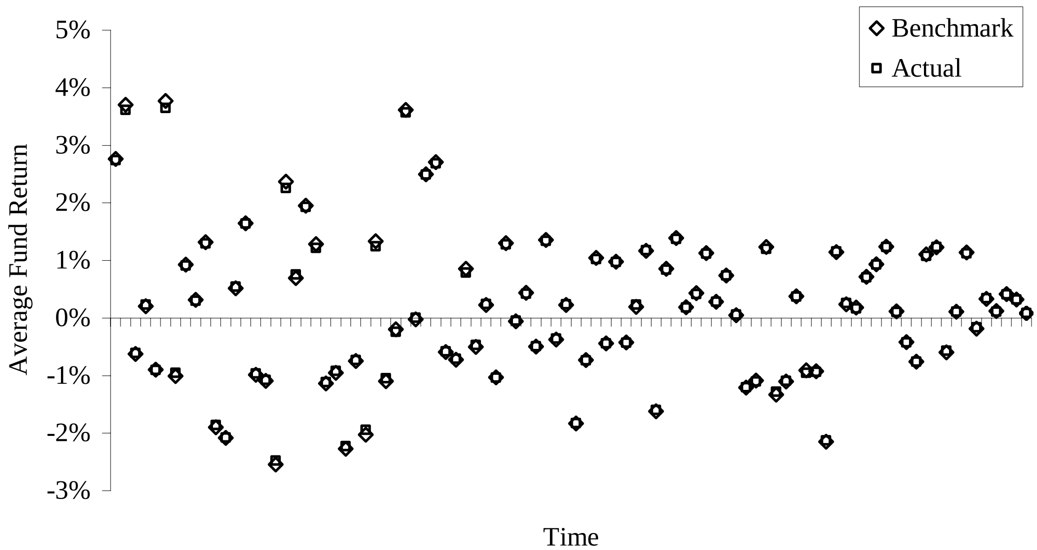

Figure 2B. Post-Period

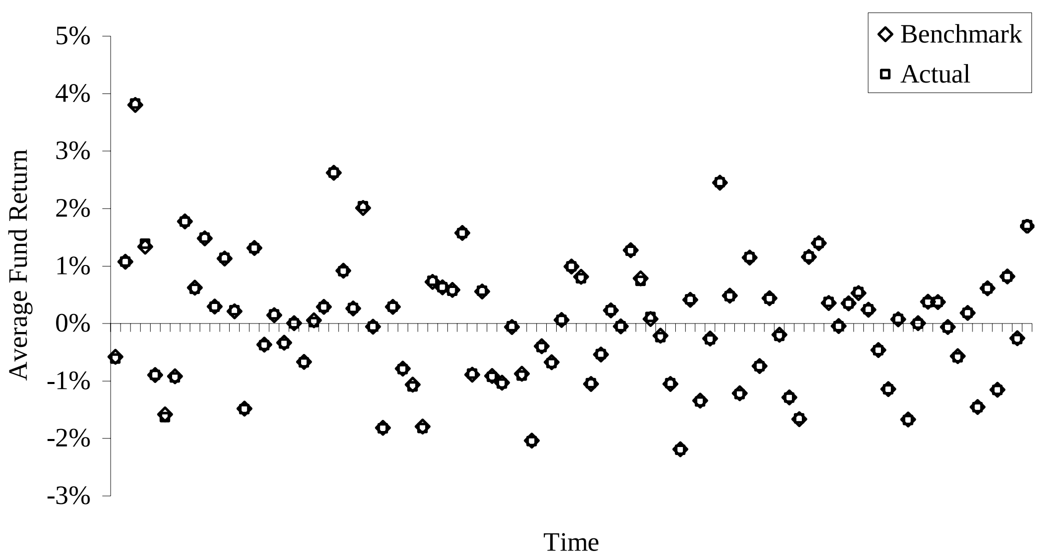

Figure 3. Distribution of Mean Trading Cost Changes for Actively Managed Funds Post-Decimalization with Randomized Benchmarks

Displayed is the distribution of 250 simulated mean trading cost changes over the five months following decimalization for actively managed funds for which benchmark portfolios are constructed by randomizing observed and unobserved trading. The estimated trading cost change is α_{p1} in the regression,

$$r_{p,benchmark,t} - r_{p,actual,t} = \alpha_p + \alpha_{p1} I_{1t} + \sum_{k=1}^{4} \beta_{pk} r_{k,t} + \varepsilon_{p,t},$$

where $I_{1t} = 0$ during the pre-period and $I_{1t} = 1$ during the post-period. Observable trade quantities are inferred from successive holding reports. The total unobservable intra-period round-trip trade is estimated by the difference between annual turnover as reported on CRSP and observable turnover. We randomize daily trade quantities of observed trade by drawing from a lognormal distribution. We randomize unobservable trade quantities for a given fund by randomly selecting stocks appearing on at least one of the fund's holding reports, randomly drawing trade quantity, and randomly assigning buy and sell dates within the period. Total simulated trade is constrained to equal the total observed and unobserved trading quantities.