# Has Decimalization Hurt Institutional Investors?
## An Investigation into Trading Costs and Order Routing Practices of Buy-side Institutions

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# Abstract

We examine the effect of decimalization on institutional investors using proprietary data. We find no evidence that decimalization has increased trading costs for institutions. In fact, we find an average decrease of 13 basis points, or roughly $224 million a month in savings of institutional trading costs following the move to decimal trading. We find little differences in institutional order routing practices overall though smaller and easier to fill orders are routed more often to electronic brokers while larger and more difficult to fill orders are sent to traditional brokers following decimalization. There is an increase in trading costs of orders routed to electronic and independent research brokers, while costs of trading with full service and soft dollar brokers have gone down. Interestingly, we find a reduced usage of soft dollar brokers suggesting that decimalization may have altered the incentives of this multi-billion dollar industry. Our results survive extensive partitioning of the data and differ in spirit from those reported around the transition of the minimum tick size from eighths to sixteenths. Our results are also surprising in light of an oft-repeated complaint among professional traders that liquidity is hard and expensive to find in a post-decimal trading milieu. Our findings have important regulatory implications.

# 1. Introduction

After much debate, the New York Stock Exchange (NYSE) finally converted all of its listed issues to decimal pricing on January 29, 2001 thereby ending a two-hundred-year tradition of trading in fractions. The debate centered on the possible effect of decimal prices on liquidity and trading costs for investors. While retail investors welcomed the idea of trading in finer price increments, institutional investors were more concerned about its adverse impact on liquidity. For example, a recent letter to the Security Industry Association (SIA) claims:

> *"The execution of large orders has been hampered by reduced depth of the Exchange's limit order book and by increased instances of market participants stepping ahead of orders by increments of as little as one penny, "*

Similarly, the Head Trader at Zurich-Kemper is quoted as saying:

> "*The net effect has been for the institutional trader to lose control of his/her order flow, since no effective tools exist in the NYSE listed market to reach the market efficiently."*

Much of their concern appear justified in the light of earlier findings on the US equity markets' move to the sixteenths as well as on results based on the introduction of decimal pricing in other markets.[1] These results indicate that spreads – both quoted and effective – decrease following a reduction in tick size but so does the market depth.

While both retail and institutional investors gain from a reduction in spreads, it is more likely that the latter faces the brunt of a reduction in market depth. Jones and Lipson (2001) who investigate institutional trading costs around the change of tick size from a eighth to a sixteenth find that realized execution costs of institutions increase following that changeover. They end their study stating, "…. institutional traders should, as a group, regard skeptically any proposal for a further reduction in minimum price increments." It is not surprising, therefore, that institutions were reluctant to embrace decimalization.[2]

Now that decimal pricing has been introduced, it begs the question of whether institutions were indeed adversely impacted by it. This paper seeks to answer that question. If liquidity had dried up, as opined by institutional investors, it should be reflected in higher trading costs following decimalization. But unlike retail investors, it is difficult to measure trading costs for institutions. Institutions often need to transact large

[1] See, for example, Bacidore (1997), Bollen and Whaley (1998), Ricker (1998), Ronen and Weaver (1998), Goldstein and Kavajecz (2000), and Jones and Lipson (2001). Bacidore, Battalio and Jennings (2001), Chakravarty, Van Ness and Wood (2002), and Chung, Van Ness and Van Ness (2001) present similar results following the introduction of decimal pricing for a select group of pilot NYSE stocks before the market-wide switchover in January 2001.

[2] See "*Decimal Move Brings Points Of Contention From Traders*," (Wall Street Journal, February 12, 2001, p. C1) and "*Deals & Deal Makers: Grasso Says NYSE Must Stick to Penny As Trade Increment*," ((Wall Street Journal, March 22, 2001, p. C18).

quantities of shares in the market and, frequently, have to wait for several days before their order gets filled. Sometimes these orders do not get filled on time or not get filled at all. Determining the impact of missed trades or delayed trades is highly subjective and depends largely on the investment horizon of the institution. While commissions paid by institutions are easy to identify, estimation of both price impact of their completed trades and opportunity costs of their missed trades requires us to make assumptions that may or may not be valid. Moreover, unlike retail investors, institutions use multiple brokers who fill orders with varying speeds and costs that make order routing an important determinant of their cost of trading. The issue of order routing has become quite important in recent years, as alternative trading systems, mostly electronic, have risen by providing features such as speed and anonymity to attract traders away from traditional trading systems. Any change in the trading landscape (such as decimalization) that favors one type of broker over another is bound to alter the way institutions route their orders and hence impact their trading costs. To further compound the issue, institutional trading costs often mask payments for services – explicit and implicit – that their executing brokers may provide (See Schwartz and Steil (2002)). This makes it almost impossible to separate the "real" trading costs from the observed trading costs.

While extant research has addressed some of these issues, investigation of order routing practices on institutional trading costs have largely been ignored until recently. Studies by Conrad, Johnson and Wahal (2001a and 2001b), for example, examine costs of trading with a certain class of brokers in isolation such as the soft dollar brokers and electronic communication networks, or ECNs, over time. Our study builds on their research by examining institutional order routing practices – not just to one class of brokers but to all broker classes – around decimalization and whether institutions have managed to circumvent some of the detrimental effects of decimalization by routing orders differently.

Following the convention used by both practitioners as well as by previous researchers on institutional trading costs, we estimate only the costs that we could measure with some certainty, namely commissions and the price impact of institutional trades. While commissions are easy to identify, price impact can only be measured against a reference price. Keim and Madhavan (1996) discuss the importance of choosing the right reference price for institutional trades. The right reference price should be one that reflects the "true" value of the security – unperturbed by the trade itself. To mitigate any problem that any one measure might have, we use several different reference prices to estimate price impact. However, we sidestep the issue of opportunity costs, as it is difficult to employ a measure that provides reliable estimates without knowing the different motivations for trading. We also do not estimate other implicit costs such as the costs of increased monitoring or the increase in back office costs that may have resulted following decimalization.

We use proprietary data from Plexus Group, a well-known firm that advises buy-side institutional investors on trading costs. The data provide us with detailed information on institutional orders and trades for all Plexus clients. In 2001, Plexus handled $4.5 trillion in institutional equity trades, or roughly a fifth of dollar

trading volume in US equity markets.[3] In addition, we have information on the investment style (Value, Diversified and Growth) of each of these clients based on an internal classification scheme used by Plexus. Since many brokers consolidate their trades before they report to their institutional clients, our data cannot identify all the individual trades that make up an order. We have information on brokerage commission as well as the type of brokers used by institutions to get their trades executed.[4] The latter is especially useful in determining whether institutions rely more on electronic brokers (ECNs) and less on traditional floor brokers to seek liquidity in the post-decimal world. Also, we can examine the impact of decimalization on the usage of "soft dollar" brokers – brokers who provide non-trade related services (such as research reports) in exchange for higher trading commissions.

Using a sample of institutional trades in NYSE stocks between November 28, 2000 and March 31, 2001, we examine measures of trading costs including commissions, price impact and the number of days it takes to complete a given trading decision. This period straddles January 29, 2001, the date when decimal pricing was introduced in all stocks, leaving us with roughly an equal number of days before and after decimalization. To mitigate any seasonality-induced biases, we compute our trading cost measures one year before decimalization (between January 29, 2000 and March 31, 2000) as well.

Our sample is unique in the sense that we examine only Plexus clients who traded the *same* set of stocks not just immediately before and after decimalization but also in the year before decimalization. This provides us with the cleanest possible test of the effects of decimalization that is not diluted by issues such as the entry and exit of institutions into the Plexus clientele and changes in the stocks that institutions trade over time. The latter is especially important given that institutional strategies are likely to be a function of market conditions, which have changed dramatically over the time period that we examine. Our sample also excludes stocks that were part of NYSE pilot programs initiated before January 29, 2001. Some of these pilot stocks started trading in decimals as early as August 2000 and were actively traded by institutions suggesting that most institutions would have been ready to handle decimalization in the broader market by January 2001. This gives us ample confidence that the time interval we examine is sufficient to capture any effects of decimalization on institutional trading costs. We find little change in the number of days institutions take to complete a given decision in our overall sample though clearly the larger and more difficult to fill decisions take longer to fill following decimalization. Further we find a small but an insignificant drop in the number of brokers that institutional investors use to execute their orders.

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[3] See www.plexusgroup.com, www.marketdata.nasdaq.com and 2001 NYSE Fact Book.

[4] Plexus classifies brokers into five types – alternate, full service, independent research, soft dollar and non-classified. The last classification is a catch-all grouping to include all brokers not classified under the other four types. There is a sixth grouping, "Execution" that was rarely used during our sample period.

We find no evidence that decimalization has increased trading costs for institutions. In fact, trading costs appear to have declined following decimalization. We find, on average, a decrease of 13 basis points in total trading costs, largely driven by decreases in price impact of institutional trades following decimalization. In economic terms, this decrease roughly translates to an average monthly savings of $224 million in institutional trading costs following the move to decimal trading. The decline is even greater when we compare post-decimalization cost estimates with estimates derived from early 2000. This suggests that some of the concerns regarding drying up of liquidity following decimalization seem unfounded in reality. While displayed liquidity, as reflected in the quoted depth, may have gone down (as reported in Chakravarty et al. (2002)), our research suggests that there is substantial liquidity in the market even after decimalization that are not well represented in the inside quotes. Our results are robust to both univariate and multivariate tests that control for other variables that influence trading costs.

We investigate the order routing practices of institutions before and after decimalization to trace the source of the reported decline in trading costs. Though there is not much change in the order routing practices overall, there seems to be an increased usage of electronic networks and crossing networks such as Instinet and Posit for orders that are relatively easy to fill (orders that are small relative to the average daily volume of the underlying security). Contrarily, we find institutions to use more of traditional full service brokers, such as Goldman Sachs and Merrill Lynch, and independent research brokers such as SG Cowen Securities, for orders that are large and need to be worked upon. Our results suggest that both electronic networks and traditional brokers can flourish side by side in a decimal world as they cater to the distinct needs of institutional investors. This may have greater implications in Nasdaq where electronic networks have a greater market share. Interestingly, the increased usage of independent research brokers is mirrored by a decrease in the usage of soft dollar brokers who provide research in lieu of trading commissions. This suggests that institutions increasingly favor unbundling of execution quality from other non-execution related services, a fact that may have less to do with decimalization and more with a declining market.[5]

Our results on order routing practices of institutions are consistent with what was widely expected among market participants and hence not entirely surprising. But what is surprising is the change in execution costs among different broker types following decimalization. Trades executed using soft dollar brokers and traditional full service brokers experienced decreases in trading costs, while trades executed using independent research brokers and electronic brokers showed increases in the cost of trading. Trading costs of orders routed to soft dollar brokers decreased from 124 bp (basis points) to 17 bp following decimal pricing, while costs of orders routed to full service brokers decreased from 57 bp to 21 bp. On the other hand, orders routed to independent research brokers cost 147 bp after decimalization as compared to -175 bp before trading moved to decimals. For orders routed to alternate or electronic brokers, trading costs increased from –161 bp to –78 bp,

[5] For more details, see the *Institutional Investor* cover story of April, 2002, entitled "The Buy Side Wakes Up."

though they provide the best execution among all broker types even after decimalization.[6] However, it is important to keep in mind that any examination of trading costs across broker types is conditional on the nature of the order flow that is being routed to these brokers. It may well be that orders that are easy to fill are sent to alternate brokers while the more difficult orders are handled by traditional brokers. Moreover, orders may be routed to electronic trading systems only after ensuring that liquidity is available, something that may not be possible with orders sent to traditional brokers. Our objective in this study is, therefore, to solely trace the source of changes in institutional trading costs and not to make cost comparisons among different brokers.

Our results are consistent with both an internal study by the Plexus Group (2001) as well as with a recent study by Werner (2002) who examines changes in institutional trading costs following decimalization on Nasdaq. Both studies indicate that institutional trading costs have not increased but rather declined following the introduction of decimal pricing. Werner (2002) documents a reduction of 31 basis points, or roughly a savings of $69M a week, in trading costs for orders in the top 100 Nasdaq stocks that were routed to sell-side dealers. Though we find smaller savings – about $29M a week for the top 40 NYSE stocks – it is clear that institutional trading costs have not gone up as projected in the debate preceding decimalization. Our results, however, seem to be in sharp contrast to that reported by Jones and Lipson (2001) who document an overall increase of about 17 basis points in total trading costs following the move to sixteenths.

Our findings should provide comfort to regulators facing criticism, mostly by practitioners and some academics, related to the possibility of a drop in liquidity supply in a post-decimal trading milieu. Though our results are based on measurable trading costs, it is possible that decimalization might have worsened some of the implicit costs of trading such as the increase in time spent on monitoring the market and increases in back office costs arising from a greater number of trade prints. Our analysis does not address these costs.

The remainder of the paper is as follows. Section 2 discusses the related literature. Section 3 provides the backdrop of our analysis and discusses the data. Section 4 provides multiple ways to measure transactions costs and provides univariate analyses of transactions costs on various partitions of the data. Section 5 examines the order routing decisions by institutions. Section 6 extends the analyses to a multivariate examination. Section 7 discusses various robustness checks performed to ensure the robustness of our conclusions. Section 8 concludes with a discussion.

## 2. Related Literature

While there has been a longstanding interest among financial economists on the impact of the equity trading process on stock prices, the last decade has seen an impressive amount of research being conducted in documenting institutional execution costs under a variety of circumstances. What makes this area of research interesting is the fact that institutions trade large quantities and they trade often, which makes them significantly

[6] Negative numbers for price impact suggest buying as prices go down and selling when prices go up.

impact prices. There appear to be two three streams of research involving institutional price impact studies. The first stream investigates the determinants of such price impacts. Thus, for example, Chan and Lakonishok (1995) report that institutional trading impact and trading cost are related to firm capitalization, relative decision 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 its impact on their 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.

The second stream of research focuses on the location of trading including upstairs versus downstairs markets as well as across U.S. equity markets. For example, Keim and Madhavan (1996) investigate a sample of "upstairs" trades in the NYSE and report that price movements (up to four weeks prior to the trade date) are significantly positively related to trade size – consistent with information leakage. More importantly, and related to our work, they point out the importance of the choice of pre-trade benchmark prices in estimating institutional price impact. Madhavan and Cheng (1997) compare execution costs in both upstairs and downstairs markets and find the economic benefits of upstairs trading are small for the average-sized block trade. Chan and Lakonishok (1997) compare institutional trade execution costs across the NYSE and the NASDAQ and report that, after appropriate controls, costs are lower on NASDAQ (NYSE) for smaller (larger) firms. Jones and Lipson (1999) compare institutional execution costs across major U.S. Exchanges and find that execution costs (including commissions) are indistinguishable across these exchanges.

The third, and emergent, stream of research, and the stream to which the current paper belongs, investigates the impact of minimum tick size reductions on institutional trade execution costs. For example, Jones and Lipson (2001) investigate institutional trading costs around the changeover in minimum tick-size from eighths to sixteenths in the NYSE in June 1997. They find that realized execution costs in their sample of firms increase after the changeover and conclude that smaller tick sizes may actually reduce market liquidity. While we both use institutional order data from Plexus, there are some important differences in both the content and the scope of the data that we examine. First and foremost, unlike their study, we restrict our examination only to those institutions that traded the *same* set of stocks before and after decimalization. This enhances our ability to tease out effects related to decimalization from other issues such as the entry and exit of firms into the Plexus clientele and changes in stocks that institutions trade over time. Second, but no less important, is the growing importance of 'worked' orders – orders that take longer than a day to fill or filled using more than one broker. While worked orders comprised of only 14 percent of all orders in the Jones and Lipson sample, they represent more than 30 percent in our sample. This suggests that institutional strategies, including order routing practices, may have changed since the move to sixteenths indicating a trend that may have started well before decimalization. Interestingly, Jones and Lipson report a reduction of 5.9 bp in the costs of trading worked orders (see their Table 5, p. 265) that is consistent with our findings following decimalization.

While we examine the effect of decimalization on NYSE-listed stocks, a recent study by Werner (2002) reports similar decreases in institutional trading costs for Nasdaq stocks. Using only orders sent to Nasdaq sell-side dealers, she finds an average decrease of 31 bp in total trading cost for the top 100 Nasdaq stocks that is larger than the decrease of 4 bp that we find for the top 40 NYSE stocks. While her sample includes all institutional orders sent to Nasdaq dealers but not to electronic brokers such as ECNs, we have the orders sent to all brokers but only for a selected group of institutions that are Plexus clients. Our studies, therefore, are complementary and provide a fair representation of the actual effects of decimalization on institutional trading costs. However, our data provide us with a better understanding of institutional order routing practices that could help explain the source for this decline in trading costs following decimalization.

## 3. Background and Data

Theoretical models, such as Kyle (1985), predict that informed investors will trade in a progressive manner such that the full impact of their information will gradually assimilate into market clearing prices. But such stylized models do not account for market frictions and other imperfections that plague actual institutional order executions. Institutions tend to trade large quantities of stock -- each decision to establish or liquidate a position requiring multiple trades over multiple trading days and involving multiple brokers. Traditional measures of transaction costs like the bid-ask spreads are not useful to correctly account for all the costs embedded in such extensive trading activities by a single investor. The most common problem is that of information leakage prior to, and contemporaneous with, the completion of the execution of an order, which moves prices against the ongoing trade. There is also the pure liquidity demand cost, aside from the information effect, associated with finding contra-parties taking the other side of large trades. Thus, information on single quotes and trades is insufficient to correctly capture the full breath of the costs faced by institutions when unloading or building large equity positions.

We are, however, able to directly observe execution details pertaining to a large sample of institutional equity orders provided by the Plexus Group. Plexus is a consulting firm that advises its institutional clients on how to reduce transactions costs. These clients provide detailed history of their orders and trades to Plexus that form the basis of our data. In 2001, Plexus examined about $4.5 trillion in equity transactions that roughly amounted to a fifth of the dollar trading volume in US equity markets. 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 (1995, 1997), Conrad et al. (2001a, 2001b), and Jones and Lipson (1999, 2001)).

Before we describe 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 trading decision is made that comprises

of all buy/sell order activity that occurs within a certain period of time for that stock. The portfolio manager then makes one or more releases to the trader who works for the manager against that decision. The trader, in turn, releases one or more orders to either one or many brokers (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 limits our ability to infer whether the number of trades have exploded since decimalization, a common complaint among institutional traders. We, therefore, restrict our focus to the total time (in days) it takes to complete a decision rather than the number of trades to examine the issue of trade difficulty following decimalization.

### *3.1 Data*

Our data contain information on all orders and trades in NYSE-listed stocks of Plexus clients, who are typically large buy side firms, over the period November 28, 2000, to January 26, 2001 (BEFORE), and over the period January 30 – March 31, 2001 (AFTER). We choose this period so that it straddles the date when all stocks went to decimal pricing (January 29, 2001) such that we have equal number of days before and after decimalization. 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 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 under 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 on January 29, 2001. We also exclude decisions taken before January 29 but completed after to keep our analysis clean and simple. Further, to properly benchmark our findings, we also obtain all institutional trading records in all NYSE stocks over the period January 30 – March 31, 2000 (Q1 – 2000). This enables us to separate out seasonality effects from the true effects of decimalization on institutional trading costs

We classify these stocks into three equal market capitalization groups (small, medium and large), based on the closing stock price of the last trading day of September 2000. From each group, we pick the *fifty* most active stocks based on the average daily trading volume over the month of September 2000. We do this to reduce the sample to a manageable size without compromising valuable information. Any interesting pattern in the data is likely to be contained in the relatively active stocks in each group.[8] From each group we now retain only those stocks that have decision records in each of the three quarters in our study. Out of the 150 stocks in the three groups, 11 had records only on one period, 31 had records in two period and 107 stocks had trading records in all three periods. Of the 107 stocks, we exclude 3 stocks (with tickers SGP, NT, and GLW) that had

[7] See Chakravarty et al. (2002) for the list of stocks that were on these pilot rounds.

[8] We satisfy ourselves that our results are not an artifact of the number of stocks in each size category.

abnormal price changes following decimalization that had little to do with decimalization itself. This made any comparisons of trading costs pre- and post-decimalization meaningless for these stocks.

One important limitation of earlier studies that use Plexus data is the fact that they fail to recognize changes in the composition of Plexus clientele over time. It is difficult to interpret changes in institutional trading behavior when the population of institutions that are examined changes as well. This problem is further exacerbated by changes in the universe of stocks that institutions trade from. Though their investment style is unlikely to change, institutions may trade different stocks with different underlying liquidity over time that may make it difficult to make inferences on trading costs. We address these problems by examining trading costs of Plexus clients who trade the *same* set of stocks in *each* of the three periods that we examine. This provides us with the cleanest possible test of the effects of decimalization on institutional trading costs. Our final sample includes 32 buy-side institutions that traded from a range of 1 to 53 stocks in each of the three periods. In the final count, we have 92 stocks that were traded by one or more institutions in all three periods.

It should be noted that unlike retail orders that are filled in a single transaction, institutional orders are large, often requiring multiple transactions and spanning several days. We denote each such sequence of trades that originate from a single release from a portfolio manager as a "trading decision." For each trading decision, the data include a) the stock to be traded and the date the decision was made; b) the desired number of shares to be bought or sold; c) whether the decision was to buy or sell; d) the dates the individual components of the trading decision were released to the executing broker; e) the dates and prices at which the various components of the decision 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 decision was filled; h) the manager submitting the orders as belonging to one of three trading styles: value, diversified or growth; and i) the different brokers a trading decision is released to.

The identification of the underlying manager's style behind each trading decision 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 buy and sell stocks based less on company fundamentals and more on short-term price appreciation. They are similar to technical traders. Diversified managers are expected to lie in between growth and value managers and 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 in 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.

The data also provide us with a clear picture of the order routing strategies (through the choice of broker types) adopted by institutions before and after the move to decimals. Conrad, Johnson and Wahal (2001a) provide an excellent review of the different broker categories employed by Plexus. We discuss the issue of order routing in greater detail later in the paper.

### *3.2 Descriptive Statistics*

Table 1 provides summary statistics of our data. It is designed to provide the backdrop with which to examine the research questions addressed in the paper. We examine statistical significance through out our analysis using a paired t-test that controls for stock-specific differences that may impact our inference. We test specifically whether the cross-sectional average measure after decimalization differs significantly from the average measure in either of the two pre-decimalization periods (BEFORE and Q1-2000).

For ease of interpretation, Table 1 reports statistics for small stocks (14), medium stocks (38) and large stocks (40) computed under each period separately. Market capitalization is based on closing stock prices on September 30, 2000. The average market capitalization of stocks in the three size categories shows an impressive dispersion: $0.2B for small stocks, $0.97B for medium stocks and $106B for large stocks. Given the well-known correlation between market capitalization and trading volume and, through volume, on the available market liquidity, our classification is designed to highlight differences in the parameters of interest across such differences in liquidity.

First, the frequency of institutional trading activity appears to have significantly declined over the year 2000, mirroring the fall in the stock market.[9] There were 7,974 institutional trading decisions in early 2000 but only 5,193 in the two months before Jan 29, 2001. It appears that institutions fled the stock market for other safe havens during the market fall following the burst of the technological bubble. This precipitous drop is, however, reversed following decimalization despite continuing fall in the market. The total number of institutional trading decisions increased to 8,542 in the two months immediately following decimalization. However, the total dollar value of these decisions fell from $309 billion in early 2000 to $207 billion in late 2000 but increased to $281 billion following decimalization. Though we cannot attribute these changes to decimalization, it is clear that trading activity from the same group of institutions was quite different in each of the three periods we examine.

The number of decisions per stock has almost doubled following the move to decimals suggesting that institutions may be splitting their decisions in a lower tick environment. However, we do not find evidence for

[9] The S&P 500 Index increased by 3 percent in the first quarter of 2000 but fell by 5.7% in the last quarter of 2000 and the twenty-six days in January prior to decimalization. It continued to fall in the first quarter of 2001 by as much as 15 percent after stocks started trading in decimals.

this. There is little change in the average size, both in shares and in dollar value, of institutional decisions pre- and post-decimalization. Moreover, there is little evidence that such decision splitting happens within a day. Roughly 80 percent of all decisions within a day involve only one stock, a number that has been consistent since early 2000 (see Figure 1). There appears to be an increased trading activity among institutions post-decimalization that manifests among all stock size categories.

We also do not find differences in institutional order fill rates pre- and post-decimalization. About 96 percent of all decisions in our sample are filled completely, a fact that remains consistent in each of the three periods we examine. Since we find little difference in the fill rates before and after decimalization, we avoid the contentious issue of imputing costs of unfilled decisions by considering only decisions that were filled at least up to 80% of their desired size for all further analysis. About 98 percent of all decisions in our sample satisfied this criterion. Institutions within our sample buy and sell with roughly the same frequency though they remain net buyers in small stocks.

Overall, our summary statistics reveal important differences in aggregate institutional activity but not in individual trading decisions, following the move to decimals.

### *3.3 Trading Performance*

Table 2 reports details on the average (and median) number of days it takes to complete a trading decision, and the average (median) number of brokers used in each decision, BEFORE, AFTER and over Q1-2000. Recall that we restrict our analysis to the number of days rather than the number of trades (to complete a decision) to examine whether it has become more difficult to trade large orders following decimalization. The tables are based on decisions filled at least up to 80% of their original desired size. Restricting our analyses to decisions that were filled completely does not alter our results in any significant way.

We present our results for the overall sample (Panel A) as well as for different groups based on market capitalization (Panel B), by buys and sells (Panel C), by complexity of decision (Panel D) and by manager style (Panel E). Our classification scheme is designed to highlight differences that may be masked during aggregation. For example, it is likely that decimalization has made it more difficult to fill large orders while having little or no effect on smaller orders. Similarly, it is conceivable that growth traders may have been more impacted by any drop in liquidity given their need to catch the momentum than value traders.

For decision complexity, we classify orders based on the size of the decision relative to the average daily volume for that stock in the month of September 2000. We classify all orders under the 33$^{rd}$ percentile cutoff as 'easy' to fill orders, and all orders above the 66$^{th}$ percentile cutoff as 'difficult' to fill orders, with the rest being classified as 'moderate' difficulty orders. We also use an alternative classification scheme that uses only the absolute decision size in shares for some of our analysis. Since stocks differ widely in their liquidity, it is unreasonable to expect orders of similar size to have the same difficulty irrespective of the ability of the

market to absorb them. For this reason, we report our results on difficulty using order size relative to the average daily volume for the stock.

We find a marginal decrease in the number of days it takes to complete a decision (Panel A). It takes an average of 2.33 days to fill an institutional order after decimalization as compared with 2.38 days before. The median difference is a little greater but still statistically insignificant, indicating that outliers do not pose a problem in our data. Interestingly, it took about the same time (2.30 days) to fill an order during the boom in early 2000 than during market drop experienced in the latter part of 2000. We find small but insignificant decreases in the average number of brokers used in a decision following the move to decimals. We examine order routing strategies to brokers in greater detail later in the paper.

Panel B presents the same results by different market capitalization categories. Decisions involving small stocks take less time to execute (down from 3 days to 2.67 days), while those involving medium size stocks take significantly longer to execute (up from 1.91 days to 2.31 days), since trading started in decimals. Large size stocks appear to take slightly less time to execute following decimalization. Decimalization appears to have made trading in small illiquid stocks easier while leaving the execution of large liquid stocks largely unchanged.

We find little differences between buys and sells (Panel C) suggesting that market prices work well to attract liquidity suppliers (and demanders) irrespective of market conditions. Panel D presents results based on the complexity of the decision. As expected, decimalization has increased the time to completion of difficult decisions but it has had little effect on easy and moderately difficult decisions. There is little variation in broker usage across orders of different complexity, indicating that it may be the composition of brokers, rather than the number of brokers itself, that could have changed following decimalization.

Panel E classifies results on time to completion and broker usage by manager style. Both value and growth managers take less time to complete their trades, while diversified managers take longer post decimalization. These changes are, however, statistically significant only for value and diversified managers. We find consistent results on the number of brokers used in a decision, i.e., less (more) execution time implies fewer (more) brokers. Interestingly, when comparing between early 2001 and early 2000, only growth managers display a significant difference – both in the reduced number of days taken to complete a decision and a corresponding fewer number of brokers employed to do so. It appears that the most aggressive managers in our sample appear to be reaping considerable benefits of decimalization.

In sum, our univariate results do not seem to indicate any major change in the time to completion or the number of brokers used following decimalization, except that trades in small stocks take less time to complete with fewer brokers, and growth managers appear to be doing well. Given that the size of institutional trading decisions has not changed with the move to decimals, we find little evidence to indicate that decimalization has worsened the search for liquidity for institutional investors. We, however, recognize the inherent limitations of

univariate tests and therefore perform a more detailed multivariate analysis later in the paper that explicitly controls for stock specific differences.

In the following sections, we tackle the issue of trading costs more directly by examining commissions and price impact of institutional trades before and after the move to decimals.

## 4. Measuring Trading Costs

There are several factors that make capturing trading costs for institutional investors harder than for retail investors. Each institutional trading decision, for example, involves several transactions, sometimes spanning multiple trading days, to complete. Thus, traditional measures like bid-ask spreads are unable to properly account for all costs associated with such protracted trading strategies. Even the theoretical models of price impact in response to informed (or strategic) trading, such as Kyle (1985) and the significant body of literature in its wake (see O'Hara (1995) for a summary), assume that trades by informed (or strategic) traders are completed in relatively short intervals. There is also the added risk that there may be information leakage when a large institutional order is brought to the upstairs market to be shopped around and prices may move adversely even before this order is exposed to the market.

Though the "true" costs to an institutional trader include administrative costs of working an order as well as the opportunity costs of missed trades, we restrict our focus only to costs that can be more explicitly measured – commissions and price impact – that have been used widely both in academic research as well as in practice. Of the two, 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, our 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 several different variants for the unperturbed price. We use: (1) the closing price of the stock on the day prior to the trading decision (BM1), (2) the value-weighted average price (VWAP) across all trades, both by the institution as well as by others, over all days over which the decision was executed (BM2), (3) the VWAP across all trades over the day in which the trading decision was made (BM3), (4) the VWAP across all trades on the day of the last fill of the decision (BM4), and (5) the average of the closing price prior to the day of the trading decision and the transaction price of the last fill of the decision (BM5).

Most studies on institutional trading costs use BM1, as it is the purest form of the unperturbed price that one could measure. Though its importance is diminished by the fact that traders often can and do trade after hours, it still remains to be the most popular benchmark to measure price impact. Perold (1988) popularized the use of BM1 while Berkowitz, Logue and Noser (1988) popularized BM2 based on the notion that no single trader can influence the value-weighted average price of all trades during a day. It is widely used in practice both for cost measurement and trader evaluation though its use can eliminate incentives to seek out better

executions. We report our results using these two widely used benchmarks though we use other variants to ensure robustness of our findings. Our price impact measure is, therefore, computed as the percentage deviation of the value weighted average trade price for each decision from the unperturbed price. We multiply this deviation by –1 if the decision is a sale to ensure that it measures trading costs appropriately for buy and sell orders.

Table 3 presents average commissions and price impact of institutional trades before and after decimalization. Note that price impact is negative (positive) if the trader buys at a price below (above) the unperturbed price. The reverse holds for sellers. Thus, liquidity suppliers should enjoy negative price impact on an average, while liquidity demanders would have positive price impact for their trades. Since we do not have reliable data on the use of limit and market orders by institutions, we do not examine the impact of decimalization on liquidity suppliers and demanders like Werner (2002). We report all our results in basis points (bp). We do not consider the opportunity cost associated with the unexecuted portion of a trading decision. But since about 96% of the decisions in our sample are fully completed in all the three periods we examine, this exclusion should not alter the results in any significant way.

Panel A presents results for the overall sample. Irrespective of the benchmark used, we find price impact and total trading costs to have declined following decimalization. The effect is more dramatic when we use BM2 as our measure of the unperturbed price. Commissions appear to have increased marginally by 0.6 bp from immediately preceding pre-decimalization levels but show an increase of 2.4 bp since early 2000. We believe this trend would be more visible in Nasdaq where several big brokerage houses have reverted to commissions to ensure revenue in recent times.[10] Overall, we find institutional trading costs to have gone down by 13 bp and 133 bp using BM1 and BM2, respectively. The decline is smaller when we use BM1 indicating much price variation during our sample period. This contrasts sharply with an increase of 17.2 bp reported by Jones and Lipson (2001) in their study on the move to sixteenths. The decline in trading costs represents a significant economic decrease in trading costs though not in statistical terms. Given post-decimalization

[10] In the article entitled "Nasdaq Traders Stumbling over Decimals" (WSJ, May 25, 2001, p. C1), author Kate Kelley writes, in part:

> *"…The "decimalization" of stock trading -- in which share prices are quoted in individual cents rather than fractions of a dollar, such as 1/8 or 1/16 -- has benefited investors by narrowing the difference between buy and sell orders, in some cases creating better prices for stocks.*
>
> *But these significantly smaller spreads have squeezed the trading revenues of many major trading firms, including Merrill Lynch & Co., Morgan Stanley, Goldman Sachs Group Inc., Credit Suisse Group's Credit Suisse First Boston, and Lehman Brothers Holdings Inc.*
>
> *To address this concern, traders during recent weeks have been talking to their institutional clients -- the mutual-fund companies, hedge funds, and other money-management entities who provide them with their biggest buy and sell orders -- about switching from their traditional payment system to a commission system, in which the traders and institutions agree to a set fee….."*

institutional trading activity in our sample stocks, this represents an approximate total savings of $448M overall ($56M per week) during the two month period after decimalization which breaks down into $3M savings in small stock executions, $329M savings in medium stock execution and $116M savings in large size stock execution.[11] The decline is even more appreciable when we compare post-decimalization trading costs with costs in early 2000. Our results suggest that the downward trend in institutional trading costs have not been reversed despite changes in market structure that seem detrimental to them.

Further examination of the different sub-categories of institutional trades reveals interesting variations related to decimalization. Panel B presents results by market capitalization of the underlying stock that is traded. Commissions have largely remained unchanged except for smaller, and presumably less active, stocks. But the contrast is most visible in case of price impact (using BM1) where institutional orders in medium size stocks experience a reduction of 694 bp while orders in small and large stocks experience a decrease of 280 bp and 4 bp respectively. The results reverse when we use BM2 with larger stocks experiencing a decline of 134 bp while small stocks show an increase of 41 bp indicating that institutions may be more concerned about benchmarking against VWAP for larger and more active stocks.

Panel C classifies our results by buys and sells. Given declining price levels during our sample period, it is not surprising that buy orders had negative price impact while sell orders had positive price impact when we use the previous close as our benchmark. Interestingly, institutional buyers perform relatively worse than sellers when benchmarked to the VWAP measure suggesting that buying quickly in a falling market may still make the trader look bad in his or her performance evaluation.[12]

Panel D presents results by decision complexity. Recall that we use decision size relative to the average daily volume in September 2000 to determine the difficulty in filling an institutional order. We use the 33$^{rd}$ (2 percent of the daily volume) and 66$^{th}$ percentile (25 percent of the daily volume) cutoffs to classify trades as easy, moderate and difficult, respectively. Easy trades have lower price impact, and hence lower trading costs, relative to difficult trades. But, interestingly, it is the easier trades that experience an increase in trading costs following decimalization while the more difficult trades see a reduction in their costs of trading. This is true under both benchmarks suggesting possible cross-subsidization, an issue that we deal with in more detail when we examine order routing strategies of institutions. Specifically, there is a 13 bp reduction in overall trading costs of large orders involving sizes greater than 25 percent of the average daily volume in the security, indicating that decimalization has not worsened trading large sizes as feared by the buy side. Our results are consistent with Jones and Lipson (2001) who find an increase in trading costs following the move to sixteenths

[11] We derive our estimate by aggregating average savings in total trading costs for each of three stock size categories – small, medium and large – on their average monthly dollar volume post decimalization.

[12] See Schwartz and Steil (2002) for an excellent review of the perils of VWAP trading.

for orders not worked (presumably easy to fill orders) but not for worked orders (presumably difficult to fill orders). We find similar trends that we discuss earlier when we compare post-decimalization costs with costs one year before decimalization.

Our results by manager style (Panel E) show that total trading costs have declined for growth managers, using either benchmark, following the move to decimals. For the value and diversified managers, however, the results are mixed and depend on the benchmark we believe. But these latter results are also statistically insignificant, although we believe that our multivariate analyses, presented later in the paper, should help bring out differences among investment styles.

Our results seem to indicate a declining trend in institutional trading costs since early 2000 suggesting that reasons other than decimalization could be driving down these costs. As far as decimalization was concerned, our univariate analysis reveal that institutional traders are, at best, doing better and, at worst, doing no worse, after decimalization than they were before. It is possible that much of our results are driven by changes in the way institutions use brokers following decimalization. We examine this issue in the following section.

# 5. Order Routing Decisions by Institutions

## *5.1 Usage frequency by broker type*

The decision of the kind of brokers to rout their trading decisions to is an important one for institutional money managers as it impacts the explicit and implicit trading costs incurred by them – especially given the size of their orders. Conrad, Johnson and Wahal (2001a) explore routing decisions through soft dollar brokers, in particular, who are known to provide non-execution services such as data or macroeconomic forecasts in exchange for commissions. Here we provide a detailed look at frequency of usage, as well as trading costs, associated with the entire range brokers, as provided by Plexus, around decimalization. In particular, Plexus classifies brokers into the five major categories:

1. **Alternate Brokers**: This group includes electronic SuperDOT entry desks of full service brokers as well as crossing networks and ECNs. Examples are the Arizona Stock Exchange, ITG-Posit, and Instinet.
2. **Full-Service Brokers**: This group includes brokers who provide a menu of services including execution, portfolio management and data to their clients. Examples are Goldman Sachs, Merrill Lynch and Morgan Stanley.
3. **Research Brokers**: These brokers execute trades and provide in-house research, usually separately, to their clients. Examples include Hambrecht Quist, SG Cowen Securities, and Zacks.

4. **Soft-dollar Brokers**: They provide free research and other services usually in exchange for trades directed their way. Examples include Capital Institutional Services, Lynch, Jones and Ryan, and Pershing Securities.
5. **Non-classified**: A catch-all category used by Plexus to classify brokers it cannot place in the four above categories for a given decision. Brokerage arms of banks and insurance companies are usually classified in this group.

We present the frequency of order routing decisions by institutions across the five broker types around decimalization in Table 4. Unfortunately, more than a quarter of all brokers post-decimalization, and about a third of brokers pre-decimalization, remain non-classified presenting us with problems regarding inference. It is possible that any change in order routing that we observe may have more to do with classification issues rather than decimalization. One comforting fact is that the percentage of unclassified brokers is on the decline from early 2000. Given that we could do little to correct this problem, we present our results for all broker types including those brokers who are unclassified hoping to highlight differences among them. We breakdown our results further by decision complexity – size of the decision relative to the average daily volume in September 2000 (Panel B) – by manager style (Panel C) and by the size of orders routed (Panel D) to highlight the effect of decimalization, if any, on the way institutions use brokers.

We do not find major shifts in the order routing strategies of institutions post decimalization. We find a marginal increase in the use of full-service and independent research brokers that is not statistically significant. Part of this increase comes from reduced usage of soft dollar brokers and from an improved accuracy of the Plexus classification methods. The decrease in the use of soft dollar brokers is statistically significant at the 5 percent confidence level. Moreover, the average order size routed to these brokers increased following decimalization while soft dollar brokers received smaller orders. There is little change neither in the usage of alternate brokers nor in the size of orders routed to them following decimalization. The increase in patronage of independent research brokers at the expense of soft dollar brokers suggests that institutions are increasingly favoring unbundling of research and other services from execution quality – making it easier to evaluate trading costs.

Not surprisingly, institutions prefer executing a greater percentage of easier decisions through alternate brokers while leaving the more difficult decisions predominantly with full-service and independent research brokers. This preference seems to have strengthened following decimalization indicating that ECNs could coexist with traditional floor brokerage even for NYSE-listed stocks. While alternate systems guarantee fast executions at relatively low cost, full-service brokers provide the experience and expertise of working a large order that is often crucial to institutions. Roughly more than a quarter of all value-weighted orders that are easy to fill, and a third of moderately difficult orders, are executed using alternate brokers, while the institutions route only 3 percent of the more difficult orders to them. In contrast, soft dollar brokers have seen a decline in

their market share of easy, moderate and difficult orders. In particular, their market share declines from 16% to 6% in easy to fill orders, from 9% to 5% in moderately difficult orders and from 5% to 3% in the more difficult orders. All these declines are statistically significant indicating an increasing awareness among institutions to separate execution services from other services such as research that brokers offer following decimalization (and probably the falling market).

Panel C presents order routing results by manager style. There is a greater preference for alternate brokers, over other broker types, by value managers, suggesting the attractiveness of these systems to cost-conscious traders. Similarly, there is a distinct preference among growth and diversified managers to use full-service and independent research brokers rather than alternate brokers to execute their orders. Interestingly, there is some variation in these preferences following the move to decimals. For example, value managers have diverted some of the order flow from full service and soft dollar brokers to alternate brokers, while growth managers use more of full service and independent research brokers after decimalization at the expense of soft dollar brokers. About 55 percent of all post-decimalization orders were directed by value managers to alternate brokers while full-service and independent research brokers receive less than 30 percent of their order flow. There is an 80 percent reduction in the usage of soft dollar broker usage by value managers following decimalization suggesting that they are willing to trade off free research for better executions in a tight market. On the other hand, growth managers route more than 60 percent of their order flow to full service and independent research brokers but route only 2 percent of orders to alternate brokers. Their soft dollar usage has also fallen by 40 percent following decimalization.

We present market share of different brokers based on the aggregate size of orders routed to them by institutions in Panel D. This enables us to compare the relative performance of brokers handling similar sized orders. We use four size categories: < 1,000 shares, 1,001-5,000 shares, 5,001-10,000 shares and > 10,001 shares. Though full service brokers have the greatest market share in each of these size categories, alternate brokers handle about a third of all orders less than 10,000 shares. Soft dollar brokers handle more of the smaller sized orders in contrast to independent research brokers who handle larger sized orders. In fact, the average size of orders routed to independent research brokers has increased 500 percent following decimalization indicating greater reliance on these brokers to work large orders. The use of alternate brokers has increased post decimalization while soft dollar brokers have gone down in almost every size category. We use these size categories later to evaluate the trading performance of different brokers following decimalization.

Despite strong competition from electronic networks, we find traditional brokerage to hold court even after decimalization indicating the importance of face-to-face negotiations for institutional investors. On the other hand, we see a clear trend towards separating trading costs from costs related to other activities such as payment for research that may change the way institutions trade in the future. These results suggest that

institutions are actively managing their brokers, something that may not have been widely practiced in 1997 during the move to sixteenths. We examine whether trading costs have changed as a result in the next section.

### *5.2 Trading costs by broker type*

Evaluating trading costs by broker type is a tricky exercise. Brokers specialize in handling different types of order flow. Some orders may be easy to fill even though they may be large while smaller orders sometimes may be difficult to execute under certain market conditions. Moreover, orders are often times routed to electronic markets such as Instinet only after ensuring that adequate liquidity is available which is often not possible for orders routed to traditional brokers. Though it is difficult to control for all order flow characteristics in measuring trading costs, we use a simple yardstick that is well recognized by traders – size of orders routed. We hope to capture the relative advantages and advantages of different brokers by examining their trading performance of different sized orders. We present our results on trading costs by broker types in Table 5. Panel A presents results on commissions, while Panel B and Panel C present results on price impact and total costs, respectively. We include results on unclassified brokers to show the possible effect of any identification issues in Plexus data. All our cost measures represent dollar value-weighted averages within each size category.

Commissions were the lowest for alternate brokers and the highest for the independent research brokers immediately preceding decimalization. Surprisingly, independent research brokers appear to be charging higher commissions than full service and soft dollar brokers. We find that all brokers, except alternate brokers, have increased their commissions following decimalization. While the increase is a tenth of a basis point for full service brokers, it is as much as 3 bp for soft dollar brokers and 1.50 bp for independent research brokers. The trend is even more apparent when we compare it with commissions in early 2000. Commissions for alternate brokers decreased from 3.39 bp to 2.94 bp that is statistically significant, though the levels are higher when compared with early 2000.

As expected, commissions are lowest for smaller sized orders though there is an interesting dispersion among brokers within each size category. Alternate brokers charge the lowest commissions in every size category though they also receive the easier to fill orders relative to full service and independent research brokers. Decimalization has further reduced these costs by as much as 35 percent in orders less than 1,000 shares and by 5 percent in orders greater than 10,000 shares. Independent research brokers charge higher commissions than full service brokers and sometimes more than soft dollar brokers as well.

Our results on price impact (Panel B) present a different picture. Though alternate brokers, given that they receive mostly easy to fill orders, provide the lowest price impact, their executions have worsened after decimalization. There is a relative increase in price impact by 84 bp (from –165 bp to –81 bp) for trades executed through alternate brokers following decimalization. The increase is 81 bp for large orders (> 10,000 shares) while it was 10 bp for small orders (< 1,000 shares). Our results perhaps underscore the fact that the

effect of decimalization on Nasdaq could be quite different from what we observe here at the NYSE given that ECNs have a much larger market share in Nasdaq.[13] Full service and soft dollar brokers seem to be providing relatively better executions after decimalization. There is a 36 bp decrease or a 75 percent reduction in price impact for large orders (> 10,000 shares) filled through full service brokers, while the decrease is 107 bp or 89 percent for similar sized orders when filled through soft dollar brokers. This suggests that soft dollar brokers do not always compromise execution quality to subsidize research.

Panel C consolidates our results from Panels A and B. Overall, trading costs (commissions plus price impact) have declined for full service and soft dollar brokers while it has increased for alternate and independent research brokers. Alternate brokers seem to have negated their advantage in commissions by their poor executions. The total cost of trading with alternate brokers increased by 83 bp after decimalization, while it increased by 322 bp for trading through independent research brokers. In contrast, it appears to have declined by about 36 bp for executions through full service brokers and by 107 bp through soft dollar brokers. Despite the absolute cost advantage of alternate brokers, we do not find an increase in their market share post decimalization. This suggests the importance of traditional brokers (including floor brokers) to institutions who need to fill large orders with minimal price impact. Though soft dollar brokers had the greatest decrease in trading costs, they have not been rewarded with increased order flow suggesting that institutions favor separating trading costs from costs related to other services. This should be good news to thousands of investors who have been subsidizing costs that should have been borne by their asset management companies.

In sum, while there is a general trend toward increased commissions, the combination of upstairs market presence and their clout on the trading floor appears to make it attractive for institutions to use full service brokers following decimalization.

Thus far, we have examined trading costs, overall as well as by broker type, independently by manager style, decision complexity, order side, and market capitalization of the underlying stocks. Our univariate tests could ignore cross-correlations among these factors that could distort the real effect of decimalization. For example, counter to intuition, growth managers experience a decrease in trading costs following decimalization while the less aggressive diversified managers experience an increase. It is possible that growth managers trade more in small stocks, which experience a greater decrease in trading costs relative to larger stocks. We seek to mitigate the effects of these cross-correlations through a multivariate analysis, described in the next section.

# 6. Impact of Decimalization of Institutional Trade Execution: Multivariate Analysis

## *6.1 Total Trading Costs and Decimalization*

[13] The decrease in trading costs reported by Werner (2002) for Nasdaq stocks is based only on orders routed to Nasdaq sell

We use a regression analysis to disentangle the effects of decimalization on institutional trade execution costs after controlling for the candidate factors representing information asymmetry through firm size, a measure of return volatility, a measure of the complexity of the trading decision, and inverse price representing the degree of difficulty of executing a trade. Thus, for example, a relatively larger priced stock (and hence with a lower inverse price) has a lower percentage spread associated with it implying that the cost of front running such stocks is low. Easier front running should result in higher trading costs and longer time to completion of institutional orders. We also add dummy variables to control for managers' styles between value and growth (with diversified representing the omitted category). Finally, a dummy variable, AFTER, is included to isolate the possible effect of decimalization on institutional execution costs. The formal regression model is as follows:

$$\{Total\ Cost; Num\ Days\} = \alpha + \beta_1 LogMktCap + \beta_2 Volatility + \beta_3 Complexity + \beta_4 InversePrice + \beta_5 Valuedummy + \beta_6 Growthdummy + \beta_7 Afterdummy + \beta_8 (Valuedummy \text{ x } Afterdummy) + \beta_9 (Growthdummy \text{ x } Afterdummy) + \varepsilon$$

Each observation in our regression represents a complete decision. The dependent variables are the total trading cost (commissions plus price impact) in basis points and the number of days it takes to complete the decision. We compute price impact using the closing price prior to the day the decision was made (BM1) as our benchmark.

Among independent variables, *LogMktCap* is defined as the natural logarithm of market capitalization of the stock as of September 30, 2000. *Volatility* is defined as the average daily standard deviation for the stock in the month of September 2000. *Complexity* is defined as the decision size relative to average daily volume in September 2000; and *InversePrice* is the inverse of the stock's price at the time of the decision. We use two dummies to indicate value and growth style manager, while we use *Afterdummy* to indicate the post-decimalization period. We restrict our analysis only to decisions made during the periods BEFORE and AFTER that we discuss above. In addition to the three dummies, we use two interaction dummies to capture the incremental effects of decimalization on the value and growth style managers separately. Our main variables of interest are *Afterdummy*, which we expect to be positive and significant if decimalization has increased the implicit costs of trading for institutional investors, and the two interaction dummies.

Panel A in Table 6 presents coefficient estimates and standard errors of variables known to impact trading costs. Except for inverse price, all other variables have little explanatory power in determining the change in trading costs around decimalization. The coefficient on inverse price is positive instead of being negative, as we would expect. This suggests that lower priced stocks have higher trading costs for institutions

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side dealers, analogous to full service brokers at the NYSE.

after controlling for other factors such as volatility and market capitalization of the underlying stock. We find that trading costs are higher for orders in smaller cap and more volatile stocks, and for orders that are large relative to the average daily volume in the underlying stocks. As expected, trading costs are higher for growth managers and lower for value managers when compared with the costs paid by diversified managers. This suggests that the style classification adopted by Plexus captures their client aggressiveness quite well. We find a difference of 21 bp in trading costs after controlling for other factors between the trading costs paid by growth managers and by value managers. Contrary to our univariate findings, but consistent with our intuition, we find trading costs to have gone up for growth managers while they have gone down for value managers following decimalization.

We find, after controlling for other factors, a marginal decrease in trading costs after decimalization that is statistically not significant. The implication is that after controlling for the standard determinants of institutional execution costs, the act of decimalization itself has not had a significant impact on trade execution costs. This flies in the face of popular wisdom claiming that liquidity has dried up outside the best bid and offer prices thereby leading to costlier executions – especially for large institutional orders – in the wake of decimalization.[14] Our multivariate analysis presents a simple framework designed to tease out the effect of decimalization without the confounding effects of other factors.

To investigate if institutional trades are taking longer to fully execute following decimalization, we regress the number of days taken to complete a decision on the same set of independent variables as above. Panel B of Table 6 provides the regression coefficient estimates with standard errors. Here, unlike in Panel A, we find the *Afterdummy* to be positive and statistically significant, indicating that decimalization did worsen the search process for counterparties for institutional trades. In particular, the act of decimalization itself has resulted in a typical institutional trading decision taking 0.27 days longer to fully execute. But not all managers face this delay: growth (value) managers take more time (less time) than diversified managers following decimalization.

Overall, we find that even though the act of decimalization appears to have increased the number of days necessary to complete a decision, the most important trading metric to institutions -- the total trading cost -- appears to not have been adversely affected by decimalization. This is an important finding that should be significant to policy makers debating the merits of this historic decision amidst demands from the buy side.

### *6.2 Total Trading Costs and Decimalization Classified by Broker Type*

Recall that our earlier univariate results reveal evidence of significant differences in trading costs across the major types of brokers following decimalization. But it is possible that after controlling for all other

[14] To ensure the robustness of our conclusions, we also re-estimate the same model with the benchmark price being measured as the VWAP across all trades over all days over which the decision was filled (i.e., BM2). These results are qualitatively similar and are not presented.

determinants of institutional trading costs, decimalization itself may not have impacted trading costs. To examine this issue, we re-estimate the earlier regression model across the four important types of brokers – alternate brokers, full-service brokers, independent research brokers and soft dollar brokers. Our investigation is also motivated by the pattern of trading costs reported by Conrad et al. (2001), using Plexus data from 1994 – 1996, with special emphasis on soft dollar brokers. In particular, they report that incremental implicit costs of trades executed through soft dollar brokers are between 29 and 41 basis points greater than full-service brokers. While such investigations provide valuable insight into the trading practices of an important class of brokers, they also predate changeover of minimum tick sizes to sixteenths, and significantly before conversion to decimals. As mentioned in the introduction, much has changed in the market in the intervening years, including the emergence of alternative brokers, in the form of ECNs, and their growing dominance in the markets. A minimum tick size of a penny has also made it cheaper for professional investors to engage in front-running practices by stepping ahead of selected trades ahead of a price move and selling into these trades if the price moved the other way. Overall, institutional investors have become significantly more cost conscious in their trade executions. It is therefore unclear if the intuitions of studies like Jones and Lipson and Conrad et al.carry over to the new world of decimals.

Table 7 provides the results of estimating the regression model separately for each of the four broker classes. As in Table 6, we compute price impact based on the closing stock price the day prior to the execution of the decision. Panels A, B, C and D present results for alternate, full service, independent research and soft dollar brokers respectively. Our main variable, *Afterdummy,* is positive, indicating an increase in trading costs post decimalization, for orders routed to alternate and independent research brokers, but is statistically significant only in case of the former. There is a 99 bp increase for orders sent to alternate brokers and a 97 bp increase for orders sent to independent research brokers in total trading costs since decimalization took effect. On the other hand, both full service and soft dollar brokers executed institutional order flow at lower costs, although the decrease in trading costs is significant only for full service brokers. The decrease in trading costs was 32 bp for full service brokers while it was 33 bp for soft dollar brokers.

Alternate brokers seem to provide better executions to value managers after decimalization. The *Valuedummy* and *Growthdummy* are both positive, while the interaction terms of these dummies with *Afterdummy* are both negative in the regression of orders sent to alternate brokers. Both *Growthdummy* and *Valuedummy* are positive and significant as well indicating higher costs for both passive and active strategies in electronic markets. Interestingly, orders that are more difficult to fill have lower trading costs when sent to alternate brokers. We have to interpret this result with caution given that very few difficult trades get routed to these brokers. More importantly, alternate brokers include crossing networks that, by design, may execute larger trades than ECNs and other types of alternate brokers. Our complexity variable may just be the dummy variable for crossing networks such as Posit.

The results on full service brokers suggest a significant increase in trading costs for value managers relative to managers following the two remaining styles. *Afterdummy* is negative and significant indicating an overall significant decline (of about 32 bp) in total execution costs following decimalization. However, orders of growth managers seem to have the worst executions post decimalization from full service brokers indicating greater difficulty in filling liquidity demanding orders in a decimal environment. While trading costs of orders executed by independent research brokers have gone up following the move to decimals, it does not appear that growth and value managers have suffered in this process. Both of them experience a decrease in trading costs following decimalization partly to offset the high trading costs that they faced prior to decimalization from these brokers. The regression for soft dollar brokers indicates that complex orders are executed relatively cheaply but *Afterdummy* is statistically insignificant indicating no significant change after decimalization.

In sum, after controlling for all significant determinants of trading costs, decimalization itself appears to not have adversely impacted total trade execution costs in all but those trades executed through independent research brokers.

## 7. Robustness Issues

We perform a variety of checks to ensure the robustness of our conclusions. It is well accepted that larger (smaller) size stocks are usually more (less) liquid and have relatively smaller (larger) spreads associated with them. The larger spreads associated with small stocks could be the result of higher adverse selection and/or lower liquidity. What matters from our perspective is that a manager may have higher costs associated from executing an institutional order on a larger size stock than he would if he were to be trading in a small stock. Here we are interested in the question of whether, for a given manager, there has been a difference in execution costs across the stocks of various sizes following decimalization. To do so, we classify the stocks in our sample into small, medium and large size groups within each style category. These results (not presented) indicate that regardless of the managers' style and the benchmark used, the vast majority of managers show no statistically significant difference in execution costs around decimalization for any size stocks.

Jones and Lipson (2001) argue that if the liquidity environment across the transition to sixteenths changed in complex manner, with some specific orders benefiting while others doing poorly, then a simple regression specification with a dummy to control for change in tick size and a vector of control variables associated with institutional orders, may not be adequate. Instead, the authors fit execution costs to order, manager and market characteristics, and then compare pre-sixteenths and post-sixteenths residuals on a firm-by-firm basis. To ensure that our conclusions are not driven by the nature of the regression specification, we too replicate our regressions similarly. Mindful of the data intensive nature of the procedure, and to give us enough degrees of freedom for a powerful test, we run firm-by-firm regressions on the 10 most active stocks in our sample, using only pre-decimal orders as benchmark. The fitted model is then used with post decimal orders to

compute the corresponding means and medians of each measure in our cross sectional regression framework as provided in Section 6.1. Our results remain essentially the same as those reported in the paper and are not reported for brevity.

Overall, decimalization appears to have had little or no impact on institutional execution costs regardless of how the data are partitioned. The implication is that there appears to be liquidity available outside the best bid and offer prices, which should allay the fears of regulators, practitioners and academics.

# 8. Concluding Discussion

In the wake of decimalization in the NYSE, there has been considerable speculation that liquidity outside the best bid and offer (BBO) prices may have dried up, which may have increased the implicit trading costs experienced by institutional investors who typically trade large quantities and are therefore unable to take advantage of the smaller spreads and the relatively smaller sizes that are being guaranteed at those improved prices. In related research, Jones and Lipson (2001), investigating institutional trading costs around changeover in minimum tick size from eighths to sixteenths, and using data from the same source as us, report that realized execution costs increase after the changeover.

In contrast, using a large sample of institutional order executions in NYSE stocks, we find no evidence that decimalization has increased trading costs for institutions. In fact, trading costs appear to have declined following the move to decimals. We document a decrease of 13 basis points on an average in total trading costs mostly driven by decreases in price impact. In economic terms, this decrease roughly translates to an average monthly savings of $224 million in institutional trading costs following the move to decimal trading. The decline is even greater when we compare post-decimalization estimates with estimates derived from early 2000, suggesting that institutions are managing their trading costs quite well in recent years. Our results are consistent with both an internal study by Plexus Group (2001) as well as with a related study on Nasdaq by Werner (2002).

We present a detailed analysis of the order routing practices of institutions by examining orders routed to four major broker categories – alternate (includes ECNs and crossing networks), full service (includes large brokerage houses that provide multiple services), independent research (smaller and medium-sized brokerage that provide independent research) and soft dollar (brokerage who provide research in exchange for trades). Though there is not much change in the order routing practices overall, we find an increased usage of ECNs and crossing networks such as Instinet and Posit for orders that are relatively easy to fill, and full service and independent research brokers for orders that are difficult to fill. Our results suggest that both electronic networks and traditional brokers could exist side by side as they cater to two different needs of institutional investors.

We find an interesting variation in the effects of decimalization on trading costs across broker categories. The total cost of trading increased by 83 bp for orders routed to alternate brokers, while it increased by 322 bp for orders routed to independent research brokers after decimalization. In contrast, we find a decrease of 36 bp for executions through full service brokers while executions through soft dollar brokers were cheaper by 107 bp. Despite their superior executions, we find a reduced usage of soft dollar brokers – a trend that is visible since early 2000. This suggests that institutions are increasingly favoring separating execution services from other services that brokers may provide, something that should be welcomed by thousands of investors and fund sponsors alike. Our results are robust to both univariate and multivariate test that control for other variables influencing trading costs.

Our findings provide important evidence that decimalization has not improved market quality for retail investors at the expense of institutional traders.

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# Table 1
# Summary Statistics

This table presents the summary statistics of our sample. Using all NYSE stocks that moved to decimal trading on January 29, 2001, we select the fifty most active stocks within each of the three size categories based on the market capitalization as on September 30, 2000. Our final sample includes only those stocks that have been traded in all three periods we examine by the same set of Plexus clients. A trading decision refers to a single decision by an institution to buy or sell stock that may be accomplished by one or more trades. We exclude decisions where details on individual brokers are missing. 'Before' includes the period between November 28, 2000 and January 26, 2001, 'After' includes the period between January 29 - March 31, 2001, and 'Q1(2000)' includes the period between January 29 – March 31, 2000. We use the 33rd and 66th percentile cutoffs using all NYSE stocks traded by Plexus clients to form our groups for market capitalization.

| Variable | Period | Market capitalization as at Sep 30, 2000 | | | |
|---|---|---|---|---|---|
| | | All Stocks | Small | Medium | Large |
| Number of stocks | | 92 | 14 | 38 | 40 |
| Average market capitalization as at Sep 30, 2000 ($ billion) | | 46.6 | 0.20 | 0.97 | 106.17 |
| Average trading volume in the month of Sep 2000 ('000 shares) | | 3,675 | 325 | 1,021 | 7,368 |
| Total number of trading decisions | After | 8,542 | 80 | 919 | 7,543 |
| | Before | 5,193 | 35 | 475 | 4,683 |
| | Q1(2000) | 7,974 | 112 | 958 | 6,904 |
| Total dollar value of trading decisions (in $M) | After | 280,716 | 118 | 4,739 | 275,859 |
| | Before | 207,691 | 34 | 1,934 | 205,723 |
| | Q1(2000) | 309,428 | 511 | 6,108 | 302,809 |
| Average number of trading decisions per day | After | 193 | 2 | 21 | 171 |
| | Before | 130 | 2 | 11 | 117 |
| | Q1(2000) | 182 | 3 | 22 | 157 |
| Average number of trading decisions per stock | After | 93 | 6 | 24 | 189 |
| | Before | 56 | 3 | 13 | 117 |
| | Q1(2000) | 87 | 8 | 25 | 173 |
| Average size of trading decisions (in'000 shares) | After | 64 | 38 | 51 | 84 |
| | Before | 69 | 38 | 57 | 91 |
| | Q1(2000) | 90 | 148 | 90 | 71 |
| Average dollar value of trading decisions (in $M) | After | 16 | 1 | 4 | 32 |
| | Before | 19 | 1 | 4 | 39 |
| | Q1(2000) | 22 | 6 | 8 | 42 |
| Percentage of trading decisions that were filled completely (completed up to at least 80% of their original size) | After | 95 (98) | 89 (94) | 97 (99) | 95 (98) |
| | Before | 96 (98) | 83 (83) | 95 (96) | 96 (99) |
| | Q1(2000) | 97 (99) | 95 (97) | 96 (97) | 97 (99) |
| Percentage of trading decisions that were purchases | After | 52 | 60 | 51 | 52 |
| | Before | 52 | 49 | 55 | 52 |
| | Q1(2000) | 50 | 65 | 52 | 50 |

# Table 2
# Statistics on Institutional Trading Decisions

This table presents statistics on institutional trading decisions in our sample stocks. Using all NYSE stocks that moved to decimal trading on January 29, 2001, we select the fifty most active stocks within each of the three size categories based on the market capitalization as on September 30, 2000. Our final sample includes only those stocks that have been traded in all three periods we examine by the same set of Plexus clients. A trading decision refers to a single decision by an institution to buy or sell stock that may be accomplished by one or more trades. We exclude decisions where details on individual brokers are missing. 'Before' includes the period between November 28, 2000 and January 26, 2001, 'After' includes the period between January 29 - March 31, 2001, and 'Q1(2000)' includes the period between January 29 – March 31, 2000. Each cell in our table represents the dollar value-weighted cross-sectional average under each period of the time series averages of each stock. We test whether the average measure for either of the two pre-decimalization periods ('Before' and 'Q1(2000)') is statistically different from the average measure after decimalization ('After') using a paired t-test. An asterisk denotes significance at 5% level. We report our results using four different partitions based on the market capitalization of the traded stock, order side, complexity of the trading decision and manager style. We use the 33rd and 66th percentile cutoffs to form our groups for market capitalization and decision complexity.

**Panel A: Full sample**

| Variable | Period | Full Sample |
|---|---|---|
| Average (Median) number of days to complete a decision | After | 2.33 (2.34) |
| | Before | 2.38 (2.44) |
| | Q1(2000) | 2.30 (2.27) |
| Average (Median) number of brokers used per decision | After | 2.51 (2.58) |
| | Before | 2.59 (2.61) |
| | Q1(2000) | 2.70* (2.76) |

**Panel B: Classification by market capitalization as on September 30, 2000**

| Variable | Period | Market capitalization as at Sep 30, 2000 | | |
|---|---|---|---|---|
| | | Small | Medium | Large |
| Average (Median) number of days to complete a decision | After | 2.67 (3.00) | 2.31(2.67) | 2.33 (2.34) |
| | Before | 3.07* (2.33) | 1.91* (1.69) | 2.39 (2.44) |
| | Q1(2000) | 2.99* (2.60) | 2.29 (1.80) | 2.30 (2.27) |
| Average (Median) number of brokers used per decision | After | 1.87 (2.00) | 1.71 (1.90) | 2.53 (2.58) |
| | Before | 2.50* (2.33) | 1.86* (1.31) | 2.60 (2.61) |
| | Q1(2000) | 2.26* (2.20) | 2.18 (1.50) | 2.71 (2.76) |

**Table 2 (Continued)**

**Panel C: Classification by purchases and sales**

| Variable | Period | Purchases | Sales |
|---|---|---|---|
| Average (Median) number of days to complete a decision | After | 2.51 (2.47) | 2.16 (2.22) |
| | Before | 2.63 (2.70) | 2.15 (2.17) |
| | Q1(2000) | 2.48* (2.41) | 2.23 (2.16) |
| Average (Median) number of brokers used per decision | After | 2.79 (2.66) | 2.25 (2.33) |
| | Before | 2.99 (3.08) | 2.28 (2.29) |
| | Q1(2000) | 2.83 (2.85) | 2.74* (2.65) |

**Panel D: Classification by complexity of decision (size of the trading decision relative to the average daily trading volume in September 2000**

| Variable | Period | Complexity of the trading decision | | |
|---|---|---|---|---|
| | | Easy | Moderate | Difficult |
| Average (Median) number of days to complete a decision | After | 1.33 (1.34) | 2.07 (2.12) | 4.00 (3.96) |
| | Before | 1.31 (1.32) | 2.15 (2.08) | 3.94* (4.23) |
| | Q1(2000) | 1.38 (1.42) | 1.80* (1.79) | 4.77* (4.66) |
| Average (Median) number of brokers used per decision | After | 1.19 (1.20) | 1.75 (1.77) | 5.22 (5.43) |
| | Before | 1.19 (1.17) | 1.83 (1.83) | 5.10* (5.18) |
| | Q1(2000) | 1.44* (1.61) | 1.93 (1.78) | 6.47* (6.12) |

**Panel E: Classification by manager style**

| Variable | Period | Manager style | | |
|---|---|---|---|---|
| | | Value | Diversified | Growth |
| Average (Median) number of days to complete a decision | After | 1.71 (1.71) | 2.47 (2.39) | 2.70 (2.57) |
| | Before | 2.15* (2.06) | 2.20* (2.19) | 3.01 (3.04) |
| | Q1(2000) | 1.64* (1.65) | 2.47 (2.42) | 3.33* (2.68) |
| Average (Median) number of brokers used per decision | After | 1.21 (1.13) | 2.86 (2.73) | 3.00 (2.82) |
| | Before | 1.61* (1.49) | 2.59* (2.68) | 3.52* (3.71) |
| | Q1(2000) | 1.23 (1.15) | 2.88 (2.67) | 4.88* (4.29) |

# Table 3
# Institutional Trading Costs Around Decimalization

We present total trading costs (in basis points) for institutions around decimalization. Using all NYSE stocks that moved to decimal trading on January 29, 2001, we select the fifty most active stocks within each of the three size categories based on the market capitalization as on September 30, 2000. Our final sample includes only those stocks that have been traded in all three periods we examine by the same set of Plexus clients. A trading decision refers to a single decision by an institution to buy or sell stock that may be accomplished by one or more trades. We exclude decisions where details on individual brokers are missing. 'Before' includes the period between November 28, 2000 and January 26, 2001, 'After' includes the period between January 29 - March 31, 2001, and 'Q1(2000)' includes the period between January 29 – March 31, 2000. Total costs include commissions as well as price impact of trades. Price impact for each decision is measured as the signed deviation of the value-weighted average trade price for each decision from a benchmark price, where deviation is multiplied by –1 if the decision was a sale. We use two different benchmark prices to best capture the price unperturbed by the decision. Each cell in our table represents the value-weighted cross-sectional average under each period of the time series averages of each stock. We test whether cross-sectional average post-decimalization differs from either of the two pre-decimalization periods using a paired t-test. An asterisk denotes significance at 5% level. We report our results using four different partitions based on the market capitalization of the traded stock, order side, complexity of the trading decision and manager style. We use the 33rd and 66th percentile cutoffs to form our groups for market capitalization and decision complexity.

**Panel A: Full sample**

| | Period | Commission | Price Impact Measure I (relative to the closing price prior to the day of the decision) | Price Impact Measure II (relative to the value-weighted average price across all trades over all days over which the decision was filled) | Total Cost I (using price impact measure I) | Total Cost II (using price impact measure II) |
|---|---|---|---|---|---|---|
| | | | | (in basis points) | | |
| Full Sample | After | 10.2 | 32.9 | -76.0 | 43.2 | -65.4 |
| | Before | 9.6 | 46.8 | 56.9* | 56.4 | 66.6* |
| | Q1(2000) | 7.8* | 125.8* | -3.9* | 133.6* | 3.9* |

## Table 3 (Continued)

**Panel B: Classification by market capitalization as on September 30, 2000**

| Market capitalization | Period | Commission | Price Impact Measure I (relative to the closing price prior to the day of the decision) | Price Impact Measure II (relative to the value-weighted average price across all trades over all days over which the decision was filled) | Total Cost I (using price impact measure I) | Total Cost II (using price impact measure II) |
|---|---|---|---|---|---|---|
| | | (in basis points) | | | | |
| Small | After | 94.9 | 104.3 | -66.5 | 199.2 | 33.9 |
| | Before | 65.8* | 413.3* | -67.5 | 479.1* | -7.5 |
| | Q1(2000) | 60.8* | 315.2 | 130.4 | 376.0 | 190.9 |
| Medium | After | 30.1 | -313.5 | -19.8 | -283.4 | 11.5 |
| | Before | 31.1 | 379.6* | -42.9 | 410.7* | -11.8 |
| | Q1(2000) | 28.6* | 196.1* | 59.9* | 224.7* | 88.5* |
| Large | After | 9.8 | 39.0 | -77.0 | 48.8 | -66.8 |
| | Before | 9.4 | 43.6 | 57.8* | 53.0 | 67.3* |
| | Q1(2000) | 7.3 | 124.1* | -5.4* | 131.3* | 1.9* |

**Panel C: Classification by purchases and sales**

| Order Side | Period | Commission | Price Impact Measure I (relative to the closing price prior to the day of the decision) | Price Impact Measure II (relative to the value-weighted average price across all trades over all days over which the decision was filled) | Total Cost I (using price impact measure I) | Total Cost II (using price impact measure II) |
|---|---|---|---|---|---|---|
| | | (in basis points) | | | | |
| Purchases | After | 10.2 | -221.1 | 36.5 | -210.9 | 47.0 |
| | Before | 9.2 | -14.5* | 48.2 | -5.3* | 57.4* |
| | Q1(2000) | 8.1 | 73.1* | -40.2* | 81.2* | -32.2* |
| Sales | After | 10.2 | 263.3 | -178.1 | 273.5 | -167.3 |
| | Before | 10.2 | 120.6* | 67.3* | 130.8* | 77.6* |
| | Q1(2000) | 7.4* | 171.1* | 27.3* | 178.6* | 34.9* |

## Table 3 (Continued)

**Panel D: Classification by complexity of decision (size of the trading decision relative to the average daily trading volume in September 2000)**

| Decision Complexity | Period | Commission | Price Impact Measure I (relative to the closing price prior to the day of the decision) | Price Impact Measure II (relative to the value-weighted average price across all trades over all days over which the decision was filled) | Total Cost I (using price impact measure I) | Total Cost II (using price impact measure II) |
|---|---|---|---|---|---|---|
| | | | (in basis points) | | | |
| Easy | After | 5.7 | 13.3 | 14.9 | 19.0 | 20.6 |
| | Before | 7.0 | -12.4 | 5.2 | -5.4 | 12.3 |
| | Q1(2000) | 3.1 | -3.6 | 3.8* | -0.4 | 6.9* |
| Moderate | After | 5.2 | -1.5 | 11.6 | 3.7 | 16.9 |
| | Before | 7.1* | 20.7 | 3.7 | 27.7 | 10.7 |
| | Q1(2000) | 3.7 | 9.7 | 1.5 | 13.4 | 5.2 |
| Difficult | After | 10.4 | 33.8 | -78.2 | 44.1 | -67.5 |
| | Before | 9.7 | 47.4 | 58.1* | 57.1 | 67.9* |
| | Q1(2000) | 7.9* | 130.3* | -4.1* | 138.3* | 3.8* |

**Panel E: Classification by manager style**

| Manager Style | Period | Commission | Price Impact Measure I (relative to the closing price prior to the day of the decision) | Price Impact Measure II (relative to the value-weighted average price across all trades over all days over which the decision was filled) | Total Cost I (using price impact measure I) | Total Cost II (using price impact measure II) |
|---|---|---|---|---|---|---|
| | | | (in basis points) | | | |
| Value | After | 5.0 | 22.1 | 6.0 | 27.1 | 11.2 |
| | Before | 6.5 | -102.1 | 44.9 | -95.6 | 51.2 |
| | Q1(2000) | 4.4 | 91.3 | 19.7 | 95.7 | 24.2 |
| Diversified | After | 11.0 | 52.3 | 17.2 | 63.3 | 28.8 |
| | Before | 9.9* | -53.7 | 40.4 | -43.8 | 50.4 |
| | Q1(2000) | 7.8* | 53.8 | -16.2 | 61.6 | -8.5 |
| Growth | After | 10.0 | 20.6 | -141.9 | 30.6 | -131.6 |
| | Before | 9.6 | 112.6 | 67.1* | 122.2 | 76.8* |
| | Q1(2000) | 7.9 | 178.6* | 3.6* | 186.5* | 11.6* |

## Table 4
## Order Routing Decisions by Institutions

This table reports frequency of the usage of different brokers by institutions before and after decimalization along with the average order sizes routed to them in shares. Using all NYSE stocks that moved to decimal trading on January 29, 2001, we select the fifty most active stocks within each of the three size categories based on the market capitalization as on September 30, 2000. Our final sample includes only those stocks that have been traded in all three periods we examine by the same set of Plexus clients. A trading decision refers to a single decision by an institution to buy or sell stock that may be accomplished by one or more trades. We exclude decisions where details on individual brokers are missing. 'Before' includes the period between November 28, 2000 and January 26, 2001, 'After' includes the period between January 29 - March 31, 2001, and 'Q1(2000)' includes the period between January 29 – March 31, 2000. Each cell represents the dollar value-weighted percentage of decisions routed to a particular broker. We use the same terminology to classify brokers that is used by Plexus in their data. Alternate brokers refer to ECNs, crossing systems such as ITG-Posit and SuperDOT access desks of large brokerage houses. Full service brokers refer to brokers who provide executions either through their upstairs desk or floor operations at the NYSE. Soft dollar brokers provide free research in exchange for presumably higher trading commissions, while Independent research brokers provide research and execution service independently and may or may not have floor operations at the NYSE. Non-classified includes all brokers that Plexus could not identify or not able to classify under any of the other four categories. We present statistics by the complexity of the decision (as measured by the decision size relative to the average daily volume in September 2000) and by the manager style. We use the 33rd and 66th percentile cutoffs to form our groups for decision complexity. We test whether cross-sectional average post-decimalization differs from either of the two pre-decimalization periods using a paired t-test. An asterisk denotes significance at 5% level.

**Panel A: Full sample**

| | Period | Alternate Brokers | | Full Service Brokers | | Independent Research Brokers | | Soft Dollar Brokers | | Non-Classified | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size |
| Full sample | After | 4 | 3,585 | 55 | 63,658 | 10 | 10,818 | 3 | 3,366 | 27 | 29,413 |
| | Before | 4 | 3,595 | 52 | 52,627* | 8 | 8,754 | 5* | 4,765* | 31 | 31,180 |
| | Q1(2000) | 3* | 1,765* | 53 | 43,351* | 7* | 6,743* | 5* | 3,801 | 32* | 23,526* |

**Panel B: Classification by complexity of decision (size of the trading decision relative to the average daily trading volume in September 2000)**

| Decision Complexity | Period | Alternate Brokers | | Full Service Brokers | | Independent Research Brokers | | Soft Dollar Brokers | | Non-Classified | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size |
| Easy | After | 23 | 118 | 53 | 296 | 1 | 3 | 6 | 50 | 17 | 102 |
| | Before | 12* | 86* | 48 | 299 | 1 | 3 | 16* | 83* | 23* | 174* |
| | Q1(2000) | 35* | 314* | 37* | 311* | 2 | 12* | 5 | 47 | 21* | 191* |
| Moderate | After | 36 | 2,338 | 42 | 2,398 | 2 | 119 | 5 | 314 | 15 | 901 |
| | Before | 22* | 1,365* | 49* | 2,991* | 3 | 176 | 9* | 616* | 17 | 1,168* |
| | Q1(2000) | 28 | 1,541* | 44 | 3,400 | 2 | 154 | 5 | 408 | 20* | 1,424* |
| Difficult | After | 3 | 9,859 | 55 | 210,870 | 11 | 37,868 | 3 | 11,558 | 27 | 96,461 |
| | Before | 3 | 10,685 | 52 | 166,713* | 8 | 28,531* | 5* | 14,850 | 31 | 101,052 |
| | Q1(2000) | 2* | 4,266* | 53 | 169,233* | 7* | 24,595* | 5* | 15,882* | 32* | 96,473 |

**Table 4 (Continued)**

**Panel C: Classification by manager style**

| Manager Style | Period | Alternate Brokers | | Full Service Brokers | | Independent Research Brokers | | Soft Dollar Brokers | | Non-Classified | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size |
| Value | After | 55 | 6,299 | 28 | 3,987 | 2 | 145 | 2 | 216 | 13 | 2,468 |
| | Before | 31* | 5,655 | 42* | 10,062* | 3 | 392 | 10* | 1,868* | 15 | 4,607 |
| | Q1(2000) | 45 | 3,134* | 40 | 5,189 | - | 17 | 5* | 814 | 11* | 1,658* |
| Diversified | After | 4 | 2,253 | 62 | 52,219 | 10 | 10,387 | 5 | 3,620 | 20 | 14,545 |
| | Before | 3 | 2,437 | 58 | 44,204* | 7 | 4,962* | 5 | 3,185 | 25* | 17,098 |
| | Q1(2000) | 3 | 1,874* | 54* | 47,462* | 6* | 4,602* | 5 | 3,715 | 32* | 27,913* |
| Growth | After | 2 | 4,904 | 52 | 206,263 | 11 | 33,667 | 3 | 8,220 | 33 | 106,280 |
| | Before | 2 | 6,695 | 49 | 125,000* | 9 | 27,292 | 5* | 11,853 | 34 | 100,344* |
| | Q1(2000) | 1 | 1,710* | 53 | 124,641* | 8* | 21,293* | 5* | 10,392 | 33 | 70,947* |

**Panel D: Classification by order size**

| Number of Shares Routed | Period | Alternate Brokers | | Full Service Brokers | | Independent Research Brokers | | Soft Dollar Brokers | | Non-Classified | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size | % orders | Average order size |
| 0 – 1,000 shares | After | 20 | 857 | 53 | 830 | 3 | 929 | 9 | 816 | 14 | 828 |
| | Before | 10 | 879 | 44 | 856 | 2 | 833 | 22 | 865 | 22 | 869 |
| | Q1(2000) | 29 | 750 | 35 | 760 | 4 | 762 | 8 | 732* | 24 | 737 |
| 1,001 – 5,000 shares | After | 28 | 3,048 | 43 | 2,991 | 2 | 3,210 | 8 | 3,224 | 19 | 2,954 |
| | Before | 18 | 3,133 | 45 | 3,042 | 3 | 3,334 | 15 | 3,082 | 20 | 3,244* |
| | Q1(2000) | 36 | 3,069 | 34 | 3,022 | 2 | 3,245 | 6 | 2,904 | 21 | 3,067 |
| 5,001 – 10,000 shares | After | 35 | 7,349 | 39 | 7,376 | 2 | 7,406 | 7 | 7,320 | 17 | 7,383 |
| | Before | 23 | 7,618 | 46 | 7,632 | 2 | 7,602 | 12 | 7,265 | 18 | 7,584 |
| | Q1(2000) | 33 | 7,327 | 36 | 7,553* | 4 | 7,794 | 8 | 7,838 | 19 | 7,547 |
| > 10,001 shares | After | 3 | 127,090 | 56 | 4,721,492 | 11 | 3,730,974 | 3 | 630,736 | 27 | 1,327,785 |
| | Before | 3 | 179,473 | 52 | 1,322,856 | 8 | 602,018* | 5 | 413,038* | 31 | 1,939,733 |
| | Q1(2000) | 2 | 115,892 | 54 | 1,298,618 | 7 | 970,874* | 5 | 353,740* | 32 | 709,352 |

# Table 5
# Trading Costs by Broker Type

This table reports trading costs for different order sizes executed by brokers employed by institutions before and after decimalization. Using all NYSE stocks that moved to decimal trading on January 29, 2001, we select the fifty most active stocks within each of the three size categories based on the market capitalization as on September 30, 2000. Our final sample includes only those stocks that have been traded in all three periods we examine by the same set of Plexus clients. A trading decision refers to a single decision by an institution to buy or sell stock that may be accomplished by one or more trades. We exclude decisions where details on individual brokers are missing. 'Before' includes the period between November 28, 2000 and January 26, 2001, 'After' includes the period between January 29 - March 31, 2001, and 'Q1(2000)' includes the period between January 29 – March 31, 2000. We use the same terminology to classify brokers that is used by Plexus in their data. Alternate brokers refer to ECNs, crossing systems such as ITG-Posit and SuperDOT access desks of large brokerage houses. Full service brokers refer to brokers who provide executions either through their upstairs desk or floor operations at the NYSE. Soft dollar brokers provide free research in exchange for presumably higher trading commissions, while Independent research brokers provide research and execution service independently. Non-classified includes all brokers that Plexus could not identify or not able to classify under any of the other four categories. Price impact for each decision is measured as the signed deviation of the value-weighted average trade price for each decision from a benchmark price, where deviation is multiplied by –1 if the decision was a sale. We use the closing price prior to the day when the decision was made as our benchmark. Each cell in our table represents the cross-sectional average under each period of the time series value-weighted averages of each stock. We test whether cross-sectional average post-decimalization differs from either of the two pre-decimalization periods using a paired t-test. An asterisk denotes significance at 5% level. We present statistics by the complexity of the decision, as measured by the decision size relative to the average daily volume in September 2000. We use the 33$^{rd}$ and 66$^{th}$ percentile cutoffs to form our groups for decision complexity.

**Panel A: Commissions in basis points**

| Number of Shares Routed | Period | Alternate Brokers | Full Service Brokers | Independent Research Brokers | Soft Dollar Brokers | Non-Classified |
|---|---|---|---|---|---|---|
| Full sample | After | 2.94 | 9.63 | 12.38 | 12.76 | 11.35 |
| | Before | 3.39* | 9.54 | 11.15 | 9.89 | 10.09* |
| | Q1(2000) | 1.87* | 7.74* | 9.60 | 9.01 | 7.69* |
| 0 – 1,000 shares | After | 0.77 | 5.19 | 8.13 | 6.90 | 7.00 |
| | Before | 1.19 | 7.75 | 7.98 | 6.63 | 5.72 |
| | Q1(2000) | 0.30 | 3.85 | 5.92 | 6.01 | 5.36* |
| 1,001 – 5,000 shares | After | 0.83 | 7.23 | 16.33 | 9.91 | 8.31 |
| | Before | 1.69* | 7.08 | 10.62 | 9.67 | 9.60 |
| | Q1(2000) | 0.31 | 4.02 | 8.35 | 8.02 | 6.62 |
| 5,001 – 10,000 shares | After | 1.01 | 6.95 | 13.20 | 9.98 | 9.56 |
| | Before | 2.17* | 7.18 | 13.49 | 9.59 | 9.83 |
| | Q1(2000) | 0.28* | 4.82 | 8.44 | 7.27 | 6.72* |
| > 10,001 shares | After | 3.42 | 9.68 | 12.37 | 12.92 | 11.39 |
| | Before | 3.59 | 9.59 | 11.14 | 9.92 | 10.10 |
| | Q1(2000) | 2.98* | 7.82 | 9.62 | 9.09 | 7.71* |

**Table 5 (Continued)**

**Panel B: Price impact (relative to the closing price prior to the day of the decision) in basis points**

| Number of shares routed | Period | Alternate Brokers | Full Service Brokers | Independent Research Brokers | Soft Dollar Brokers | Non-Classified |
|---|---|---|---|---|---|---|
| Full sample | After | -81.15 | 11.12 | 134.15 | 4.59 | 58.63 |
| | Before | -164.80 | 47.50 | -186.01* | 114.51 | 122.37 |
| | Q1(2000) | -44.64* | 86.53* | 121.47 | 236.90 | 189.75* |
| 0 – 1,000 shares | After | 47.41 | -48.50 | -227.23 | -84.61 | -44.97 |
| | Before | 37.59 | 88.10 | -149.04 | -141.52 | 112.60 |
| | Q1(2000) | -9.30 | 35.71 | 124.34 | -48.32 | 22.94 |
| 1,001 – 5,000 shares | After | 18.70 | 11.88 | 24.67 | -161.52 | -10.86 |
| | Before | -7.90* | 30.70 | -54.32 | -0.65* | 27.13 |
| | Q1(2000) | 4.91 | 2.77 | -143.98 | -46.66 | 41.76 |
| 5,001 – 10,000 shares | After | -1.31 | -14.56 | 218.12 | -150.19 | -63.39 |
| | Before | 18.87 | 69.40* | -21.12* | 58.00 | -8.10 |
| | Q1(2000) | -8.60 | -30.51 | 75.93 | 30.68 | 5.17 |
| > 10,001 shares | After | -102.35 | 11.38 | 134.33 | 13.46 | 60.17 |
| | Before | -189.00 | 47.41 | -186.88* | 120.59 | 123.91 |
| | Q1(2000) | -74.96 | 88.81* | 123.32 | 249.42 | 193.47* |

**Panel C: Total trading costs in basis points**

| Number of shares routed | Period | Alternate Brokers | Full Service Brokers | Independent Research Brokers | Soft Dollar Brokers | Non-Classified |
|---|---|---|---|---|---|---|
| Full sample | After | -78.20 | 20.76 | 146.53 | 17.35 | 69.98 |
| | Before | -161.41 | 57.04 | -174.86* | 124.40 | 132.47 |
| | Q1(2000) | -42.78* | 94.27* | 131.08 | 245.91 | 197.44* |
| 0 – 1,000 shares | After | 48.18 | -43.31 | -219.10 | -77.71 | -37.97 |
| | Before | 38.78 | 95.85 | -141.06 | -134.89 | 118.32 |
| | Q1(2000) | -9.01 | 39.56 | 130.26 | -42.31 | 28.31 |
| 1,001 – 5,000 shares | After | 19.53 | 19.11 | 41.01 | -151.61 | -2.55 |
| | Before | -6.20* | 37.78 | -43.70 | 9.02* | 36.73 |
| | Q1(2000) | 5.23 | 6.79 | -135.63 | -38.64 | 48.38 |
| 5,001 – 10,000 shares | After | -0.30 | -7.61 | 231.32 | -140.20 | -53.83 |
| | Before | 21.05 | 76.58* | -7.63* | 67.59 | 1.73 |
| | Q1(2000) | -8.32 | -25.69 | 84.37 | 37.95 | 11.89 |
| > 10,001 shares | After | -98.93 | 21.07 | 146.70 | 26.39 | 71.57 |
| | Before | -185.41 | 57.00 | -175.74* | 130.51 | 134.01 |
| | Q1(2000) | -71.98 | 96.63 | 132.95 | 258.51 | 201.18* |

## Table 6
## Regressions of Total Trading Costs and Number of Trading Days to Complete a Decision

This table presents results of regressions of institutional trading costs and the number of trading days it takes to complete a decision. Total trading costs (in basis points) include commissions as well as price impact. Price impact for each decision is measured as the signed deviation of the value-weighted average trade price for each decision from a benchmark price, where deviation is multiplied by –1 if the decision was a sale. We use the closing price prior to the day when the decision was made as our benchmark. We include all trading decisions that were placed by Plexus clients between November 28, 2000 and March 31, 2001. We include only decisions in stocks that the clients traded both before and after decimalization. The After dummy is an indicator variable that takes the value 1 if the decision was placed after January 29, 2001, the date when stocks started trading in decimals. The Value dummy and the Growth dummy are indicator variables to denote manager style. We also use two interaction dummy variables to capture the residual effects of decimalization on manager style. Log Market Capitalization is the natural logarithm of the market capitalization of the underlying stock at the end of September 2000. Volatility is the daily return standard deviation in the month of September 2000, while Inverse Price represents the inverse of the price at the time the decision was made. Decision complexity is the size of the decision relative to the average daily volume of the underlying stock. An asterisk means that the coefficient for the variable is significantly different from zero at the 5 percent level. Standard errors are in parentheses.

**Panel A: Dependent variable = Total trading cost (which includes price impact measured relative to the closing price prior to the day of the decision)**

| Intercept | Log Market Capitalization | Volatility | Order complexity | Inverse Price | Value dummy | Growth dummy | After dummy | Value x After dummy | Growth x After dummy | R-square | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29.19 | -3.59 | 1.34 | -0.30 | 533.73* | -0.85 | 19.91 | -12.82 | -17.58 | 10.81 | 0.01 | 13,488 |
| (19.09) | (2.63) | (3.21) | (0.20) | (77.82) | (13.61) | (12.92) | (9.57) | (16.51) | (17.09) | | |

**Panel B: Dependent variable = Number of trading days taken to complete the decision**

| Intercept | Log Market Capitalization | Volatility | Order complexity | Inverse Price | Value dummy | Growth dummy | After dummy | Value x After dummy | Growth x After dummy | R-square | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.21* | 0.09* | -0.003 | 0.04* | -0.25 | -0.18* | 0.41* | 0.27* | -0.42* | -0.47* | 0.09 | 13,488 |
| (0.14) | (0.01) | (0.02) | (0.01) | (0.38) | (0.07) | (0.07) | (0.05) | (0.08) | (0.09) | | |

## Table 7
## Regressions of Total Trading Costs by Broker Type

This table presents results of regressions of total trading costs for different brokers used by institutions before and after decimalization. Alternate brokers refer to ECNs, crossing systems such as ITG-Posit and program trading desks of large brokerage houses. Full service brokers refer to brokers who provide executions either through their upstairs desk or floor operations at the NYSE. Soft dollar brokers provide free research in exchange for presumably higher trading commissions, while Independent research brokers provide research and execution service independently and may or may not have floor operations at the NYSE. Total trading costs (in basis points) include commissions as well as price impact. Price impact for each decision is measured as the signed deviation of the value-weighted average trade price for each decision from a benchmark price, where deviation is multiplied by –1 if the decision was a sale. We use the closing price prior to the day when the decision was made as our benchmark. We include all trading decisions that were placed by Plexus clients between November 28, 2000 and March 31, 2001. We include only decisions in stocks that the clients traded both before and after decimalization. The After dummy is an indicator variable that takes the value 1 if the decision was placed after January 29, 2001, the date when stocks started trading in decimals. The Value dummy and the Growth dummy are indicator variables to denote manager style. We also use two interaction dummy variables to capture the residual effects of decimalization on manager style. Log Market Capitalization is the natural logarithm of the market capitalization of the underlying stock at the end of September 2000. Volatility is the daily return standard deviation in the month of September 2000, while Inverse Price represents the inverse of the price at the time the decision was made. Order complexity is the size of the order routed to a particular broker relative to the average daily volume of the underlying stock. An asterisk means that the coefficient for the variable is significantly different from zero at the 5 percent level. Standard errors are in parentheses.

**Panel A: Alternate Brokers**

| Intercept | Log Market Capitalization | Volatility | Order complexity | Inverse Price | Value dummy | Growth dummy | After dummy | Value x After dummy | Growth x After dummy | R-square | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -90.56* | -5.63 | 4.65 | -22.53* | 261.82 | 89.62* | 143.88* | 98.77* | -83.13* | -74.49 | 0.01 | 3,544 |
| (38.16) | (4.03) | (5.42) | (8.61) | (152.67) | (28.99) | (36.28) | (32.01) | (35.43) | (48.90) | | |

**Panel B: Full Service Brokers**

| Intercept | Log Market Capitalization | Volatility | Order complexity | Inverse Price | Value dummy | Growth dummy | After dummy | Value x After dummy | Growth x After dummy | R-square | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 123.96* | -14.92* | -11.72* | -0.59 | 574.83* | 69.81* | -14.61 | -31.57* | -147.37* | 48.23* | 0.01 | 7,288 |
| (35.52) | (5.16) | (5.33) | (0.35) | (200.18) | (29.03) | (18.41) | (13.89) | (38.26) | (23.93) | | |

## Table 7 (Continued)

**Panel C: Independent Research Brokers**

| Intercept | Log Market Capitalization | Volatility | Order complexity | Inverse Price | Value dummy | Growth dummy | After dummy | Value x After dummy | Growth x After dummy | R-square | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -181.72* | 7.98 | 45.91* | -1.35 | 1176.85 | 524.15* | 74.03 | 96.83 | -549.51* | -93.58 | 0.03 | 682 |
| (170.81) | (26.05) | (22.37) | (1.64) | (793.46) | (207.48) | (76.54) | (70.40) | (254.09) | (100.73) | | |

**Panel D: Soft Dollar Brokers**

| Intercept | Log Market Capitalization | Volatility | Order complexity | Inverse Price | Value dummy | Growth dummy | After dummy | Value x After dummy | Growth x After dummy | R-square | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 149.50 | -22.56 | -2.05 | -19.12* | -519.49 | 37.21 | -22.06 | -33.15 | -19.74 | 53.36 | 0.01 | 1,700 |
| (101.61) | (14.89) | (14.93) | (6.36) | (488.91) | (45.30) | (45.99) | (39.10) | (63.17) | (63.86) | | |

## Figure 1: Number of Decisions Per Day Involving the Same Stock