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Did decimalization hurt institutional investors?☆

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Abstract

We examine institutional trading costs around the move to penny size ticks in 2001 (i.e., decimalization). We find that overall trading costs declined, with improvements in most partitions across order size, firm size, and manager style. Improvements were most pronounced for orders that were executed over multiple days and for stocks where the minimum tick sizes were likely to have been binding. However, costs did increase for orders executed within a single day. The improvements we document contrast with changes accompanying the reduction of minimum ticks to sixteenths in 1997 though, in both cases, results suggest that more patient traders fare relatively better than those that demand immediacy.

JEL classification: G1

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1. Introduction

Beginning January 29, 2001, the New York Stock Exchange started quoting and trading all its listed issues in increments of a penny rather than in increments of a sixteenth of a dollar (a move commonly referred to as 'decimalization'). The effect of a reduction in tick size on liquidity and trading costs for investors has been a matter of much debate among academics, practitioners and regulators. While several studies show that quoted and effective spreads are significantly lowered following a reduction in tick size, there is only one study that examines directly the effect of a tick size reduction on institutional trading costs.[1] Jones and Lipson (2001) find that, while average execution costs increased (by about 22.5 basis points) when the tick size was reduced from \$1/8 to \$1/16 in 1997, they increased more for orders that demanded liquidity, including large orders, and orders that were not worked by the trading desk. We provide fresh evidence to this debate by examining changes in institutional trading costs following the reduction of the minimum tick size to a penny.

Using proprietary data from the Plexus Group, we examine the trading costs of 34 large buy-side institutions trading NYSE stocks over a period of 41 days before and 44 days after decimalization.[2] The Plexus group was an independent transaction cost consulting firm in this period handling over \$4.5 trillion in institutional equity trades, or roughly a fifth of dollar trading volume in US equity markets.[3]

We find mixed evidence for the effect of decimalization on institutional trading costs. Costs increased for orders that aggressively sought liquidity. For instance, costs increased by almost 10 basis points for not-worked orders (orders filled within a day) but declined by about 32 basis points for worked orders (orders filled over multiple days). This disparity between worked and not-worked orders is especially pronounced when we consider large orders. Upon partitioning the sample on bid-ask spread quartiles, we find that the greatest decline in trading costs (of about 61 basis points) occurred in the smallest spread quartile—a group where the pre-decimal minimum tick size of \$1/16 was more likely a binding constraint. However, we find an increase in trading costs for the largest spread quartile, suggesting that liquidity may have become harder to find in the post-decimal world for stocks not constrained by the minimum tick size. Overall, however, institutional trading costs declined by about 22 basis points following decimalization. While our findings, especially those related to increased costs, are consistent with the findings of Jones and Lipson (2001), our overall result differs from them mainly because of the difference in the proportion of worked orders in our respective samples (81.6 percent of the shares

[1] See, for example, Ahn et al. (1998), Bacidore (1997), Bollen and Whaley (1998), Ricker (1998), and Ronen and Weaver (2001). Bacidore et al. (2003), Bessembinder (2003), Chakravarty et al. (2004), and Chung et al. (2004) study the impact of decimal pricing in the US markets.

[2] Though we are the first to use Plexus data to examine institutional trading following decimalization, many researchers have used it to examine a wide variety of topics related to institutional trading behavior (see Keim and Madhavan, 1996, 1997; Conrad et al., 2001, 2003; and Jones and Lipson, 1999, 2001).

[3] See www.plexusgroup.com, www.marketdata.nasdaq.com, and the 2001 NYSE Fact Book. The Plexus Group has subsequently been acquired by J.P. Morgan Chase Bank.

traded in our sample as compared to 49.6 percent in theirs). Our conclusions are robust to the sample selection method, to the benchmark price for computing price impact, and to changes in order characteristics and market conditions, as well as to possible time trends in trading costs. In sum, our findings suggest that decimalization appears to have benefited those institutions that were working their orders on the exchange floor.

We also find that the average size of an institutional order declined from 41,205 shares before decimalization to 34,017 shares after decimalization.[4] The decline in average order size was the highest in stocks with the greatest liquidity, namely large cap stocks, stocks with the lowest spreads, stocks with the highest volume, and stocks with the lowest volatility. These also happen to be the stocks that institutions traded the most as seen in our data. It is, therefore, possible that institutions had aggressively altered their strategies following decimalization to avoid costs they incurred following the move to sixteenths. In contrast, the average order size, as reported by Jones and Lipson (2001) during the move to sixteenths, declined only marginally, from 25,129 shares to 24,368 shares. Our results, and those in Jones and Lipson, collectively suggest that institutional trading strategies are dynamic, adapting to the changes in market environment, thereby making it difficult to extrapolate results of one time period to another.

Recently, in a well-publicized interview, the SEC Chairman William Donaldson suggested that decimalization might have increased trading costs for large institutional investors.[5] We provide direct evidence on this issue and show exactly where such costs may have increased and where they declined following decimalization. It should be underscored, however, that even though we document overall unchanged, or declining, costs after decimals, it is not at all clear if any *further* reductions in the minimum tick size will necessarily be beneficial.

The remainder of the paper is as follows. Section 2 discusses the related literature and Section 3 discusses the data and provides some descriptive statistics. Section 4 provides multiple ways to measure transactions costs and provides univariate analyses of transactions costs on various partitions of the data. Section 5 extends the analyses to a multivariate examination and performs robustness checks of our results. Section 6 concludes with a discussion.

2. Related literature

As discussed earlier, our paper is most closely related to the work of Jones and Lipson (2001) who investigate institutional trading costs around the change in minimum tick size from eighths to sixteenths in the NYSE in June 1997. Using

[4]However, while the average size of an order fell 17%, the average time taken to fill an order remained the same, suggesting that it took longer to execute a given number of shares after decimalization than before. While changes in institutional strategies could be a result of a trend that has nothing to do with decimalization, we find that not to be the case when we specifically control for time trends using data from the year before decimalization.

[5]SEC Chairman Donaldson in CNBC Business Center (May 13, 2003).

Plexus data within 100 trading days of the June 1997 switchover to sixteenths, Jones and Lipson find that realized execution costs in their sample of firms increased after the changeover and conclude that smaller minimum tick sizes reduced market liquidity. While it is true that we both use institutional order data from Plexus, there are two important differences in both the content and the scope of the data that we examine.

First, the environment in which institutions operate has changed since 1997, and that might have a direct bearing on the trading costs reported by them. For example, the NYSE repealed Rule 390 in May 2000, allowing its members to trade outside an exchange. Kam et al. (2003) show that the NYSE specialists set tighter quotes following the repeal to prevent order flow from leaving the exchange. More importantly, the repeal, along with an explosive growth of alternate trading systems and deep discount and online brokerages, gave investors, including large institutional investors, a greater choice of how, and where, to send their orders for execution.

Second, there has been a growing usage of worked or 'not-held' orders. Large institutions place these orders to be executed at the broker's discretion. Though difficult to identify, Jones and Lipson (2001) characterize orders that take longer than a day to fill, and orders that are filled using more than one broker, as worked orders. But as discussed earlier, the proportion of worked orders in our sample is almost sixty percent higher than the proportion in their sample, suggesting that institutional control over executions may have changed significantly since the move to sixteenths.

Two other studies have tried to examine the effect of decimalization on institutional trading costs. Werner (2003), for example, finds a similar reduction in the average dollar trading costs following decimalization within Nasdaq stocks. She, however, uses data on orders placed by institutional brokers with Nasdaq dealers. Given their large size, institutional decisions often reach the market as multiple trades, and through different brokers. Hence, the true effect of decimalization on trading costs can only be determined at the order level, rather than at the trade level, something that our proprietary data allow us to view. And, contrary to our results (as well as to Werner's), Bollen and Busse (2003) find an increase in mutual fund trading costs by comparing actual mutual fund returns with the returns of a synthetic benchmark portfolio that matches the mutual fund's holdings but has zero cost by construction. While our data can allow us to directly measure commissions and price impact of actual institutional trades, they can only impute these costs from fund holdings, which are recorded at quarterly intervals at best.

Our paper also fits in with other studies that measure institutional price impact. Chan and Lakonishok (1995) report that institutional trading impact and trading cost are related to firm capitalization, relative order size, identity of the management firm behind the trade and the degree of demand for immediacy. Keim and Madhavan (1997) focus on institutional investment styles and their impact on trading costs. They report that trading costs increase with trading difficulty and that these costs vary with factors like investment styles, order submission strategies and exchange listing. We partition our results using factors cited in these two papers and also use them as controls in our regression analysis.

Keim and Madhavan (1996) point out the importance of the choice of pre-trade benchmark prices in estimating institutional price impact. Though we use Perold's implementation shortfall metric to measure price impact, we also replicate our results using value-weighted average trade price for the day as the relevant benchmark, as suggested by Berkowitz et al. (1988). Our results remain qualitatively similar though the magnitude of the decrease in trading costs is much smaller.[6] We describe our data in the next section.

3. Data

Before formally describing our data, it is important to understand how buy-side institutions trade. Each institutional client employs many portfolio managers who collectively manage its assets. The trading process begins with the stock selection by the portfolio manager. Thereafter, a decision (or an order) is made to establish a position in a given stock, keeping in mind that it could take a few days (and numerous trades) to establish that position. The portfolio manager then makes one or more releases to the trader who works for the manager. The trader, in turn, releases it to either one or many brokers for execution (called broker releases). The broker may then execute each release with one or more trades. This entire process is well recorded in Plexus data except at the final stage when brokers may elect to aggregate their trades before reporting them back to Plexus. This aggregation limits our ability to infer whether the number of trades has exploded since decimalization, a common complaint among institutional traders.

3.1. Plexus data

Our data contain information on all orders and trades in NYSE-listed stocks of 34 large institutional clients of Plexus over the period November 28, 2000, to January 26, 2001 (period before decimalization, or simply "Before"), and over the period January 30–March 31, 2001 (period after decimalization, or simply "After"). We choose this period, which straddles the date when all stocks went to decimal pricing (January 29, 2001), so that we have roughly an equal number of days before and after decimalization.

Though Plexus has more than 34 clients, we retain only institutions that traded both before and after decimalization to mitigate the effect of changes in the composition of Plexus clientele on our results. However, our results do not qualitatively change if we relax this restriction and include all Plexus clients for our analyses.

All stocks, except those that were part of the pilot programs, traded in sixteenths before January 29, 2001. The NYSE introduced decimal trading in a small group

[6]We do not present these results here but have them available on request.

of stocks, including active stocks such as Fedex, through its pilot programs starting in August 2000.[7] The pilot programs were designed to provide investors, including institutional investors, the opportunity to learn and operate in the new environment. We ignore the pilot stocks and concentrate on the overwhelming majority of the NYSE-listed stocks that started trading in decimals only from January 29, 2001.[8] We also exclude orders taken before January 29 but completed after to keep our analysis clean and simple. To ensure that our results are not driven by time-trends unrelated to decimalization, we also use additional institutional trading data over the period January 30 to March 31, 2000—a year before the advent of decimalization. We discuss our time-trend analysis in greater detail later.

For each order, the data include (a) the stock to be traded and the date the order was made; (b) the desired number of shares to be bought or sold; (c) whether the order was to buy or sell; (d) the dates when the individual components of the order were released to the executing broker; (e) the dates and prices at which the various components of the order were filled; (f) the commissions in dollars per share; (g) the volume weighted average trade price for the stock on each of the days a component of the order was filled; (h) the style of the manager submitting the order (value, diversified or growth); and (i) the different brokers an order is released to.

The identification of the underlying manager's style behind each order is significant because it enables us to get a glimpse of transactions costs as a function of the aggressiveness of an order. For example, value managers are investors whose trading strategy is based on identification of undervalued stocks with a decidedly longer-term perspective and could be termed "patient" investors. Growth managers, on the other hand, are expected to have a shorter investment horizon and to buy and sell stocks based less on company fundamentals and more on short-term price appreciation. Diversified managers are expected to lie between growth and value managers and to have elements of both in their investment strategy. Also included in this category are institutions that follow quantitative styles, including indexing, that are neither momentum nor value-based. In terms of their willingness to bear price impact as well as their desire for immediacy, it is reasonable to expect growth (value) managers to be most (least) aggressive, with diversified managers falling in between. It should be emphasized here that this style classification is made by Plexus and not by the institutions themselves. We have little reason to doubt the integrity of their classification given their experience and standing in the business of institutional trading cost measurement.

3.2. Overall summary

Table 1 presents summary statistics of our data. It is designed to provide the backdrop with which to examine the research questions addressed in the paper. Panel A presents summary statistics of institutional orders before and

[7]See Chakravarty et al. (2004) for the list of stocks that were included in these pilot rounds.

[8]To test the robustness of our results, we replicate our analysis on the pilot stocks later in the paper.

Table 1
Summary statistics. This table presents summary statistics for a sample of institutional orders in NYSE-listed stocks before and after decimalization. 'Before' includes the period between November 28, 2000 and January 26, 2001, and 'After' includes the period between January 29 and March 31, 2001. An order refers to a single decision by a portfolio manager to buy or sell stock that may be executed using one or more trades. The average market capitalization is computed using the market capitalization on the day before the order was made. All spread measures were computed from TAQ data using only stocks traded by our sample institutions.

Variable	Before	After
Panel A: summary statistics of institutional orders		
Number of days in which there was at least one trade by a Plexus institution	41	44
Total dollar value of orders (in $billion)	124.80	106.80
Number of orders	73,044	80,163
Average size of an order (in shares)	41,205	34,017
Average dollar value of an order (in $M)	1.71	1.33
Average trading price ($)	39.720	38.504
Average number of orders per day	1,782	1,822
Average daily dollar value of orders (in $billion)	3.04	2.43
Percentage of orders that were filled completely	98.32	98.86
Percentage of orders that were purchases	58.89	54.92
Number of days taken to fill an order		
Mean	1.57	1.55
Median	1.00	1.00
Minimum	1.00	1.00
Maximum	25.00	42.00
Panel B: summary statistics of stocks traded by institutions		
Number of stocks traded	1,480	1,444
Average market capitalization (in billion dollars)	13.44	11.84
Average time-weighted quoted spread in dollars	0.20	0.15
Average value-weighted effective spread in dollars	0.15	0.11
Average percentage time-weighted quoted spread	1.10	0.80
Average percentage value-weighted effective spread	0.83	0.60

after decimalization. We find that our sample institutions traded less, in dollar terms, after decimalization. The total dollar value of institutional trades dropped from $124.8 to $106.8 billion, a decrease of 14 percent.[9] Over the same period, however, the number of orders increased from 73,044 to 80,163. Given that the average trade price had little change (from $39.72 to $38.50), the decline in dollar trading activity was largely due to a reduction in the average order size. The average size of an institutional order declined from 41,205 shares to 34,017 shares, a decrease of 17 percent. This decline could just reflect an increased

[9] The S&P 500 Index marginally rose by 1 percent between the period November 28, 2000–January 26, 2001 (period before decimalization), but it declined by 15 percent between the period January 30–March 31, 2001 (period after decimalization). Though market-wide changes could drive some of our results, we explicitly control for them in the regression analyses performed later.

need by institutions to protect themselves from front running in a decimal environment.

There was little difference in the percentage of orders that were filled completely (over 98%) between the two periods. Plexus clients also remained marginally net buyers both before and after decimalization. There was little change in the average number of days it took to fill an order. An average order took about a day and half to be filled. Given that the average order size was lower by 17 percent after decimalization, it appears that it took longer to fill an order of a given number of shares in a decimal environment.

Panel B provides summary statistics of stocks that were traded by the institutions. Our sample institutions traded marginally fewer stocks after decimalization (from 1,480 to 1,444). The average market capitalization of stocks traded before decimalization was $13.44 billion while it was only $11.84 billion after decimalization. Consistent with results from other studies (see, for example, Bessembinder, 2003), we find significant decreases in quoted and effective spreads following decimalization. The average time-weighted quoted spread declined by 25 percent from $0.20 to $0.15, while the value-weighted effective spread decreased by 26.7 percent from $0.15 to $0.11. The declines in percentage quoted spreads and percentage effective spreads were similar, from 1.10% to 0.80% and from 0.83% to 0.60%, respectively.

In Table 2, we present changes in percent dollar value traded, in the number of orders and in the average order size by different partitions based on stock, order and manager style characteristics. These partitions help us understand whether institutions changed the type of stocks they traded in, the way they traded them, and/or their investment styles, following decimalization. Such changes, if any, would have a direct bearing on the changes in institutional trading costs. We use partitions based on quartiles of market capitalization, average quoted spreads, average daily share volume, and average volatility, as well as partitions based on order size and manager style.

Market capitalization quartiles are formed using the value at the end of October 2000, which is before our sample period. Quartiles for average quoted spread and average daily share volume are formed using the daily averages in the month of October 2000, while quartiles for average volatility are based on the standard deviation of close-to-close return in the month of October 2000. Most of the institutional orders were in the more liquid stocks, i.e., large cap stocks, stocks with tighter spreads, stocks with high volume, and stocks with low volatility. Therefore, the decline in trading activity following decimalization was also in these same stocks. Interestingly, institutions were trading in much smaller sizes in these liquid stocks after decimalization, suggesting that they were concerned about front running in the new environment. The average order size declined by 25 percent in large cap stocks and high volume stocks, by a little less than 33 percent in narrow spread stocks, and by around 30 percent in less volatile stocks.

Though orders greater than 100,000 shares accounted for only around six percent of all orders, they accounted for more than 80 percent of the value traded. Interestingly, there was little change in the average size of these orders, suggesting

Table 2
Characteristics of institutional trading around decimalization. This table presents stock, order and manager style characteristics for a sample of institutional orders in NYSE-listed stocks before and after decimalization. Market capitalization quartiles are assigned using the value at the end of October 2000. Quartiles for average quoted spreads and average daily share volume are assigned using daily averages in the month of October 2000. Quartiles for average volatility are assigned using the standard deviation of close-to-close return in the month of October 2000. Manager style classifications are from Plexus. 'Before' includes the period between November 28, 2000 and January 26, 2001, and 'After' includes the period between January 29 and March 31, 2001. The superscripts, '*' and '**', represent significance under a t-test and Z-test, respectively, of no difference between the periods 'After' and 'Before' in each sub-category at the 95 percent confidence level.

		Percentage of total dollar value			Number of orders			Average order size (shares)		
		Before	After	Change	Before	After	Change	Before	After	Change
Market capitalization	Quartile 1 (Smallest)	0.04	0.10	0.06	323	599	276	13,049	19,777	6,728
	2	0.81	1.24	0.43**	4,519	5,540	1,021	14,530	13,635	−895
	3	6.05	7.20	1.15**	18,130	20,164	2,034	15,999	13,175	−2,824*
	Quartile 4 (Largest)	93.10	91.46	−1.64**	50,072	53,860	3,788	43,698	32,853	−10,845*
Average quoted spreads	Quartile 1 (Smallest)	45.16	43.56	−1.60**	27,347	31,030	3,683	44,753	30,871	−13,882*
	2	40.00	38.84	−1.16**	33,482	36,423	2,941	24,654	19,067	−5,587*
	3	12.34	14.78	2.44**	10,760	11,309	549	21,204	21,286	82
	Quartile 4 (Largest)	2.50	2.82	0.32	1,455	1,401	−54	21,759	24,136	2,377
Average daily share volume	Quartile 1 (Lowest)	0.13	0.23	0.10	940	868	−72	7,291	9,897	2,606*
	2	0.75	1.07	0.32	4,156	4,691	535	9,998	10,727	729
	3	4.70	5.52	0.82**	14,303	16,354	2,051	13,355	10,836	−2,519*
	Quartile 4 (Highest)	94.43	93.19	−1.24**	53,645	58,250	4,605	43,163	32,464	−10,699*
Average volatility	Quartile 1 (Least)	33.91	29.30	−4.61**	28,818	31,287	2,469	22,729	16,300	−6,429*
	2	49.63	53.35	3.72**	33,808	37,288	3,480	33,785	26,038	−7,747*
	3	12.97	13.72	0.75	8,335	9,202	867	41,103	35,449	−5,654
	Quartile 4 (Most)	3.49	3.63	0.14	2,083	2,386	303	60,643	47,606	−13,037
Order size (in shares)	0–1,000	0.32	0.48	0.16**	27,617	35,250	7,633	371	383	12*
	1,001–10,000	2.88	3.36	0.48**	25,987	27,884	1,897	3,559	3,423	−136*
	10,001–100,000	14.78	14.96	0.18	13,808	12,040	−1,768	33,053	33,707	654*
	>100,000	82.02	81.21	−0.81	5,632	4,989	−643	416,889	424,315	7,426
Manager style	Value	12.20	13.05	0.85**	27,314	41,171	13,857	10,573	6,681	−3,892*
	Diversified	34.47	37.09	2.62**	31,035	27,565	−3,470	32,415	39,235	6,820*
	Growth	53.34	49.85	−3.49**	14,695	11,427	−3,268	93,431	104,419	10,988*

that decimalization had not changed how institutions traded large orders. We find a slight increase in the usage of relatively smaller sized orders (orders less than 100,000 shares), while orders of over 100,000 shares showed a slight decline after decimalization.[10] In terms of managers' trading styles, the percentage of dollar value traded by value managers and diversified managers increased while that of growth managers declined following decimalization. Value managers placed more orders though the average size of each order declined from 10,573 shares to 6,681 shares. It was just the opposite for both diversified and growth managers. They placed fewer orders but for a larger number of shares per order.

In sum, our results indicate that institutions did trade differently following decimalization. Whether or not these changes in trading behavior impacted trading costs is what we examine in the next section.

4. Institutional trading costs

There are several factors that make capturing trading costs for institutional investors harder than for retail investors. Traditional measures like bid-ask spreads are highly inappropriate as institutional trades are often large and take days to fill. Moreover, the "true" costs to an institutional trader include administrative costs of working an order as well as the opportunity costs of missed trades. Following other researchers who have studied institutional trading costs, including Keim and Madhavan (1996), and Jones and Lipson (2001), we examine costs that can be more explicitly measured, namely commissions and price impact.

4.1. Changes in total trading costs

Unlike commissions, the price impact of a trade—the deviation of the transaction price from the 'unperturbed' price that would prevail had the trade not occurred—is arguably more difficult to measure. Much depends on the proper identification of the unperturbed price. In particular, the measure should be such that it is least influenced by the trade itself. Keim and Madhavan (1996) discuss the importance of this issue in great detail.

We use implementation shortfall to measure price impact (see Perold, 1988). We measure implementation shortfall as the percentage deviation of the value weighted average execution price for each order from the price at close on the day prior to the decision.[11] We multiply this deviation by -1 if the order is a sale to ensure that it

[10]We also find (not formally reported) that our sample institutions were buying less when markets were going down and selling less when markets were going up. Therefore, they may not have been acting as liquidity providers, at least during extreme market conditions, which could impact their trading costs after decimalization. Orders placed during neutral market conditions had the greatest reduction in their average size, with purchases lower by 3,407 shares (or, around 16 percent) and sales by 11,100 shares (or, a little less than 30 percent).

[11]To ensure the robustness of our findings, we replicated our estimations with at least two other benchmark prices. The first, and one that is popular among practitioners, is the value-weighted average

measures trading costs appropriately for buy and sell orders. Table 3 presents dollar value-weighted average commission and implementation shortfall of institutional trades before and after decimalization. We present costs, both in dollars per share and in basis points, for the full sample first (Panel A), and then only in basis points for different partitions of stock, order and manager style characteristics (Panel B).

For the overall sample, we find a decrease in trading costs after decimalization both in terms of costs per share and in basis points. Total costs (including commissions) declined from $0.15 per share to $0.11 per share after decimalization. In basis points, the decrease was from 53.3 to 36.5, a decrease of 16.8 basis points or roughly 32 percent. Compared to the reduction in value-weighted effective spreads, this decrease is smaller than the overall average for stocks (23 basis points) that our sample institutions traded and smaller than the average for all NYSE stocks (36 basis points).[12]

Given that the change in the number of orders, and of the average order size, following decimalization varied across different partitions of the stock, the order and the manager style characteristics (see Table 2), we present changes in total trading costs for the same partitions. We find a reduction in trading costs across all partitions of market capitalization, volatility, order size, and manager style. There seems to be no consistent emergent pattern within each of these partitions. Furthermore, we find mixed results for partitions of quoted spreads and volume suggesting that decimalization may not have had the same effect for all stocks. For example, for less liquid stocks such as stocks with high pre-decimalization spreads and low volume, we find decimalization to have increased trading cost though the increase cannot be statistically distinguished from zero.

Our results (not formally presented) also indicate that costs went up for institutional sells (relative to institutional buys) after decimalization. However, given a significant decline in the market overall after decimalization versus a slight increase before (see footnote 9), it is not surprising to see higher costs incurred by institutional sellers after decimalization. We separate out the market effects, as well as the effects of selling in a falling market, later in our regression analysis.

Overall, our univariate results suggest a decrease in trading costs following decimalization though some indications exist that this effect may not be universal. We examine changes in costs using a more robust multivariate analysis in the following section.

(*footnote continued*)
price (VWAP) across all trades over the time period when the institution was trading [see Berkowitz et al., 1988]. We also used the opening price of the first day in which the order started executing as our benchmark price. Using the price at the time the order was released to the broker was problematic because the intra-day time variable in Plexus was not reliable. For example, in our sample, more than half of all orders had timestamps that were after 4:30 pm or before 9:30 am. Using alternative benchmark prices, however, does not alter our results or our conclusions.

[12]See Bessembinder (2003).

Table 3
Institutional trading costs around decimalization. This table presents trading costs (commissions and implementation shortfall) per share, and in basis points, for a sample of institutional orders in NYSE-listed stocks before and after decimalization. Panel A presents results for all orders, while panel B presents costs, in basis points, broken down by stock, order and manager style characteristics. Implementation shortfall for each order is measured as the signed deviation of the value-weighted average trade price for each order from the previous day's closing price, where deviation is multiplied by –1 if the order was a sale. 'Before' includes the period between November 28, 2000 and January 26, 2001, while 'After' includes the period between January 29 and March 31, 2001. All our cost measures are averages over time of dollar value-weighted daily averages across firms within each category. Market capitalization quartiles are assigned using the value at the end of October 2000. Quartiles for average quoted spreads and average daily share volume are assigned using daily averages in the month of October 2000. Quartiles for average volatility are assigned using the standard deviation of close-to-close return in the month of October 2000. Manager style classifications are from Plexus. The superscript, '*', represents significance (under a t-test) at the 95 percent confidence level under the null of no difference between the periods 'After' and 'Before,' assuming independence across firm-days.

Panel A: total costs for all orders

	Cost per share			Cost in basis points		
	Before	After	Change	Before	After	Change
Commissions	0.03	0.02	−0.01*	11.17	9.13	−2.04*
Implementation shortfall	0.13	0.08	−0.05*	42.14	27.36	−14.78*
Total trading cost	0.15	0.11	−0.04*	53.30	36.49	−16.81*

Panel B: total costs (in basis points only) by stock, order and style characteristics

		Before	After	Change
Market capitalization	Quartile 1 (Smallest)	84.33	74.04	−10.29
	2	68.83	49.33	−19.50*
	3	61.20	39.42	−21.78*
	Quartile 4 (Largest)	44.34	30.51	−13.83*
Average quoted spreads	Quartile 1 (Smallest)	50.74	33.05	−17.69*
	2	49.21	35.25	−13.96*
	3	70.93	43.67	−27.26*
	Quartile 4 (Largest)	42.24	69.41	27.17
Average daily share volume	Quartile 1 (Lowest)	51.37	63.91	12.54
	2	72.93	42.46	−30.47*
	3	57.19	36.83	−20.36*
	Quartile 4 (Highest)	48.22	34.36	−13.86*
Average volatility	Quartile 1 (Least)	44.97	31.12	−13.85*
	2	58.26	35.57	−22.69*
	3	62.49	54.85	−7.64
	Quartile 4 (Most)	68.53	63.08	−5.45
Order size (in shares)	0–1,000	28.55	16.71	−11.84*
	1,001–10,000	38.17	28.76	−9.41*
	10,001–100,000	53.17	45.73	−7.44
	>100,000	126.13	95.43	−30.70*
Manager style	Value	35.55	21.70	−13.85*
	Diversified	38.01	30.11	−7.90*
	Growth	73.77	68.50	−5.27

5. Multivariate analysis

5.1. Controls for order characteristics, manager style and market conditions

It is, of course, possible that the liquidity environment after decimalization changed in a fundamentally complex manner that our simple univariate analysis cannot detect. For one, we know that the market conditions were quite different during the period after decimalization than before. It is also possible that our discrete size partitions may be inadequate in capturing the tradeoff between size and cost. To better control for a broad set of variables that are known to impact trading costs, we use the approach followed by Jones and Lipson (2001) and examine the difference between actual and expected trading costs pre- and post-decimalization. This approach is akin to creating a matched sample of orders (based on some exogenously defined criteria) over the pre-decimal and post-decimal periods and then examining the dollar-weighted change in net execution costs of any possible time-trend.

To make the above intuition operational, we use the pre-decimal data to estimate the following model for each stock:

$$Cost_i = Buy + NYSEVol + LogOrderSize + Growth + Value + Momentum + InversePrice + HiLo + \varepsilon_i, \quad (1)$$

where $Cost_i$ represents the total trading cost in basis points (commissions plus implementation shortfall) for executing order i; *Buy* is the indicator variable that is 1 if the order is a buy and 0 otherwise; *NYSEVol* is the total dollar volume at the NYSE on the day prior to the order; *LogOrderSize* is the logarithm of order size in shares; *Growth* is 1 if the manager was a growth manager and 0 otherwise; *Value* is 1 if the manager was a value manager and 0 otherwise; *Momentum* is the stock's return on the day before the order multiplied by -1 if the order was a sell; *InversePrice* is the inverse of the stock's price at the time of the order; and *HiLo* is the ratio of the difference between the highest ask and the lowest bid on the day prior to the order over the stock's price. These variables are the same as those used by Jones and Lipson (2001). To obtain stable estimates, we restrict our analysis to stocks with at least 20 orders. We present the change in total trading cost and the number of firm-days for different spread quartile partitions (based on daily averages of time-weighted quoted spreads in October 2000) as well as for partitions based on order size.

We use the coefficient estimates of this model to compute the expected trading costs in the post-decimal period. The difference between the actual and the expected trading costs (or residuals) for orders placed after decimalization represents the trading costs unexplained by order characteristics, manager style and market conditions that could only be attributable to the event of decimalization. We average these residuals using dollar-volume weights for each day in the period. If there was no change in the trading environment before and after decimalization, the residuals would be distributed identically in the two periods under examination and the weighted average change in these residuals over the two periods would be zero. This is exactly what we test in our data. The interested reader is referred to Jones and Lipson (2001, pp. 267–268) for other relevant details and justification of assumptions.

Table 4 presents these estimation results. Controlling for order characteristics, market conditions and manager style, we find a statistically significant decline in total trading costs of 22.6 basis points following decimalization. In contrast, Jones and Lipson (2001) find an increase of 22.5 basis points following the move to sixteenths. Interestingly, the decline in our case was the greatest at 25.4 basis points for orders greater than 100,000 shares. We find a decrease in trading costs in other size categories as well (of around 11 basis points for orders between 10,000 and 100,000 shares, 0.4 basis points for orders between 1,001 and 10,000 shares and 7.7 basis points for orders less than 1,000 shares).

However, we find mixed results when we partition our results by different spread quartiles. For example, we find a decrease in trading costs (of about 60.8 basis points) for stocks in the smallest spread quartile, stocks where the pre-decimal tick size of $1/16 was more likely to have been binding. In contrast, for stocks in the largest spread quartile, where the tick size was not binding, trading costs actually increased by 396.7 basis points. Costs did not change much for all order sizes in the smallest quartile except when the order size exceeded 100,000 shares. Arguably, these large orders in liquid securities are more often worked than not, something that we test directly later. However, for the largest spread stocks, most of the increase in trading costs is driven by smaller orders (orders less than 10,000 shares). It should be noted though, as the number of stock-days suggests, institutions did not often trade these stocks. Similar to the extreme quartiles, we find mixed results in the middle quartiles. Trading costs increased by 18.2 basis points for stocks in quartile 2 but declined by 10.5 basis points for stocks in quartile 3 following decimalization.

We estimate the same model as above, but partitioned along those orders that were executed within a day (not-worked orders), and those that were filled over at least two days (worked orders). Jones and Lipson (2001) show that the increase in trading costs for the worked orders was much smaller than the increase in costs for the not-worked orders during the move to sixteenths, controlling for order characteristics, manager style and market conditions. We see the same trend, except that the worked orders experienced a decrease in trading costs of 32.4 basis points while the not-worked orders experienced an increase in trading costs of 9.5 basis points (See Table 5). This result seems to be mainly driven by changes in trading costs of the largest orders—orders involving more than 100,000 shares. Trading costs for such orders increased by 26.3 basis points when filled within a day while they decreased by 34.5 basis points when they were filled over multiple days. Clearly, decimalization made liquidity more expensive for orders demanding quick executions. On the other hand, it did not worsen liquidity for those who were willing to wait and work their orders—a fact that needs to be incorporated in the current regulatory debate.

Our tests based on manager style yield mixed results as well.[13] For small orders that were less likely to have been worked, we find an increase in trading costs for

[13]For style-wise analysis, we do not include style dummies in the stock-wise regression [see Eq. (1)].

Table 4
Change in institutional trading costs after controlling for order characteristics, manager style and market conditions. This table presents change in total trading costs, in basis points, for a sample of institutional orders that is not explained by order characteristics, manager style and market conditions around decimalization. We use the same methodology adopted by Jones and Lipson (2001) and report change in the dollar value-weighted trading cost residual following the move to decimals. It represents the average change in total trading costs, per dollar traded by institutions, that is unexplained by changes in order characteristics, manager style and market conditions. The trading cost residual is the difference between the actual and the expected total trading costs, where the expected total trading cost is derived from estimates of the following stock-wise regression using data from the pre-decimal period only:

$$Cost_i = Buy + NYSEVol + LogOrderSize + Growth + Value + Momentum + InversePrice + HiLo + \varepsilon_i$$

where $Cost_i$ represents the trading cost in basis points for order i, *Buy* is the indicator variable that is 1 if the order is a buy and 0 otherwise, *NYSEVol* is the total dollar volume at the NYSE on the day prior to the order, *LogOrderSize* is the logarithm of order size in shares, *Growth* is 1 if the manager is a growth manager and 0 otherwise, *Value* is 1 if the manager is a value manager and 0 otherwise, *Momentum* is the stock's return on the day before the order multiplied by –1 if the order is a sell, *InversePrice* is the inverse of the stock's price at the time of the order and *HiLo* is the ratio of the difference between the highest ask and the lowest bid on the day prior to the order over the stock's price. To obtain stable estimates, we restrict our analysis only to stocks with at least 20 orders. We present the change in total trading costs and the number of firm-days for different spread quartile partitions (based on daily averages of time-weighted quoted spreads in October 2000) as well as for partitions of order size. The superscript '*' indicates significance at the 5 percent level assuming independence across firm-days.

	Spread quartiles				
	All firms	1 (Smallest)	2	3	4 (Largest)
All orders	−22.63*	−60.77*	18.16*	−10.46*	396.69*
By order size category					
0–1,000 shares					
Change in total trading cost	−7.65*	−1.60	−1.64	−24.62*	−80.72*
Number of stock days	58,071	20,229	28,958	8,344	990
1,001–10,000 shares					
Change in total trading cost	−0.42	7.07	3.49	−17.27*	−110.80*
Number of stock days	50,448	20,296	22,632	6,678	842
10,001–100,000 shares					
Change in total trading cost	−10.90*	−2.80	−19.13*	−14.31	25.26
Number of stock days	24,019	10,226	10,017	3,252	524
>100,000 shares					
Change in total trading cost	−25.42*	−71.12*	27.11	−133.80*	497.85
Number of stock days	9,713	4,654	3,793	1,100	166

growth managers while costs for value managers decreased following decimalization. For example, costs for the smallest order size category (less than 1,000 shares) increased by 11.9 basis points for growth managers while they decreased by almost 21 basis points for value managers. There were no significant changes in trading costs for diversified managers around decimalization. However, costs of filling large

Table 5
Change in institutional trading costs after multivariate controls by time taken to fill the order and manager style. This table presents change in total trading costs after multivariate controls by partitions of time taken to fill the order and the style of manager placing the order. Using the stock-wise regression described in Table 4, we report change in the dollar value-weighted trading cost residual following the move to decimals for each category. For style-wise analysis, we do not include the style dummies in the stock wise regressions. To obtain stable estimates, we restrict our analysis only to stocks with at least 20 orders. We present the change in total trading cost and the number of firm-days for various order size partitions. The superscript '*' indicates significance at the 5 percent level assuming independence across firm-days.

	Time to fill the order		Manager style		
	≤1 day	≥2 days	Value	Diversified	Growth
All orders	9.47*	−32.42*	−21.40*	−4.84	−34.18*
By order size category					
0–1,000 shares					
Change in total trading cost	−12.25*	23.16*	−20.96*	2.30	11.95*
Number of stock days	53,798	4,880	26,905	25,192	7,433
1,001–10,000 shares					
Change in total trading cost	2.46	−6.13	−9.09*	−3.51	24.81*
Number of stock days	38,311	12,232	26,700	16,238	7,706
10,001–100,000 shares					
Change in total trading cost	−9.57	−11.95	3.50	−24.81*	−0.94
Number of stock days	13,694	10,329	7,705	10,447	5,874
>100,000 shares					
Change in total trading cost	26.27*	−34.49*	−29.51	0.12	−37.95*
Number of stock days	2,718	6,993	1,243	4,160	4,297

orders (greater than 100,000 shares) declined for both value and growth managers by 29.5 basis points and 38 basis points respectively. More than three-quarter of these orders were worked, which suggests that working the orders lowered costs significantly—even for growth managers following momentum strategies.

5.2. Some robustness tests

We perform two robustness tests to validate our results. First, the NYSE introduced decimal trading to a select group of stocks prior to January 29, 2001. Of these, 44 common stocks started trading in decimals prior to November 28, 2000, the opening day of our pre-decimal window. We used this cut-off so that we could use these stocks as controls for our sample.[14] If our results are indeed driven by decimalization, and not due to market-wide factors, we should see no change in trading costs for these control stocks around the date when the rest of the market started trading in decimals on January 29. It could also be argued that the cost reduction we observe in the data was simply a trend that started long before the advent

[14]We thank Bruce Lehmann for suggesting this robustness test.

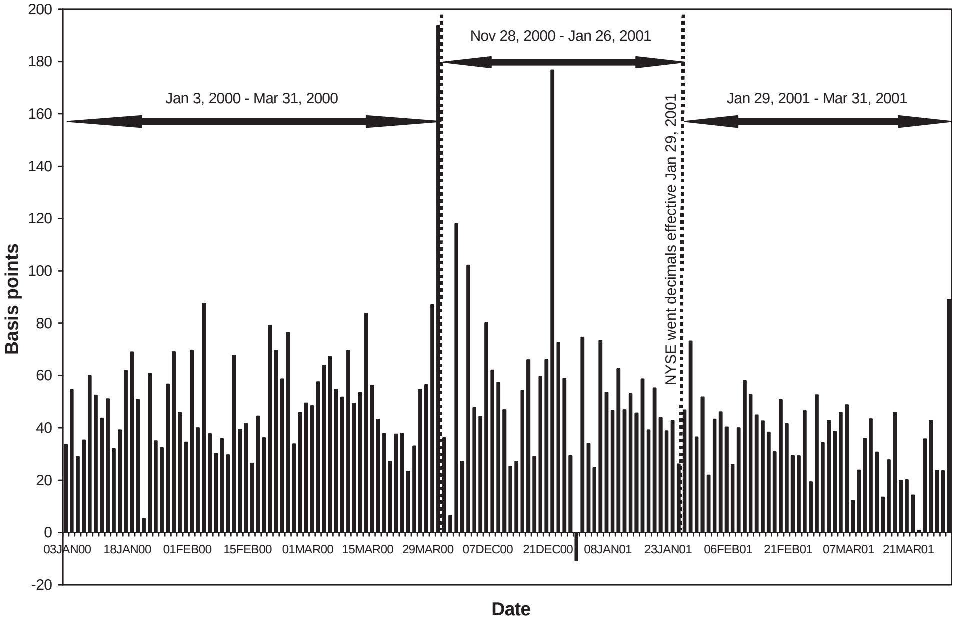

Fig. 1. Total trading costs before and after decimalization (Note: time is not continuous in the *X*-axis).

of decimals and is not related to decimalization. A simple plot of the daily average trading costs over our entire sample period, as well over the first quarter of 2000, suggests more of a regime change around decimalization than a gradual time trend (see Figs. 1 and 2). However, to control for such a possibility as a time trend, we redo all our multivariate analysis by directly controlling for time trends in our data.

Table 6 presents results of these robustness tests. We use the same procedure as described in Section 5.1 for the sample of 44 pilot stocks over the two periods straddling complete decimalization at the NYSE. We find an overall decrease in trading cost that is statistically indistinguishable from zero. However, unlike our results for the broader sample, costs increased for smaller order sizes in these pilot stocks indicating that there were no market wide factors at play that reduced costs across the board following decimalization.

To control for time trend in a more rigorous way, we made two adjustments to our multivariate analysis described earlier: first, we added the January–March 2000 data to our pre-decimal data before estimating the coefficients for our expected trading cost model (1); Second, we added another explanatory variable, *Time*, that represents the number of days from December 31, 1999 to the date of the order, that captures the effect of any possible time trend in trading costs over the course of the year before decimalization. Specifically, we estimated the following regression:

$$\begin{aligned} Cost_i = {} & Buy + NYSEVol + LogOrderSize + Growth + Value + Momentum \\ & + InversePrice + HiLo + Time + \varepsilon_i. \end{aligned} \tag{2}$$

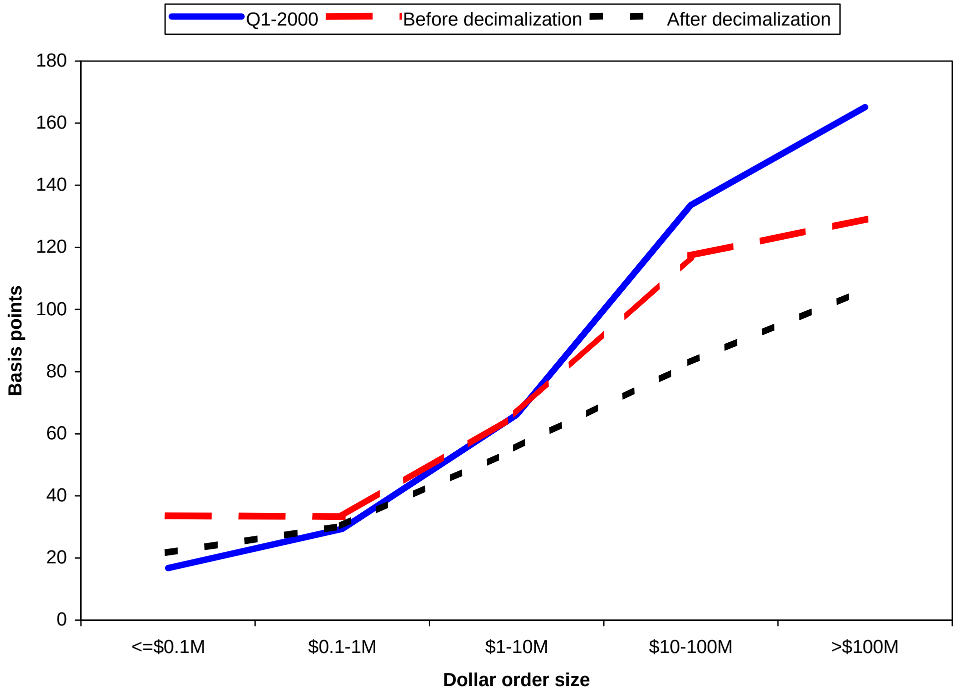

Fig. 2. Total trading cost by dollar order size.

We find that institutional trading costs decreased overall after decimalization even after we control for possible downward time trends in costs that may have started much before decimalization. We find that costs decreased overall by 39.2 basis points, with the greatest decline of 45.4 basis points occurring in orders involving more than 100,000 shares.

We perform additional robustness checks such as examining orders of all Plexus institutional clients rather than just clients who traded both before and after decimalization, and using different benchmark prices for evaluating price impact, but find no change in our results. In sum, we find evidence of an overall decrease in institutional trading costs following decimalization, with patient institutions benefiting at the expense of less patient institutions.

6. Concluding discussion

Over three years have elapsed since the advent of decimalization in the US equity markets, yet its effectiveness continues to be widely debated among market participants and regulators. Some of them, including SEC Chairman Donaldson, have argued that decimalization might have worsened trading costs for large

Table 6
Robustness results. This table presents multivariate results for 44 pilot stocks that started trading in decimals prior to November 28, 2000 as well as results of analyses that specifically control for time trend in trading costs. Each cell represents the change in the dollar value-weighted trading cost residual following the move to decimals. We use the stock-wise regressions described in Table 4 (without controlling for time trend) to obtain the residual for pilot stocks. For the trend analysis, we make two adjustments to the stock-wise regression procedure in Table 4. First, we add to our sample of pre-decimalization orders by including new data from the first quarter of 2000. Second, we add a new explanatory variable, *Time*, that represents the number of days from December 31, 1999 to the date of the order in our stock-wise regressions to compute expected trading cost. To obtain stable estimates, we restrict our analysis to stocks with at least 20 orders. We present the change in total trading cost and the number of firm-days for different partitions of order size. The superscript '*' indicates significance at the 5 percent level assuming independence across firm-days.

	Change in trading cost for 44 pilot stocks	Change in trading cost after controlling for time trend
All orders	−31.54	−39.16*
By order size category		
0–1,000 shares		
Change in total trading cost	37.15*	−10.52*
Number of stock days	2,025	59,338
1,001–10,000 shares		
Change in total trading cost	38.25*	−4.38
Number of stock days	1,796	51,109
10,001–100,000 shares		
Change in total trading cost	5.57	−12.20*
Number of stock days	821	24,263
>100,000 shares		
Change in total trading cost	−40.04	−45.40*
Number of stock days	426	9,775

institutional traders. We test this contention directly by examining trading costs for 34 large buy-side institutions around decimalization using proprietary data.

In an earlier study that examined institutional trading costs around the reduction in the minimum tick size from an eighth to a sixteenth of a dollar, Jones and Lipson (2001) reported that the average execution costs for institutions increased by 22.5 basis points. We, however, find mixed evidence on institutional trading costs following decimalization. While costs overall declined by about 22 basis points after the switchover to penny-ticks, costs increased by almost 10 basis points for orders executed within one trading day (not-worked orders) while, for orders executed over multiple days (worked orders), trading costs declined by about 32 basis points. Similarly, we find that trading costs declined for stocks with the smallest pre-decimal spreads (where the minimum tick size was more likely to have been binding) while it increased for stocks with the largest spreads (where the minimum tick size was not likely to be binding). Our results suggest that decimalization appears to have benefited patient institutions willing to work their orders through their trading desk or brokers, and might have hurt those seeking quick executions. Anecdotal evidence suggests that institutions were exercising a far greater control over their executions in 2001 than in 1997 which may explain why costs did not go up as consistently after decimalization as documented after the move to sixteenths.[15] Moreover, traders are increasingly being compensated based on how well they minimize trading costs. Fidelity, for example, bases 80% of its traders' bonuses on systematic reviews of their quality of execution. While changes in institutional strategies could be the result of a trend that has nothing to do with decimalization, we find that not to be the case when we specifically control for time trends using data from the year before decimalization.

While the move to sixteenths in 1997 did increase trading costs for institutional investors, the effect seems to have been partially reversed following the reduction of the minimum tick size to a penny. Our investigations suggest that as trading environments evolve over time, institutions adapt to that evolution in ways that control for their trading costs. An example of this kind of adaptation is the fact that institutions are breaking their larger orders into smaller-sized orders in response to lower displayed liquidity following decimalization. In that sense, institutions appear to be morphing somewhat into individual investors. But unlike individual investors, institutional investors have a need to trade large quantities and trading them through relatively smaller size orders may well expose them to additional risks that may increase their trading costs. It is, therefore, not clear if a further reduction in tick size would necessarily be beneficial to institutional investors.

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[15]The following quote from a senior trader for State Street Research & Management Co reflects growing consciousness among buy-side traders of the quality of their executions: "A few years ago I might have checked our commission list to see who's been trafficking the stock among the firms that provide us research, and most likely I'd send it over to a broker. But now I'll spend the extra time to get the best execution." (See "The Buy side wakes up," The Institutional Investor, April 2002.)

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