Selection Biases and Cross-Market Trading Cost Comparisons*

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Abstract

This paper uses data generated pursuant to SEC Rule 11Ac1-5, which was enacted to "provide a fair and useful basis for comparisons among market centers", to report on several measures of market quality for ten market centers that trade NYSE-listed stocks. In addition to reporting on average effective spreads, realized spreads, time to execute orders, percentage of orders received that are executed, and percentage of orders receiving price improvement, this study highlights the importance of selection biases in making market quality comparisons. Orders in NYSE-listed stocks that are executed off the NYSE tend to be in larger and more active stocks, to be smaller, and to contain less information. Empirical analysis indicates that, while controlling for selection biases is important in making market quality comparisons, a simple regression-based method provides results that are generally similar to those obtained when using more complex two-stage methods.

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1. Introduction

Recent years have seen a surge in published research focusing on the costs of executing trades in financial markets in general, and in stock markets in particular. The interest in documenting trading costs stems in part from the fact that traders often do not know the trading cost they pay: while commission charges are typically reported to traders, trade execution costs are not. In response to the growing perception that trade execution costs are important and relevant to traders' decisions, the U.S. Securities and Exchange Commission (SEC) recently passed a regulation, rule 11AC 1-5, (henceforth "Dash 5") that requires each U.S. market center to compile and disseminate on a monthly basis several measures of trade execution costs for each stock traded. Regarding the purpose of compiling Dash 5 data, the SEC has stated: *"One of the primary objectives of the Rule is to generate statistical measures of execution quality that provides a fair and useful basis for comparisons among different market centers".*[1] This study compiles some empirical evidence on market quality as captured in Dash 5 reports, with particular emphasis on the role of, and methods of correcting for, selection biases in market quality comparisons.

At least four reasons underlie the recent interest in trading costs. The first is the introduction of databases, including the Institute for the Study of Securities Markets (ISSM) database, the Trade and Quote (TAQ) database disseminated by the New York Stock Exchange (NYSE), and the Nastraq database disseminated by the Nasdaq Stock market, each of which contains data on individual trades and quotes.[2] The second is the assertion of Christie and Schultz (1994) that trading costs on the Nasdaq market might reflect collusion among market makers rather than competitive outcomes. This assertion directly spurred empirical research, including Huang and Stoll (1996), Bessembinder (1997), and Barclay (1997), as well as market

[1] SEC Staff Legal Bulletin No. 12.
[2] Among the earliest studies that capitalized on these data sources were Lee (1993) and Peterson and Fialkowski (1994).

reforms that became the focus of additional study (e.g. Barclay, Christie, Harris, Kandel, and Schultz (1999) and Weston (2000)). A third reason is that stock markets in both the U.S. and abroad continue to search for the optimal set of market rules. As part of this search markets have recently altered the minimum price increment or "tick size", leading to numerous empirical studies of the resulting effects on market quality.[3] The fourth reason, and the one most closely linked to the new Dash 5 reporting requirement, is that authorities at the U.S. Securities and Exchange Commission (SEC) and others have expressed concerns that brokerage firms may not be meeting their fiduciary obligation to route customer orders so as to obtain "best execution".[4]

Many empirical studies of trading costs naturally focus on the question of which market or which market mechanism provides the lowest costs. Some studies, including Huang and Stoll (1996), Bessembinder (1997), Weston (2000), Venkataraman (2001), and Boehmer (2003) compare trading costs across stocks listed on different markets. Other studies, including Lee (1993), Keim and Madhavan (1996), Madhavan and Cheng (1997), Bessembinder and Kaufman (1997), Smith, Turnbull and White (2001), Huang (2002), Bessembinder and Venkataraman (2003), and Conrad, Johnson, and Wahal (2003), compare trading costs across markets (e.g. NYSE versus regional exchanges) or across trading mechanisms (e.g. upstairs versus downstairs, or traditional brokerage versus Electronic Communications Network) for stocks listed on a given market.

An important methodological issue in any study that makes comparisons of trading costs across markets or across trading mechanisms arises due to the likelihood of sample selection bias. It is well documented (see, for example, Benston and Hagerman (1974), Harris (1994), and Keim and Madhavan (1997)), that trading costs depend on characteristics of the stock involved

[3] Bessembinder (2003) cites approximately a dozen studies of decimalization of the U.S. markets, and provides references to studies of earlier tick size changes.
[4] For example, see the speech to the Securities Industry Association delivered on November 4, 1999 by former SEC chairman Arthur Levitt, at the web site www.sec.gov/news/speeches/spch315.htm. Controversial practices include "payment for order flow", where a market maker makes a payment to a brokerage firm for the routing of a customer order, and "internalization", where buy and sell orders delivered to a brokerage firm are crossed without being exposed to the broader market.

(including market capitalization, share price, and return volatility), characteristics of the order involved (including order size, order type, and whether the order is perceived to originate with an informed or uninformed trader), as well as market conditions at the time of the trade. Selection biases can arise due to variation in the economic characteristics of the stocks traded on each market, or due to variation in the type of orders or market conditions at the time of orders for trading in a common set of stocks.

A finding that the average trade execution costs paid by customers are higher on a given market could reflect that the market employs a less efficient trading mechanism. However, to reach this conclusion based on a comparison of average execution costs requires the implicit assumption that that orders submitted to each market are similar in terms of the economic costs of completing trades. This assumption need not be accurate, and finding higher trading costs on a given market could simply reflect that the market tends to trade the shares of smaller or more volatile stocks, or that the market generally receives more difficult order flow, e.g. larger orders or orders that originate with informed traders. In short, little can be inferred about the inherent efficiency of a market or trading mechanism unless the possibility of selection bias in the trades completed at each market is somehow addressed.

Three general methods have been used to control for selection biases in studies that make trading cost comparisons: matching algorithms, regression specifications, and explicit econometric corrections. Matching algorithms are intended to ensure that trading cost comparisons focus on trades that are as identical as possible. For example, studies that compare trading costs across listing markets such as Huang and Stoll (NYSE versus Nasdaq, 1996) and Venkataraman (NYSE versus Paris Bourse, 2001) focus on subsamples of the stocks listed on each market that are comparable in terms of market capitalization, return volatility, share price, etc. Lee (1993) studies NYSE-listed stocks that are traded both at the NYSE and at the regional stock exchanges, focusing on trades in the same stock that are closely matched in size and time. However, a disadvantage of the matching algorithm approach is that a portion of the sample (that which cannot be closely matched) generally has to be discarded. In some cases, e.g. if all small orders were routed to one market and all large orders were routed to another market, the matching algorithm approach could not be implemented at all.

Regression specifications have been used for trading costs comparisons by Bessembinder and Kaufman (1997), Weston (2000), and Conrad, Johnson, and Wahal (2003), among others. The approach generally involves trading cost measures as dependent variables, with indicator variables that identify specific markets or market structures and other economic variables that are known to affect trading costs used as explanatory variables. The intent is that coefficients on the indicator variables should measure the effect of market structure, after controlling for variation in the other economic variables included in the regression. A key advantage to the regression approach is all of the available data can be used. The main disadvantage is that the results are contingent on the particular functional form (e.g. linear versus log linear, etc.) and set of explanatory variables selected by the researcher.

A third approach is the two-stage estimation procedure advocated by Heckman (1979) and Maddala (1983). This method involves first estimating a probit specification for the choice of venue. From the probit estimation two new variables are created, and these are then included as regressors in second stage regression equations as explicit corrections for selectivity bias. This two-stage approach has been adopted by Madhavan and Cheng (1997) and Bessembinder and Venkataraman (2003) in comparisons of trading costs across upstairs and downstairs stock markets, and by Conrad, Johnson, and Wahal (2003) in comparisons of traditional brokerage mechanisms to electronic communications networks (ECN's).[5]

This study provides three main contributions. First, it describes the Dash 5 data and compiles some early empirical evidence on market quality as reflected in Dash 5 reports for 500 NYSE-listed stocks. Second, it highlights the crucial importance of selection bias issues when

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[5] Mayhew and Mihov (2003) employ a variation of these methods. They use a logistic specification to predict the stocks on which option exchanges will choose to list options, and then make comparisons across stocks that are matched in terms of the likelihood of option listing.

comparing execution costs across trading venues. Third, it provides some methodological guidance to researchers as to the relative merits of the regression-based and the Heckman (1979) two-stage procedures for accommodating selection bias.

Not surprisingly, the Dash 5 data has attracted additional research interest. Lipson (2003) also examines Dash 5 data for NYSE-listed stocks, and concludes that various market centers have carved out specialized niches where each has a comparative advantage. Boehmer, Jennings, and Wei (2003) assess whether published Dash 5 data for a given interval of time affects subsequent order routing decisions. Boehmer (2003) uses Dash 5 data to compare market quality for NYSE versus Nasdaq-listed stocks. However, none of these papers focuses in particular on the existence of, or econometric methods of correcting for, selection biases in order routing.

This study supports several key conclusions. First, there are important selection biases in the orders used to compile Dash 5 data. These result both from selection biases in the set of NYSE-listed stocks that are also traded off the NYSE and in the types of orders in those stocks that are diverted from the NYSE. Broadly speaking, smaller orders in large capitalization, high volume stocks, and orders originating with uninformed traders are significantly more likely to be completed at venues other than the NYSE. The presence of selection biases implies that comparisons of average market quality statistics across market centers are likely to provide misleading inferences as to market quality, unless controls for selection bias are made. While econometric controls can be implemented by researchers, they are likely to be beyond the sophistication of many of the individual investors that the SEC intended to benefit from Dash 5 data.

Results reported here confirm that conclusions with regard to several market quality measures are indeed sensitive to whether corrections for selection biases are made. Most notably, average effective spreads for market orders are significantly higher at the NYSE if no selectivity bias adjustments are made, but are similar on and off the NYSE once selectivity bias is corrected for.

With regard to methods of correcting for selection bias, this study finds that while it is important to control for selection biases, the specific method of control has little practical effect on inference regarding market quality. In particular, the simple technique of including in a regression framework economic variables that are known to be related to trade execution costs appears to provide selectivity bias corrections that work as well as more complex two-stage methods.

II. The Dash 5 Data, and Sample Selection

The raw data used in this study is execution cost and market quality statistics reported by various market centers for the months of July and August 2002, as required by SEC rule 11AC 1-5. The Dash 5 data used in this study was compiled by the NYSE from individual market center web sites. Dash 5 data is available free of charge from individual market centers, and from companies that collect the data.[6]

The Dash 5 data provides some inherent advantages for researchers who wish to study market quality as compared to using previously available data sources such as TAQ or Nastraq. First, the data is presented as monthly averages, and is therefore much less voluminous than the databases containing individual trades and quotes. Second, and more important, the market centers that compile the data have access to order information, which users of TAQ or Nastraq do not. Whether each order is a buy or sell is known to the market center. In contrast, TAQ and Nastraq data users must infer whether trades are buyer or seller-initiated, with an inevitable degree of error. Also, order size is known to the market centers. TAQ or Nastraq users can only observe trade size, which can be larger or smaller than the size of the orders that gave rise to the trade. Further, Dash 5 data distinguishes between trading costs for market orders, marketable limit orders, and non-marketable limit orders. The Dash 5 data also reports on speed of

[6] See, for example, the web sites http://www.tagaudit.com/ and http://www.marketsystems.com/ .

execution and allows the construction of measures of the percentages of orders received that are executed at each market center, while TAQ and Nastraq do not.

However, the Dash 5 data also has some important limitations. In particular, it excludes orders of more than 10,000 shares and orders that are not captured by electronic order routing mechanisms. Boehmer (2003) estimates that the Dash 5 data pertain to about 13% of NYSE trades and 8% of Nasdaq trades. Further, the Dash 5 data are compiled by individual market centers, and are not subject to audit. Preliminary analysis indicates that the reported Dash 5 data does contain some errors. In particular, reported data on effective spreads and price improvement sometimes imply a negative quoted spread.[7] Also, the same averaging process that reduces the volume of the data to be analyzed necessarily implies that some information contained in the original trade and order data is lost.

Rule 11AC 1-5 requires each market center to provide the following data for each security, on a monthly basis.

For all orders:

- Ticker symbol for security,
- Order type (Market, Marketable Limit, Inside the quote Limit, At the quote Limit, Near the quote Limit),
- Order size category (100-499 shares, 500-1,999 shares, 2,000-4,999 shares, and 5,000-9,999 shares),
- Number of orders entered in order type/order size bracket,
- Number of shares entered in order type/order size bracket,
- Number of shares canceled in order type/order size bracket,
- Number of shares executed at the receiving market center.
- Number of shares sent to and executed at an alternate market center,
- Number of shares executed between 0 and 9.9 seconds,
- Number of shares executed between 10 and 29.9 seconds,
- Number of shares executed between 30 and 59.9 seconds,
- Number of shares executed between 60 and 299.9 seconds,
- Number of shares executed between 5 and 30 minutes,
- Average realized spread,

[7] I employ the following error filters. Any observation with an average effective spread less than -$.50 or more than $4.00 is deleted, as is any observation with an average realized spread less than $-4.00 or more than $4.00. I also delete observations where the average implied quoted spread (as computed from the effective spread and price improvement data) is less than or equal to zero. Finally, I delete observations where the reported price improvement exceeds $1.00.

For Market Orders and Marketable Limit Orders only:

- Average effective spread,
- Number of shares receiving price improvement.
- Average amount of price improvement per share, for all price-improved shares.
- Average execution speed (in seconds) for all price improved shares.
- Number of shares executed at the NBBO at the time of order entry.
- Average execution speed (in seconds) for all shares executed at the NBBO.
- Number of shares executed outside the NBBO.
- Average amount executed away from the quote per share, for all shares executed outside the NBBO
- Average execution speed (in seconds) for all shares executed outside the NBBO.

The SEC specifies that effective spreads are to be computed as twice the difference between the trade price and the midpoint of the intermarket best (NBBO) quotes in effect at the time the order is received by the market center. For buy orders the effective spread is twice the trade price less the quote midpoint, for sell orders it is twice the quote midpoint less the trade price. The realized spread is computed analogously, except that the comparison is to the midpoint of the best intermarket quotes five minutes after the trade is completed. The difference between the effective spread and the realized spread is the movement in the midpoint from order arrival until five minutes later. Following Bessembinder and Kaufman (1997) and Venkataraman (2001), I will refer to this differential as the order's "price impact". Price improved shares are defined as those executed at a price within the NBBO quotes.

I focus on Dash 5 data from July and August 2002 for 500 NYSE listed stocks. These include the 100 largest NYSE stocks by beginning of sample (June 30, 2002) market capitalization, and 400 additional NYSE stocks selected at random. I report on market quality statistics for ten market centers:

- The Boston Stock Exchange,
- The Chicago Stock Exchange,
- The Cincinnati Stock Exchange
- Instinet
- Island
- Knight Securities
- Madoff Securities
- The New York Stock Exchange
- The Philadelphia Stock Exchange

- Other NASD Market Centers.

The New York Stock Exchange, The Boston Stock Exchange, and the Philadelphia Stock exchange are traditional markets with a trading floor, floor brokers, and a designated specialist for each stock. The Chicago and Cincinnati markets were traditionally viewed as regional stock exchanges, but now mainly complete trades in NYSE and AMEX stocks, using computerized trading rather than a trading floor. Instinet and Island are Electronic Communications Networks, or ECNs. Island accepts only limit orders, while Instinet accepts both market and limit orders. Knight and Madhoff are broker-dealer firms that also execute customer trades against their own accounts, often using computerized algorithms. The Other NASD market centers are market centers present in the database with relatively small amounts of trading activity in sample stocks. The most active of these is the Computer Assisted Execution System (CAES), which is a Nasdaq system by which NASD dealers can complete trades in Exchange-listed stocks. [8]

Before analyzing the data, I aggregate it across the months of July and August 2002 and also across order size groups. Aggregation is accomplished by computing averages that are weighted by the number of orders entered. The analysis provided here focuses on cross-sectional comparisons across the 500 sample stocks and the ten market centers identified above. From the aggregated data I compute several new variables. These include the percentage of shares executed (the ratio of total shares executed to total shares entered), average order size (the ratio of total shares entered to orders entered), average execution speed (averaged across the three categories reported), the percentage of executed shares receiving price improvement, and the NBBO quoted spread at the time of order arrival (from the effective spread and price improvement data).

[8] The number of market and marketable limit orders (in thousands) contained in the sample for each of these other market centers are TCAES (228), TBRUT (111), TTHRD (72), TNYFX (12), TMKXT (10), TARCA (1), and TLQNT (0).

3. Empirical Results

3.1 Some Simple Averages by Market Center

Table 1 reports the simple average (across all stocks traded at a market center) effective spread and the simple average "price impact" (effective spread less realized spread) for market orders executed at each market center. Also reported is the number of sample stocks in which each market center executed market orders, the average size of a market order at each market center, the total number of sample market orders entered, and the mean June 2002 trading volume and market capitalization of the companies whose stocks were traded on each market center.

Two main results can be noted on Table 1. First, the average effective spread for market orders at the NYSE of 6.95 cents is second largest among the nine market centers. Of course, as emphasized in the introduction of this paper, simple comparisons of average execution costs provide little information about market quality if there are selection biases in the orders routed to each market. Indeed, the second result that can be noted on Table 1 is that the market orders that are executed at the NYSE differ fundamentally from those executed elsewhere. The NYSE completes market orders in all 500 sample stocks. The other centers execute market orders in between 77 and 163 sample stocks. The stocks that the other market centers choose to trade are much larger and more liquid, on average. The mean June 2002 market capitalization of the 500 sample stocks is $13.7 billion. In contrast, the mean market capitalization of subsample of stocks traded at the other market centers ranges from $38.4 billion for the 163 sample stocks traded by Knight Securities to $66.5 billion for the 77 sample stocks traded on the Cincinnati Stock Exchange. Also, the mean price impact of trades completed at the NYSE (5.5 cents) is systematically greater than the price impact of market orders completed at the other market centers, which range from 0.9 cents at the Boston Stock Exchange to 3.8 cents on Instinet.

Tables 2 reports on average effective spreads and price impact for marketable limit orders at each market center, while Table 3 reports on average realized spreads for non-marketable limit orders at each market center. Selection biases are again apparent, with non-NYSE market centers executing limit orders mainly in larger and more liquid stocks, and orders with lower price impact. Unlike results for market orders, however, these simple averages do not indicate NYSE execution costs in limit orders to be among the highest among market centers.

The data reported on Tables 1 to 3 indicate that orders executed at the NYSE are not random draws from the pool of all orders in NYSE listed stocks. Orders directed to market centers other than the NYSE are typically in stocks of larger capitalization and trading volume, and are orders that contain less information. Meaningful comparisons of market quality across the NYSE and other market centers require allowances for selection biases.

3.2 Correcting for Selection Biases

As noted in the introduction, one method of correcting for selection biases is to focus on matched samples. This approach would be very limiting in the present setting. For example, the Cincinnati Stock Exchange completes market orders in only 77 large-capitalization sample stocks. A matched comparison of NYSE versus Cincinnati trades would have to omit trades completed in the large majority of sample stocks.

3.2.1 Regression Based Controls for Selection Bias

I instead focus on regression-based methods to control for selection biases, including but not limited to the two-stage procedure recommended by Heckman (1979) and Maddala (1983). Figure 1 conveys the essential intuition of the regression-based method. Suppose that we observe execution costs, C, for a number of trades completed on two markets, A and B. Suppose also that we are able to construct a variable, E, that measures the ease of execution. For example, small orders originating with uninformed traders in the shares of large and liquid stocks would be relatively easy, and vice versa. We would anticipate execution costs to decline with ease of execution. Suppose also that market A receives trades that are more difficult on average (mean ease E_A) than those executed at market B (mean ease E_B). The relation between execution costs and ease of execution is estimated by OLS regression for each market, with the fitted regression equations depicted by the lines A and B on Figure 1. Since fitted OLS regression equations pass through the mean of the data, sample mean trading costs for each market are given by C_A and C_B. Average costs for market A exceed average costs for market B, but we cannot conclude that A is an inherently more costly mechanism, because A also receives more difficult order flow. Note that a comparison of regression intercepts is also misleading. Intercepts measure the mean of the dependent variable, conditional on explanatory variables being set to zero. In the case depicted on Figure 1, market A has a higher intercept, but trading cost measures conditional on an ease of execution outcome of zero have no natural economic interpretation.

The solution adopted here is to deduct the cross-sectional sample mean of each explanatory variable from each observation on the variable. The effect is to shift the point at which intercepts are evaluated from zero to the mean outcome on the explanatory variable. In terms of Figure 1, if the OLS regression for each market is estimated after deducting the sample mean level of ease, E_M, from each observation, the resulting intercepts are I_A and I_B. These have natural interpretations as expected trading costs on each market, conditional on receiving a trade of average difficulty. Of course, conditional mean trading costs could also be evaluated by comparing the fitted regression values at outcomes other than sample means.

The general approach is implemented here with regressions of the form:

$$ESPR_{is} = \alpha_1 NYSE_{is} + \alpha_2 NONNYSE_{is} + \alpha_3 X_{is} + \varepsilon_{is} \qquad (1)$$

where $ESPR_{is}$ is the mean effective spread for stock i at market center s, $NYSE_{is}$ is an indicator variable that equals one if market center s is the NYSE and zero if not, $NONNYSE_{is}$ is an indicator variable that equals one if market center s is not the NYSE and that equals zero if it is, and X_{is} is a vector of explanatory variables, each stated as the deviation from its own sample cross-sectional mean. When the X_{is} variables are excluded from the regression the coefficient estimates on the two indicator variables simply reproduce the unconditional sample mean trading costs, as reported on Tables 1 to 3. When the X_{is} variables are included in the regression the coefficient estimates on the two indicator variables reveal conditional mean execution costs on and off the NYSE, evaluated at the mean of the variables that comprise the X_{is} vector.

Panel A of Tables 4 reports estimates obtained by this method for market orders completed on and off the NYSE. Explanatory variables include the logarithm of the total number of orders for stock i in the two month Dash 5 sample, the average price impact of orders in that stock on that market, the inverse of the value-weighted average trade price for the stock during the sample, and the mean order size for stock i orders at market s, relative to total June 2002 trading volume in stock s.[9] Intercept estimates obtained in this specification therefore measure mean effective spreads on and off the NYSE for market orders of average size (relative to volume), in a stock with average in-sample number of orders, average price impact, and average (inverse) share price.

Slope coefficients on the X_{is} variables are generally consistent with those reported in previous research (e.g. Benston and Hagerman, 1974 and Harris, 1994). Average effective spreads for market orders decrease with the trading activity as measured by total orders in the stock, increase with trades' average information content, decrease with the inverse share price (increase with share price), and increase with average order size. Each coefficient estimate is highly significant.

The unconditional mean effective spread, based on the market orders actually submitted to each market center, is 6.95 cents at the NYSE compared to 4.15 cents away from the NYSE. When evaluated at sample means, effective spreads average 5.33 cents on the NYSE and 5.52 cents off the NYSE. The difference in average effective spreads evaluated at sample means is not statistically significant. The conclusion is that cross-sectional variation in the economic variables included in the regression fully explains differences in effective spreads on the NYSE versus other market centers, for market orders.

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[9] The Dash 5 data does not include share prices. The NYSE kindly provided monthly value-weighted average trade prices for sample stocks.

3.2.2 Using First-Stage Probit Estimation to Control for Selection Bias

The two-stage procedure to control for selection biases advocated by Heckman (1979) and Maddala (1983) also relies on a regression-based approach. The main distinction is the use of a first stage probit estimation to construct a pair of new variables to include in the regression analysis. The structure of the Dash 5 data requires some customization of the Probit estimation.

If data on individual orders were available then the probit estimation could be implemented as:

$$\text{Prob}(\text{NYSEIND}_{it} = 1) = g(X_i, Y_{it}) \qquad (2)$$

where NYSEIND_{it} would be an indicator variable equal to one if order t in stock i were routed to the NYSE and equal to zero if order t in stock i were routed off the NYSE, X_i is a vector of stock i variables that do not change across orders (e.g. beginning of sample market capitalization), Y_{it} is a vector of variables specific to order t in stock i (e.g. order size, or the *ex post* price impact of the order), and g(.) is the probit function.

The Dash 5 data does not report on individual orders, but only on monthly means by market center. This is equivalent to averaging the individual observations in equation (2) by stock across individual orders at each market center s, giving

$$\text{prob}(\text{NYSEIND}_{is} = 1) = g(X_i, Y_{is}) \qquad (3)$$

where NYSEIND_{is} equals one if the report is for NYSE orders in stock i and equals zero if the report is for non-NYSE orders in stock i, and Y_{is} is the average across Y_{it} for orders in stock i at market center s.

Since probit estimation can also be accomplished using a dependent variable that is continuous between 0 and 1, it would also be possible to average (3) across market centers for each stock, giving:

$$\text{NYSEPROP}_i = g(X_i, Y_i) \qquad (4)$$

where NYSEPROP_i is the proportion of orders in stock i that are routed to the NYSE and Y_i is the average across market centers of the order characteristics. Note, though, that some information would be lost: specification (3) can accommodate variation across market centers in average price impact or order size for each stock, while specification (4) would have to rely on the average price impact or order size for the stock computed across all market centers.

The probit specification estimated here is expression (3). The dependent variable equals one for those cross-sectional observations that pertain to NYSE executions and equals zero for cross-sectional observations that pertain to non-NYSE executions.[10] As explanatory variables I use the logarithm of June 2002 market capitalization, the logarithm of June 2002 trading volume, the logarithm of the mean order size in stock i at market s relative to the stock i order size computed across all markets, the average ex post price impact of orders in stock i at market s, and the mean quoted (NBBO) bid-ask spread for stock i at the time of market s orders. Coefficient estimates on June 2002 market capitalization and trading volume will reveal whether trades in larger and more liquid stocks tend to be routed to or away from the NYSE. Coefficient estimates on order size and price impact reveal how order size and order information content affect order routing. Finally, the quoted bid-ask spread at order time is included as a measure of market conditions at order time.

Results of estimating the probit specification (3) for market orders in sample stocks are reported on Panel B of Table 4, and confirm the presence of systematic selection biases in order routing. Coefficient estimates on both the logarithm of market capitalization and the logarithm of trading volume are negative and significant, confirming that orders in large and active stocks are more likely to be completed off the NYSE. The coefficient estimate on average price impact is positive and significant, confirming that those orders containing less information are more likely to be diverted from the NYSE. This result regarding the "cream-skimming" of uninformed order flow is consistent with findings obtained using alternate techniques by Bessembinder and

[10] Taken literally, the probit estimation in the averaged data could be viewed as answering the following question: We have a Dash 5 report that pertains to orders with certain characteristics in a stock with certain characteristics. What is the probability that the report was issued by the NYSE rather than a non-NYSE market center?

Kaufman (1997) and Easley, Kiefer, and O'Hara (1996). The coefficient estimate on order size is positive, indicating that larger orders tend to be routed to the NYSE, but is only marginally significant. The coefficient estimate on the quoted spread is not significant, indicating that this variable does not capture important variation in market conditions that is not already captured by the other explanatory variables.

Beyond confirming the presence of selection biases, Heckman (1979) and Maddala (1983) describe how the results of the Probit estimation can be used to make explicit corrections for selection bias. Two new variables, $\gamma_1 = f(Z)/F(Z)$ and $\gamma_2 = -f(Z)/(1-F(Z))$, where Z is the fitted value from the Probit estimation, f is the standard normal density function, and F is the standard normal distribution function, are created. These new variables are monotone decreasing in the probability that an order will be routed to the NYSE. The inclusion of these new variables in a second stage OLS regression controls for selection biases in the observed sample, and allows for consistent parameter estimation despite the presence of selection biases.[11]

Table 5 reports Pearson correlation coefficients for the two variables created from the probit explanation and several economic variables. Notably, the two constructed variables are highly correlated with each other, are negatively correlated with effective spreads and with orders' ex post price impact, are highly positively correlated with June trading volume, June market capitalization, and the in-sample number of orders, and are highly negatively correlated with inverse price. In short, the constructed variables are closely linked to variables that are known to affect execution costs, and can reasonably be interpreted as measuring the ease of order execution.

Panel C of Table 4 reports results of cross-sectional regressions when the newly constructed variables are used as regressors to explain average effective spreads. These results

[11] There appears to be some inconsistency in the Finance literature as to whether only γ_1 (the 'Inverse Mills Ratio') or both γ_1 and γ_2 should be included in second stage regressions. This may be attributable to Heckman (1979) limiting his discussion to estimation within the selected subsample. The derivations in Maddala (1983, page 209) make clear that γ_1 should be used as an additional regressor for the selected subsample, while γ_2 is used as a regressor for the non-selected subsample.

indicate that sample selection biases fully explain differences in average effective spreads for market orders across the NYSE and off NYSE market centers. Coefficient estimates on the two variables constructed from the Probit estimation are negative and significant, consistent with the interpretation that they proxy for ease of execution. When the variables constructed from the Probit specification are the only explanatory variables in the regression the conditional mean effective spread for market orders at the NYSE is 5.02 cents, compared to 4.97 cents off the NYSE. When the additional explanatory variables that were used in Panel A are also included, the conditional mean effective spread for market orders at the NYSE is 5.20 cents, compared to 5.47 cents off the NYSE. Conditional mean estimates do not differ across the NYSE and non-NYSE in either case. Note also that coefficient estimates on the two variables constructed from the probit estimation are not significant once other economic variables are included in the regression specification. This is consistent with the reasoning that the variables created from the probit estimation contain similar information as the economic variables.

To summarize the results obtained to this point, unconditional mean effective spreads for market orders in NYSE-listed stocks are higher on the NYSE than off the NYSE in Dash 5 data from July and August 2002. However, this divergence is fully attributable to selection biases in the orders routed to the NYSE and to the alternate market centers. *Either* controlling for stock and order characteristics in a multivariate regression *or* controlling for selection biases by use of a Probit model leads to estimates of conditional mean effective spreads that are similar or slightly lower on the NYSE as compared to other market centers.

3.3 Results for Limit Orders

Table 6 reports results of an analysis identical to that reported on Table 4, except applied to marketable limit orders. Several points can be noted. First, average effective spreads for marketable limit orders on the NYSE (4.51 cents) are lower than off the NYSE (5.75 cents) even without any corrections for selectivity bias. Including demeaned-economic variables as explanatory variables increases the divergence. Evaluated at the sample mean of the market capitalization, trading volume, price impact, inverse share price, and order size variables the average effective spread for marketable limit orders at the NYSE is 3.05 cents, compared to 6.29 cents off the NYSE.

Results of estimating a probit specification for order routing as reported on Panel B of Table 6 confirm the presence of selection biases in the routing of marketable limit orders as well. Marketable limit orders are significantly less likely to be routed to the NYSE if they are in more active stocks and when quoted spreads are wide, and are more likely to be routed to the NYSE if they contain more information as measured by the price impact variable.

Panel C of Table 6 reports results obtained when variables constructed from the probit estimation to control for selection bias are included in the cross-sectional regression specification. Negative and significant coefficient estimates are obtained on the constructed variables, which is again consistent with the interpretation that the constructed variables proxy for the ease of order execution. The intercept estimates reported on Panel C of Table 6 continue to indicate that effective spreads for marketable limit orders are significantly lower at the NYSE than at other market centers.

Some consistency of results can be observed across Table 4 for market orders and Table 6 for marketable limit orders. In each case the probit analysis and slope coefficients obtained on the variables constructed from the probit analysis are consistent with the reasoning that more difficult orders are routed to the NYSE. Controlling for selection bias, either by including variables known to be linked to order execution costs, or by including variables constructed from the probit model, or by including both economic variables and the constructed variables, indicates lower trading costs on the NYSE and higher trading costs off the NYSE as compared to unadjusted estimates. Further, point estimates of selectivity-bias-adjusted trading costs are reasonably similar regardless of adjustment method.

3.4 Selection Bias in Non-Marketable Limit Orders

Table 7 reports the results of a Probit estimation similar to (3), but for non-marketable limit orders. Since the Dash 5 data does not include effective spreads for limit orders this specification cannot include a measure of orders' price impact or quoted spreads at order arrival time. The results, however, confirm the presence of systematic selection biases in non-marketable limit orders as well. In particular, large limit orders are more likely to be routed to the NYSE, while limit orders in more active stocks are more likely to be diverted from the NYSE. Market capitalization does not have significant explanatory power for the routing of non-marketable limit orders. I construct γ_1 and γ_2 variables from this probit estimation in the same manner as described above, and use these variables to make selectivity bias corrections in measures of realized spreads for limit orders, as reported in Section 3.6 below.

3.5 Results for Orders of Various Size Categories.

As noted in the Section 2, Dash 5 data is reported separately for orders in four size categories. The empirical results reported to this point focus on estimates obtained after averaging trading cost and order data across order size categories. Table 8 reports results analogous to those on Tables 4 and 6 for market and marketable limit orders, separately by order size category. Explanatory variables are the same as used for the specifications reported on Tables 4 and 6. I suppress the results obtained from the probit estimation and the slope coefficients obtained on the economic variables, reporting only intercept estimates. Results reported on row 1 include no control variables. Results reported on row 2 include economic variables as explanatory variables. Results reported on row 3 include the γ_1 and γ_2 variables constructed from the probit estimation as control variables. Results reported on row 4 include both the γ_1 and γ_2 variables, as well as economic variables as controls.

The point estimates reported on Table 8 indicate larger effective spreads for larger orders, both on and off the NYSE, and both before and after corrections for selectivity bias. As in the results aggregated across all size categories, unadjusted means indicate higher effective spreads on the NYSE for market orders in all size categories. However, controlling for selectivity bias yield estimated effective spreads on the NYSE that are similar to or slightly lower that effective spreads off the NYSE, in each order size category. For marketable limit orders, raw means indicate lower effective spreads on the NYSE, for all but the largest order size group. After controlling for selectivity bias effective spreads for marketable limit orders are lower on the NYSE by about 2 to 4 cents, in all order size groups. Once again, inference is similar regardless of which method is used to control for selectivity bias.

3.6 Other Measures of Execution Quality

Results to this point have focused on effective spreads as the measure of execution quality. The Dash 5 data also reports on realized spreads. Further, other measures of execution quality can be constructed from the Dash 5 data, including the percentage of shares submitted to a market that are ultimately executed there, the percentage of shares executed at a market that receive a price better than the NBBO quotes, and the average elapsed time from order arrival until execution. Table 9 reports on averages of these additional measures of market quality. Analogous to results reported on Tables 8, results reported on row 1 are simple sample means without any control variables, and results reported on row 2 include the same economic variables as used for Tables 4 and 6 as control variables. Results reported on row 3 include the γ_1 and γ_2 variables constructed from the probit estimation as control variables, while results reported on row 4 include both the γ_1 and γ_2 variables and economic variables as controls. Results of estimating the probit regression and slope coefficients on the various control variables are suppressed.

Unadjusted means reported on Table 9 indicate that realized spreads are lower and the percentage of market and marketable limit orders executed is higher on the NYSE as compared to other market centers. The NYSE executes 99.0 percent of the market orders and 79.4 percent of the marketable limit orders it receives, compared to 90.6 percent of market orders and 62.3 percent of marketable limit orders that are executed by the receiving market off the NYSE. However, the percentage non-marketable limit orders executed by the NYSE is lower (21.5 percent versus 39.5 percent), as is the percentage of market and marketable limit orders receiving price improvement, and average execution speed is longer at the NYSE. The execution speed differential is modest for market orders (25.4 seconds at the NYSE versus 15.7 seconds on average at other market centers), but is more notable for marketable limit orders (80.2 seconds at the NYSE versus 28.2 seconds at other market centers).

Adjusting for selectivity bias alters some, but not all, conclusions regarding these market quality measures. Realized spreads for market orders and non-marketable limit orders do not differ significantly across the NYSE and other market centers after controlling for selection biases, by any method. The lower realized spreads on the NYSE apparently reflect the more difficult order flow there.   Realized spreads for marketable limit orders, in contrast, remain lower at the NYSE even after correcting for selection biases in order routing. The percentage of market and marketable limit orders executed remains higher at the NYSE, while the percentage of non-marketable limit orders executed remains lower at the NYSE, even after controlling for selection biases. The differential in the percent of market and marketable limit orders receiving price improvement is reduced by controlling for selectivity bias, but price improvement rates remain lower on the NYSE. Similarly, controlling for selectivity bias reduces, but does not fully eliminate, differentials in average execution speed.

3.7 Comparisons to Individual Market Centers

All results reported to this point have reflected comparisons of NYSE execution quality to the quality of non-NYSE market centers in aggregate. Tables 10 through 12 report on pairwise comparisons of NYSE market quality versus each other market center in the sample, for market orders, marketable limit orders, and non-marketable limit orders, respectively. The framework is identical to that used for the Table 9. However, to conserve space the only coefficient estimate reported is the difference between the regression intercept of the non-NYSE market center and the regression intercept for the NYSE. Negative coefficients indicate smaller outcomes off the NYSE, while positive coefficients indicate larger outcomes off the NYSE.

Tables 10 through 12 contain a large number of market quality comparisons. A few of these stand out. Focusing first on market orders, simple mean effective spreads are lower off the NYSE than on the NYSE for each alternative market center except those in the 'NASD other" group. Controlling for selectivity bias in order flow eliminates the significant differential in average effective spreads between the NYSE and other market centers, with two exceptions: Instinet continues to show lower average effective spreads after the selectivity adjustment, and average effective spreads at other NASD market centers are significantly higher than at the NYSE after selectivity adjustments.

Differentials between the NYSE and other market centers in the sample average percentage of market orders executed generally are not large, with two exceptions. Instinet's execution rate for market orders is 29.7% lower (69.3%, as compared to 99.0% on the NYSE as reported on Table 9), and the other NASD market centers execution rate for market orders is 43.2% lower. Thus, although Instinet has lower effective spreads than the NYSE for those market orders it executes, traders much also consider the lower rate of execution there. Controlling for selectivity bias generally does not alter inference with respect to market order execution rates much, with the exception of Madhoff Securities, whose execution rate after correcting for sample selection bias is between 6 and 11 percent less than that of the NYSE.

Each of the other market centers has a higher price improvement rate for market orders than the NYSE, ranging from a 2% higher rate for Boston to a 23% higher rate for Madhoff securities, when evaluating raw means. Controlling for selection biases, however, indicates lower price improvement rates for market orders at the Boston and Philadelphia Stock Exchanges, and at the other NASD market centers. Price improvement rates remain higher at Instinet, Knight

Securities, Madhoff Securities, and the Chicago Stock Exchange, even after controlling for selection biases.

Every market center except Instinet has quicker executions of market orders than the NYSE, on average. However, controlling for selection biases in the type of orders received at each market center eliminates the differential in execution speed between the NYSE and the Boston, Cincinnati, and Philadelphia Stock Exchanges, and indicates slower average executions at the Chicago Exchange. Broker-dealer firms Knight Securities and Madhoff Securities continue to have more rapid executions of market orders than the NYSE, even after controlling for selection biases.

Comparisons of the NYSE to individual market centers with regard to marketable limit orders are reported on Table 11. The larger effective spreads for marketable limit orders off the NYSE is primarily attributable to the Island ECN, where effective spreads are 5.5 cents greater than at the NYSE. After controlling for selection biases effective spreads for marketable limit orders tend to be broadly similar across the NYSE and several of the other market centers, the notable exceptions being Island where effective spreads are 5 to 6 cents greater, and the other NASD market centers, where effective spreads are 5 to 9 cents greater. Differentials in realized spreads across market centers show a similar pattern, with the largest realized spreads observed at Island and the NASD market centers.

Execution rates for marketable limit orders vary widely. The Boston and Cincinnati Stock Exchanges and broker dealer firms Knight and Madhoff have execution rates ranging from 13 to 18 percent higher than the NYSE in the raw data. The Chicago Stock Exchange and other NASD dealers have execution rates for marketable limit orders that are modestly lower than the NYSE. Notably, the two ECN's have execution rates for marketable limit orders that are much (46 to 66%) lower than the NYSE. Controlling for selectivity biases has little impact on conclusions regarding execution rates for marketable limit orders. In particular, execution rates at the Island and Instinet ECNs remain about 65% and 40% lower than on the NYSE, respectively, after controlling for selection biases.

Although the ECN's have much lower execution rates for marketable limit orders, they have higher price improvement rates for the orders that they do execute. The higher improvement rate at Instinet survives adjustments for selection biases, but the higher improvement rate at Island does not. The Boston and Chicago Stock Exchanges and Madhoff Securities have higher price improvement rates for marketable limit orders even after controlling for selection biases, while the Cincinnati Exchange, the Philadelphia Exchange, Knight Securities, and other broker-dealers have lower price improvement rates than the NYSE.

Average execution speeds for marketable limit orders are always faster off the NYSE in the raw data, ranging from 21 seconds faster at Knight Securities to over 70 seconds faster at the Island ECN, at Madhoff Securities, and at the other NASD centers. Controlling for selectivity biases has a major effect on inference regarding execution speed, however. After such controls, every market center except Island shows slower execution speeds for marketable limit orders.

Finally, Table 12 reports on comparisons of the NYSE to other market centers, for non-marketable limit orders. After controlling for selection biases, each market center except Island and other NASD centers show larger realized spreads for non-marketable limit orders. Since realized spreads for non-marketable NYSE limit orders as reported on Table 9 are near zero, realized spreads for these limit orders off the NYSE are generally positive. That is, the non-marketable limit orders executed off the NYSE and contained in the Dash 5 data pay for liquidity, as opposed to being paid to provide liquidity.

Execution rates for non-marketable limit orders are much higher off the NYSE in the cases of the Boston, Cincinnati, Chicago, and Philadelphia Stock Exchanges, and also for Knight and Madhoff Securities. In contrast, execution rates for non-marketable limit orders are significantly lower at the two ECN's and at the other NASD market centers, as compared to the

NYSE. Controlling for selectivity biases has little or no effect on inference regarding execution rates for non-marketable limit orders.

4. Conclusions

This study provides an empirical summary of several measures of market quality, based on data reported by individual market centers as required by SEC rule 11AC 1-5. The study focuses on 500 NYSE-listed common stocks during the months of July and August, 2002, and on ten market centers that reported market quality statistics for sample stocks.

A stated SEC goal in enacting rule 11AC 1-5 is to provide investors with statistical data that can be used to compare execution quality across market centers. This study highlights some difficulties that remain, even with access to the Dash 5 data. In particular, market centers self-select the stocks in which they will make markets. Further, even for stocks that are traded at multiple market centers, selection biases in which orders are routed to which markets arise. In short, comparisons of average market quality statistics across market centers provide little meaningful information unless explicit controls for selection bias are made. Unfortunately, implementing such controls may well be beyond the sophistication of many individual investors that the SEC intended to benefit from Dash 5 data.

This study reports on Probit regression specifications, the results of which confirm the presence of selection biases in Dash 5 data. Smaller orders in large capitalization, high volume stocks, and orders originating with uninformed traders are significantly more likely to be completed at venues other than the NYSE. Conclusions as to several market quality measures are sensitive to whether corrections for selection biases are made. Most notably, average effective spreads for market orders are significantly higher at the NYSE if no selectivity bias adjustments are made, but are similar on and off the NYSE once selectivity bias is corrected for.

This study evaluates two regression-based methods of controlling for selectivity bias. The first simply includes economic variables that are known to be determinants of trade executions costs in the regression framework along with indicator variables that identify the market centers of interest. The second is the two-stage procedure advocated by advocated by Heckman (1979) and Maddala (1983). This method involves first estimating a probit specification for the choice of venue, creating two new variables from the probit estimation, and including these new variables in a regression specification as controls for selection bias. In the present context the two variables constructed from the Probit estimation can be reasonably interpreted as measures of order execution ease. A striking conclusion that can be drawn for the results reported here is that, while controlling for selection biases does affect inference, the specific method of control, whether the simple inclusion of relevant economic variables in a regression framework or the two-stage probit estimation, has very little practical effect on inference regarding market quality. A conclusion that simple regression-based methods that rely on the inclusion of economic variables known to affect trade execution costs as controls for selection biases works as well as more complex two-stage procedures appears to be well supported.

The results reported here leave an unresolved question. Prior studies that used the public trade and quote data to examine execution costs for NYSE-listed stocks, including Lee (1993) and Bessembinder and Kaufman (1997), report slightly lower execution costs on the NYSE, even without corrections for selection biases. The present study, as well as Lipson (2003), focus on more recent data contained in the Dash 5 reports, and report lower average execution costs off the NYSE, if no corrections for selection biases are made. This difference in conclusions might reflect imperfections in cost measurements constructed from trade and quote data, or it might reflect improvements over time in the competitiveness of off-NYSE markets. Alternately, it might reflect biases that result from Dash 5 reports focusing on only a subset of total order flow or due to the lack of independent audits of market centers' Dash 5 reports. Ascertaining why the recent Dash 5 data suggests lower execution costs off the NYSE as compared to earlier trade-and-quote-based research comprises an interesting topic for future research.

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Table 1: Average Spreads for Market Orders, and Characteristics of Stocks traded at each Market Center. The sample includes 500 NYSE-listed stocks of varying market capitalization, and results pertain to July and August of 2002. Reported is the number of sample stocks that were traded at each of ten market centers, the mean effective spread for trades in those stocks, the mean price impact (effective spread less realized spread), the mean size of a market order on each market, and the mean June 2002 trading volume (in millions of shares) and mean June 30, 2002 market capitalization (in millions of dollars) for the stocks traded on each market. Each mean is the simple average across the stocks traded at the indicated market center.

Market Center	Number of Sample Stocks Traded	Mean Effective Spread (Cents)	Mean Price Impact (Cents)	Mean Sample Order Size	Number of Sample Orders Entered (000)	June 2002 Trading Volume	June 2002 Market Capitalization
Boston	119	4.01	0.94	499	2,319	133.9	52,401
Chicago	148	4.43	1.87	490	1,003	108.2	42,260
Cincinnati	77	3.55	1.10	521	830	172.1	66,483
Instinet	129	1.95	3.77	729	42	123.6	48,416
Island	0				0		
Knight	163	4.89	2.76	510	1440	98.4	38,405
Madoff	109	2.81	1.17	399	1927	145.2	56,932
NASD-other	113	7.19	1.06	798	73	139.0	54,424
New York	500	6.95	5.49	629	31,557	39.5	13,689
Philadelphia	111	4.02	1.29	428	258	136.7	54,318

Table 2: Average Spreads for Marketable Limit Orders, and Characteristics of Stocks traded at each Market Center. The sample includes 500 NYSE-listed stocks of varying market capitalization, and results pertain to July and August of 2002. Reported is the number of sample stocks that were traded at each of ten market centers, the mean effective spread for trades in those stocks, the mean price impact (effective spread less realized spread), the mean size of a market order on each market, and the mean June 2002 trading volume (in millions of shares) and mean June 30, 2002 market capitalization (in millions of dollars) for the stocks traded on each market. Each mean is the simple average across the stocks traded at the indicated market center.

Market Center	Number of Sample Stocks Traded	Mean Effective Spread (Cents)	Mean Price Impact (Cents)	Mean Order Size	Number of Sample Orders Entered (000)	Mean June 2002 Trading Volume	Mean June 2002 Market Capitalization
Boston	119	3.14	1.54	1053	264	133.9	52,403
Chicago	139	5.70	4.42	978	267	115.1	44,968
Cincinnati	77	2.36	-0.22	1018	74	172.1	66,483
Instinet	151	3.90	3.73	605	718	106.1	41,440
Island	429	7.45	2.29	510	2,242	47.6	16,478
Knight	162	3.87	2.41	1300	284	99.0	38,642
Madoff	106	2.50	1.93	780	94	148.1	57,977
NASD-other	161	6.48	4.23	601	361	99.6	38,880
New York	500	4.51	5.10	743	26,165	39.5	13,689
Philadelphia	111	5.76	3.19	904	24	139.5	54,402

Table 3: Average Spreads for Non-marketable Limit Orders, and Characteristics of Stocks traded at each Market Center. The sample includes 500 NYSE-listed stocks of varying market capitalization, and results pertain to July and August of 2002. Reported is the number of sample stocks that were traded at each of ten market centers, the mean effective spread for trades in those stocks, the mean price impact (effective spread less realized spread), the mean size of a market order on each market, and the mean June 2002 trading volume (in millions of shares) and mean June 30, 2002 market capitalization (in millions of dollars) for the stocks traded on each market. Each mean is the simple average across the stocks traded at the indicated market center.

Market Center	Number of Sample Stocks Traded	Mean Realized Spread (Cents)	Mean Order Size	Number of Sample Orders Entered (000)	Mean June 2002 Trading Volume	Mean June 2002 Market Capitalization
Boston	116	4.45	1040	369	137.2	53,739
Chicago	143	2.98	1063	245	111.9	43,709
Cincinnati	77	2.47	984	159	172.1	66,483
Instinet	150	0.76	692	2369	106.8	41,716
Island	429	-1.14	420	21,799	45.9	15,904
Knight	163	3.84	1399	426	98.4	38,405
Madoff	106	3.49	765	163	148.1	57,977
NASD-other	122	-2.92	215	1,608	130.1	50,955
New York	500	-0.16	595	81,379	39.5	13,689
Philadelphia	110	-0.13	904	44	137.9	54,627

Table 4: Selection Bias and Average Effective Spreads for Market Orders; NYSE versus all other market centers. Panels A and C report results of estimating equations for mean effective spreads on and off the NYSE. The dependent variable for results reported on Panels A and C is the mean effective spread for stock i at market center s. $NYSE_{is}$ and $NONNYSE_{is}$ are indicator variables that equal one when market s is the NYSE and when market s is not the NYSE, respectively, and zero otherwise. All other explanatory variables used for results reported on Panels A and C are expressed as deviations from the cross-sectional mean of the variable, which facilitates the interpretation of coefficients on the indicator variables as effective spreads evaluated at the cross-sectional sample mean. $LOGORDERS_i$ is the logarithm of the total number of orders in stock i completed at any market during the sample. $IMPACT_{is}$ is the mean price impact of stock i orders completed at market s. $INVPRICE_i$ is the inverse of the value-weighted mean transaction price for stock i. $STDORDERSIZE_{is}$ is the mean order size for stock i orders at market s, relative to total June 2002 trading volume in stock s. Panel B reports results of Probit estimation, where the dependent variable equals one for NYSE observations and zero for off-NYSE observations. $LOGCAP_i$ and $LOGVOL_i$ are the logarithm of June 2002 market capitalization and June 2002 trading volume for stock i , respectively. $LOGRELORDERSIZE_{is}$ is the logarithm of the mean order size in stock i at market s relative to the mean stock i order size computed across all markets. $QSPREAD_{is}$ is the mean quoted (NBBO) bid-ask spread for stock i at the time of market s orders. γ_{1is} and γ_{2is} are variables created from the Probit estimation that control for selection biases.

Panel A: OLS Estimation of Conditional Mean Effective Spreads

$$ESPR_{is} = \alpha_1 NYSE_{is} + \alpha_2 NONNYSE_{is} + \alpha_3 LOGORDERS_i + \alpha_4 IMPACT_{is} + \alpha_5 INVPRICE_i + \alpha_6 STDORDERSIZE_{is} + \varepsilon_{is}$$

	α_1	α_2	α_3	α_4	α_5	α_6		
Coefficient	6.951	4.194						
(t-stat)	24.57	20.43						
Coefficient	5.330	5.517[a]	-0.912	0.172	-8.954	0.482		
(t-stat)	17.50	23.97	-8.69	4.65	-6.69	3.10		

Panel B: Probit Regression Equation for the Likelihood an Order is Routed to the NYSE

$$Prob(NYSE_{is} = 1) = g(\beta_0 + \beta_1 LOGCAP_{is} + \beta_2 LOGVOL_{is} + \beta_3 LOGRELORDERSIZE_{is} + \beta_4 IMPACT_{is} + \beta_5 QSPREAD_{is})$$

	β_1	β_2	β_3	β_4	β_5			
Coefficient	-0.158	-0.219	0.184	0.021	-0.013			
(χ^2 –stat)	14.20	20.16	3.04*	28.20	2.47*			

Panel C: Second Stage OLS Estimation of Conditional Mean Effective Spreads

$$ESPR_{is} = \alpha_1 NYSE_{is} + \alpha_2 NONNYSE_{is} + \alpha_3 NYSE_{is} * \gamma_{1is} + \alpha_4 NONNYSE_{is} * \gamma_{2is} + \alpha_5 LOGORDERS_i + \alpha_6 IMPACT_{is} + \alpha_7 INVPRICE_i + \alpha_8 STDORDERSIZE_{is} + \varepsilon_{is}$$

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
Coefficient	5.020	4.965[a]	-4.337	-3.794				
(t-stat)	13.55	21.38	-7.74	-6.40				
Coefficient	5.199	5.473[a]	-0.402	0.133	-0.887	0.176	-8.907	0.468
(t-stat)	14.36	22.84	-0.37*	0.11*	-3.60	4.48	-6.63	2.88

* denotes a chi-square or t-statistic that is *not* significant an the .05 level.

[a] denotes an α_2 estimate that does *not* differ significantly at the .05 level from the corresponding α_1 estimate.

Table 5: Correlation Matrix for Effective Spreads, Selected Explanatory Variables, and Selectivity Bias Variables Obtained from Probit Estimation. Reported are Pearson Correlation Coefficients computed from averages for market orders by stock and market center. γ_1 and γ_2 are variables created from a Probit specification where the dependent variable equals one for orders routed to the NYSE. ESPR is the average effective bid-ask spread for the stock at the market center. LOGORDERS is the logarithm of the total number of orders in the stock completed at any market during the sample. IMPACT is the mean price impact of orders in each stock at each market. INVPRICE is the inverse of the value-weighted mean transaction price for each stock. LOGCAP and LOGVOL are the logarithm of June 2002 market capitalization and June 2002 trading volume for each stock. P-values are reported in parentheses.

	γ_2	ESPR	LOG CAP	LOGVOL	IMPACT	LOG ORDERS	INVPRICE
γ_1	.958 (0.000)	-.309 (0.000)	.947 (0.000)	.941 (0.000)	-.160 (0.000)	.934 (0.000)	-.281 (0.000)
γ_2		-.354 (0.000)	.937 (0.000)	.953 (0.000)	-.191 (0.000)	.952 (0.000)	-.284 (0.000)
ESPR			-.255 (0.000)	-.371 (0.000)	.345 (0.000)	-.336 (0.000)	-.058 (0.028)
LOGCAP				.917 (0.000)	0.019 (0.462)	.947 (0.000)	-.389 (0.000)
LOGVOL					-.038 (0.151)	.973 (0.000)	-.204 (0.000)
IMPACT						-.008 (0.741)	-.096 (0.000)
LOGORDERS							-.289 (0.000)

Table 6: Selection Bias and Average Effective Spreads for Marketable Limit Orders; NYSE versus all other market centers. Panels A and C report results of estimating equations for mean effective spreads on and off the NYSE. The dependent variable for results reported on Panels A and C is the mean effective spread for stock i at market center s. $NYSE_{is}$ and $NONNYSE_{is}$ are indicator variables that equal one when market s is the NYSE and when market s is not the NYSE, respectively, and zero otherwise. All other explanatory variables used for results reported on Panels A and C are expressed as deviations from the cross-sectional mean of the variable, which facilitates the interpretation of coefficients on the indicator variables as effective spreads evaluated at the cross-sectional sample mean. $LOGORDERS_i$ is the logarithm of the total number of orders in stock i completed at any market during the sample. $IMPACT_{is}$ is the mean price impact of stock i orders completed at market s. $INVPRICE_i$ is the inverse of the value-weighted mean transaction price for stock i. $STDORDERSIZE_{is}$ is the mean order size for stock i orders at market s, relative to total June 2002 trading volume in stock s. Panel B reports results of Probit estimation, where the dependent variable equals one for NYSE observations and zero for off-NYSE observations. $LOGCAP_i$ and $LOGVOL_i$ are the logarithm of June 2002 market capitalization and June 2002 trading volume for stock i, respectively. $LOGRELORDERSIZE_{is}$ is the logarithm of the mean order size in stock i at market s relative to the mean stock i order size computed across all markets. $QSPREAD_{is}$ is the mean quoted (NBBO) bid-ask spread for stock i at the time of market s orders. γ_{1is} and γ_{2is} are variables created from the Probit estimation that control for selection biases.

Panel A: OLS Estimation of Conditional Mean Effective Spreads

$$ESPR_{is} = \alpha_1 NYSE_{is} + \alpha_2 NONNYSE_{is} + \alpha_3 LOGORDERS_i + \alpha_4 IMPACT_{is} + \alpha_5 INVPRICE_i + \alpha_6 STDORDERSIZE_{is} + \varepsilon_{is}$$

	α_1	α_2	α_3	α_4	α_5	α_6		
Coefficient	4.510	5.753						
(t-stat)	14.45	30.01						
Coefficient	3.050	6.287	-1.029	-0.036	-7.817	0.049		
(t-stat)	9.39	33.04	-9.72	-1.52*	-6.56	0.52*		

Panel B: Probit Regression Equation for the Likelihood a Order is Routed to the NYSE

$$Prob(NYSE_{is} = 1) = g(\beta_0 + \beta_1 LOGCAP_{is} + \beta_2 LOGVOL_{is} + \beta_3 LOGRELORDERSIZE_{is} + \beta_4 IMPACT_{is} + \beta_5 QSPREAD_{is})$$

	β_1	β_2	β_3	β_4	β_5			
Coefficient	-0.046	-0.248	0.008	0.015	-0.034			
(χ^2 –stat)	1.62*	36.13	0.01*	10.21	18.90			

Panel C: Second Stage OLS Estimation of Conditional Mean Effective Spreads

$$ESPR_{is} = \alpha_1 NYSE_{is} + \alpha_2 NONNYSE_{is} + \alpha_3 NYSE_{is} * \gamma_{1is} + \alpha_4 NONNYSE_{is} * \gamma_{2is} + \alpha_5 LOGORDERS_i + \alpha_6 IMPACT_{is} + \alpha_7 INVPRICE_i + \alpha_8 STDORDERSIZE_{is} + \varepsilon_{is}$$

	α_1	α_2	α_3	α_4	α_5	α_6	α_7	α_8
Coefficient	3.696	6.090	-2.572	-3.928				
(t-stat)	9.61	30.42	-3.55	-5.27				
Coefficient	3.802	6.240	10.357	11.953	-2.776	0.015	-8.993	-0.024
(t-stat)	10.37	32.71	8.45	7.86	-12.20	0.61*	-7.63	-0.25*

* denotes a chi-square or t-statistic that is *not* significant an the .05 level.

[a] denotes an α_2 estimate that does *not* differ significantly at the .05 level from the corresponding α_1 estimate.

Table 7: Probit estimation of the likelihood that a non-marketable limit order is routed to the NYSE. The dependent variable equals one for NYSE observations and zero for off-NYSE observations. $LOGCAP_i$ and $LOGVOL_i$ are the logarithm of June 2002 market capitalization and June 2002 trading volume for stock i, respectively. $LOGRELORDERSIZE_{is}$ is the logarithm of the mean order size in stock i at market s relative to the mean stock i order size computed across all markets. $QSPREAD_{is}$ is the mean quoted (NBBO) bid-ask spread for stock i at the time of market s orders.

Probit Regression Equation for the Likelihood a Order is Routed to the NYSE

$$Prob(NYSE_{is}) = 1 = g(\beta_0 + \beta_1 LOGCAP_{is} + \beta_2 LOGVOL_{is} + \beta_3 LOGRELORDERSIZE_{is})$$

	β_1	β_2	β_3
Coefficient	-0.055	-0.254	0.512
χ^2–stat (p-value)	2.24 (0.134)	39.11 (0.000)	57.90 (0.000)

Table 8: Average Effective Spreads by Order Size Category, NYSE versus all other Venues. Row 1 reports the mean spread computed across all orders in the sample. Row 2 reports intercepts obtained in a regression specification that includes the same zero-mean economic variables as Panel A of Table 4. Row 3 reports intercepts obtained in a regression specification that also includes selectivity-bias adjustment variables obtained from Probit regressions that predict whether an order will be routed to the NYSE. Row 4 reports intercepts obtained in a regression specification that includes both selectivity bias adjustment variables and the zero-mean economic variables, as in Panel C of Table 4. P-val denotes the probability value for the hypothesis that coefficient estimates are equal across the NYSE and other venues.

Panel A: Market Orders															
	All Orders			**100-499 Shares**			**500-1999 Shares**			**2000-4999 Shares**			**5000-9999 Shares**		
Controls Used	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**
1. None	6.951	4.194	0.000	5.795	3.610	0.000	8.491	5.015	0.000	14.576	8.039	0.000	22.243	10.898	0.000
2. Regression Variables	5.330	5.517	0.008	4.644	4.510	0.744	6.560	6.381	0.637	10.166	11.205	0.070	15.751	15.576	0.864
3. Selectivity Bias	5.020	4.965	0.899	4.302	4.236	0.881	5.993	5.588	0.341	8.653	10.061	0.037	14.245	13.428	0.478
4. Selectivity Bias & Regression Variables	5.199	5.473	0.528	4.560	4.592	0.941	6.448	6.141	0.443	9.610	10.830	0.047	14.895	14.370	0.625
Panel B: Marketable Limit Orders															
	All Orders			**100-499 Shares**			**500-1999 Shares**			**2000-4999 Shares**			**5000-9999 Shares**		
Controls Used	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**
1. None	4.510	5.753	0.001	4.164	5.157	0.005	4.703	6.314	0.004	5.386	6.608	0.045	6.387	5.433	0.024
2. Regression Variables	3.050	6.287	0.000	2.897	5.730	0.000	2.789	7.077	0.000	3.215	7.601	0.000	4.316	6.561	0.000
3. Selectivity Bias	3.696	6.090	0.000	3.409	5.493	0.000	3.581	6.878	0.000	2.522	6.865	0.000	3.528	6.002	0.000
4. Selectivity Bias & Regression Variables	3.802	6.240	0.000	3.756	5.723	0.000	3.937	7.169	0.000	4.665	7.502	0.000	4.262	6.439	0.000

Table 9: Various Measures of Order Execution Quality, NYSE versus all other Venues. Row 1 reports the mean of the indicated measure computed across all orders in the sample. Row 2 reports intercepts obtained in a regression specification that includes the same zero-mean economic variables as Panel A of Table 4. Row 3 reports intercepts obtained in a regression specification that also includes selectivity-bias adjustment variables obtained from Probit regressions that predict whether an order will be routed to the NYSE. Row 4 reports intercepts obtained in a regression specification that includes both selectivity bias adjustment variables and the zero-mean economic variables, as in Panel C of Table 4. P-val denotes the probability value for the hypothesis that coefficient estimates are equal across the NYSE and other venues.

Panel A: Market Orders												
	Realized Spread			**Percent Executed**			**Percent Improved**			**Execution Speed**		
Controls Used	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**
1. None	1.466	2.272	0.107	98.978	90.609	0.000	26.572	38.447	0.000	25.367	15.718	0.000
2. Regression Variables	0.018	1.557	0.000	98.340	90.844	0.000	29.300	35.268	0.000	21.189	18.542	0.008
3. Selectivity Bias	3.311	2.396	0.158	98.855	90.510	0.000	30.972	36.706	0.000	22.721	19.560	0.002
4. Selectivity Bias & Regression Variables	3.216	2.443	0.149	99.119	90.689	0.000	30.869	35.638	0.000	22.657	19.589	0.003
Panel B: Marketable Limit Orders												
	Realized Spread			**Percent Executed**			**Percent Improved**			**Execution Speed**		
Controls Used	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**	**NYSE**	**Other**	**P-val.**
1. None	-0.587	2.794	0.000	79.404	62.310	0.000	13.696	19.312	0.000	80.240	28.220	0.000
2. Regression Variables	-1.241	2.730	0.000	80.232	61.913	0.000	17.916	17.704	0.758	51.635	38.969	0.003
3. Selectivity Bias	0.452	2.593	0.000	76.190	61.034	0.000	18.014	17.494	0.483	37.505	33.051	0.354
4. Selectivity Bias & Regression Variables	0.537	2.632	0.000	76.545	61.006	0.000	18.105	17.565	0.461	41.312	34.986	0.160
Panel C: Non-marketable Limit Orders												
	Realized Spread			**Percent Executed**			**Percent Improved**			**Execution Speed**		
1. None	-0.156	1.183	0.000	21.475	39.511	0.000						
2. Regression Variables	0.354	0.980	0.118	28.109	36.868	0.000						
3. Selectivity Bias	0.595	0.762	0.696	25.998	35.212	0.000						
4. Selectivity Bias & Regression Variables	0.553	0.831	0.516	26.684	34.900	0.000						

Table 10: Quality Comparisons for Market Orders, NYSE versus Individual Market Centers. Each cell of the table reports the difference between a regression intercept obtained for the indicated market and the corresponding regression intercept obtained for the NYSE. Row 1 reports results when no other explanatory variables are included in the regression. Row 2 reports intercepts obtained in a regression specification that includes the same zero-mean economic variables as Panel A of Table 4. Row 3 reports intercepts obtained in a regression specification that also includes selectivity-bias adjustment variables obtained from Probit regressions that predict whether an order will be routed to the NYSE. The p-value for the hypothesis that the difference is zero is reported in parentheses.

	Boston	**Cincinnati**	**Chicago**	**Island**	**Instinet**	**Knight**	**Madhoff**	**Philadelphia**	**Other**
Panel A: Effective Spreads									
1. No Controls	-2.946 (0.000)	-3.406 (0.001)	-2.403 (0.002)		-4.889 (0.000)	-2.066 (0.005)	-4.118 (0.000)	-2.935 (0.000)	0.510 (0.601)
2. Regression Variables	0.894 (0.531)	0.302 (0.860)	0.618 (0.595)		-1.355 (0.133)	-0.273 (0.712)	-0.750 (0.591)	0.897 (0.458)	5.350 (0.000)
3. Selectivity Bias	-1.492 (0.873)	0.353 (0.764)	0.431 (0.643)		-3.656 (0.006)	0.211 (0.783)	-1.959 (0.202)	-0.094 (0.909)	8.064 (0.000)
Panel B: Realized Spreads									
1. No Controls	1.601 (0.216	0.980 (0.541)	1.158 (0.325)		-3.233 (0.012)	0.662 (0.550)	0.191 (0.888)	1.258 (0.347)	4.474 (0.002)
2. Regression Variables	-1.573 (0.481)	-3.443 (0.200)	-1.202 (0.505)		-1.215 (0.386)	1.966 (0.091)	-2.741 (0.212)	-0.424 (0.824)	5.201 (0.002)
3. Selectivity Bias	0.998 (0.672)	-2.128 (0.633)	-0.304 (0.834)		-4.533 (0.022)	-0.689 (0.567)	-2.813 (0.293)	-0.018 (0.99	7.134 (0.014)
Panel C: Percent Executed									
1. No Controls	0.874 (0.000)	0.985 (0.000)	-0.118 (0.668)		-29.660 (0.000)	0.744 (0.000)	-0.318 (0.441)	-0.276 (0.223)	-43.195 (0.000)
2. Regression Variables	1.227 (0.000)	1.394 (0.000)	-1.243 (0.005)		-29.004 (0.000)	0.865 (0.000)	-5.752 (0.000)	-0.717 (0.031)	-41.083 (0.000)
3. Selectivity Bias	0.892 (0.000)	1.006 (0.001)	-0.709 (0.039)		-24.224 (0.000)	0.774 (0.000)	-11.074 (0.000)	-2.549 (0.000)	-29.856 (0.000)
Panel D: Percent Improved									
1. No Controls	2.454 (0.012)	10.831 (0.000)	11.367 (0.000)		21.366 (0.000)	8.306 (0.000)	23.050 (0.000)	4.206 (0.000)	14.995 (0.000)
2. Regression Variables	-8.383 (0.000)	0.243 (0.868)	2.921 (0.014)		15.746 (0.000)	4.455 (0.000)	8.845 (0.000)	-5.407 (0.000)	-5.350 (0.005)

3. Selectivity Bias	1.558 (0.016)	3.955 (0.148)	5.236 (0.000)		25.027 (0.000)	3.524 (0.000)	5.515 (0.000)	-5.773 (0.000)	-19.064 (0.000)
Panel E: Execution Speed									
1. No Controls	-8.211 (0.000)	-14.942 (0.000)	-3.530 (0.029)		2.446 (0.031)	-14.637 (0.000)	-24.168 (0.000)	-9.611 (0.000)	-7.418 (0.000)
2. Regression Variables	-6.023 (0.002	-11.722 (0.000)	5.387 (0.026)		5.249 (0.000)	-11.351 (0.000)	-20.159 (0.000)	-2.711 (0.093)	-2.766 (0.058)
3. Selectivity Bias	0.451 (0.714)	-2.249 (0.527)	8.503 (0.000)		-0.005 (0.998)	-10.384 (0.000)	-20.584 (0.000)	2.873 (0.096)	-1.182 (0.625)

Table 11: Quality Comparisons for Marketable Limit Orders, NYSE versus Individual Market Centers. Each cell of the table reports the difference between a regression intercept obtained for the indicated market and the corresponding regression intercept obtained for the NYSE. Row 1 reports results when no other explanatory variables are included in the regression. Row 2 reports intercepts obtained in a regression specification that includes the same zero-mean economic variables as Panel A of Table 4. Row 3 reports intercepts obtained in a regression specification that also includes selectivity-bias adjustment variables obtained from Probit regressions that predict whether an order will be routed to the NYSE. The p-value for the hypothesis that the difference is zero is reported in parentheses.

Controls Used	**Boston**	**Cincinnati**	**Chicago**	**Island**	**Instinet**	**Knight**	**Madhoff**	**Philadelphia**	**Other**
Panel A: Effective Spreads									
1. No Controls	-1.371 (0.028)	-2.124 (0.006)	1.276 (0.033)	5.517 (0.000)	-0.627 (0.264)	-0.636 (0.236)	-2.008 (0.002)	1.599 (0.021)	2.145 (0.002)
2. Regression Variables	1.453 (0.029)	1.208 (0.160)	3.414 (0.000)	6.572 (0.000)	1.493 (0.006)	1.135 (0.028)	1.209 (0.083)	4.731 (0.000)	4.498 (0.000)
3. Selectivity Bias	-0.743 (0.535	-2.112 (0.401)	1.215 (0.160)	4.800 (0.000)	0.201 (0.776)	0.811 (0.216)	-1.565 (0.523)	0.147 (0.927)	9.709 (0.000)
Panel B: Realized Spreads									
1. No Controls	2.187 (0.018)	3.188 (0.006)	1.880 (0.031)	7.537 (0.000)	0.732 (0.369)	2.049 (0.010)	1.154 (0.234)	3.484 (0.002)	2.914 (0.003)
2. Regression Variables	1.453 (0.173)	1.116 (0.421)	3.771 (0.000)	7.249 (0.000)	1.846 (0.034)	2.160 (0.010)	0.987 (0.378)	4.808 (0.000)	4.797 (0.000)
3. Selectivity Bias	-0.069 (0.969)	-5.396 (0.157)	1.630 (0.055)	4.612 (0.000)	0.982 (0.342)	-0.665 (0.471)	-1.958 (0.598)	-0.106 (0.967)	6.496 (0.005)
Panel C: Percent Executed									
1. No Controls	18.631 (0.000)	16.339 (0.000)	-6.498 (0.000)	-66.245 (0.000)	-45.739 (0.000)	12.655 (0.000)	17.821 (0.000)	0.781 (0.468)	-12.785 (0.000)
2. Regression Variables	24.343 (0.000)	24.125 (0.000)	-0.426 (0.615)	-63.974 (0.000)	-40.352 (0.000)	15.263 (0.000)	24.918 (0.000)	7.304 (0.000)	-7.306 (0.000)
3. Selectivity Bias	21.687 (0.000)	23.121 (0.000)	-1.574 (0.217)	-65.759 (0.000)	-39.370 (0.000)	16.068 (0.000)	17.927 (0.000)	4.505 (0.041)	2.486 (0.000)
Panel D: Percent Improved									
1. No Controls	11.155 (0.000)	-2.564 (0.000)	14.535 (0.000)	4.580 (0.000)	9.870 (0.000)	3.639 (0.000)	22.286 (0.000)	0.724 (0.466)	-3.531 (0.000)
2. Regression Variables	4.483 (0.000)	-7.923 (0.000)	5.551 (0.000)	0.998 (0.235)	5.054 (0.000)	-0.885 (0.093)	14.515 (0.000)	-6.114 (0.000)	-7.183 (0.000)
3. Selectivity Bias	5.462 (0.000)	-5.187 (0.000)	9.342 (0.000)	1.644 (0.113)	4.128 (0.000)	-4.200 (0.000)	12.923 (0.000)	-1.975 (0.303)	-15.087 (0.000)

Panel E: Execution Speed									
1. No Controls	-34.832 (0.002)	-36.289 (0.003)	-47.620 (0.000)	-73.194 (0.000)	-34.811 (0.000)	-20.804 (0.028)	-73.500 (0.000)	-36.897 (0.000)	-78.875 (0.000)
2. Regression Variables	44.661 (0.000)	46.585 (0.000)	19.463 (0.005)	-37.684 (0.000)	23.133 (0.000)	29.175 (0.000)	9.261 (0.229)	47.805 (0.000)	40.677 (0.000)
3. Selectivity Bias	15.173 (0.188)	56.243 (0.000)	14.551 (0.046)	-40.459 (0.000)	5.773 (0.565)	18.504 (0.095)	15.463 (0.075)	76.274 (0.000)	70.901 (0.000)

Table 12: Quality Comparisons for Non-marketable Limit Orders, NYSE versus Individual Market Centers. Each cell of the table reports the difference between a regression intercept obtained for the indicated market and the corresponding regression intercept obtained for the NYSE. Row 1 reports results when no other explanatory variables are included in the regression. Row 2 reports intercepts obtained in a regression specification that includes the same zero-mean economic variables as Panel A of Table 4. Row 3 reports intercepts obtained in a regression specification that also includes selectivity-bias adjustment variables obtained from Probit regressions that predict whether an order will be routed to the NYSE. The p-value for the hypothesis that the difference is zero is reported in parentheses.

Controls Used	**Boston**	**Cincinnati**	**Chicago**	**Island**	**Instinet**	**Knight**	**Madhoff**	**Philadelphia**	**Other**
Panel A: Realized Spreads									
1. No Controls	4.604 (0.000)	2.622 (0.006)	3.249 (0.000)	-1.400 (0.001)	0.944 (0.167)	3.998 (0.000)	3.645 (0.000)	0.026 (0.977)	-2.876 (0.002)
2. Regression Variables	3.719 (0.000)	1.700 (0.103)	2.492 (0.000)	-1.906 (0.001)	0.360 (0.620)	3.444 (0.000)	2.781 (0.003)	0.739 (0.441)	-3.818 (0.000)
3. Selectivity Bias	3.823 (0.014)	2.437 (0.307)	2.469 (0.009)	-1.765 (0.002)	0.234 (0.790)	3.301 (0.000)	3.153 (0.000)	1.480 (0.373)	-0.856 (0.940)
Panel B: Percent Executed									
1. No Controls	67.451 (0.000)	54.574 (0.000)	34.725 (0.000)	-15.501 (0.000)	-8.720 (0.000)	32.089 (0.000)	46.543 (0.000)	33.723 (0.000)	-20.481 (0.000)
2. Regression Variables	60.327 (0.000)	50.092 (0.000)	30.863 (0.000)	-16.768 (0.000)	-10.856 (0.000)	28.759 (0.000)	42.012 (0.000)	30.169 (0.000)	-25.036 (0.000)
3. Selectivity Bias	65.542 (0.000)	52.732 (0.000)	34.183 (0.000)	-14.172 (0.000)	-9.884 (0.000)	23.042 (0.000)	40.265 (0.000)	36.659 (0.000)	-9.015 (0.419)

Figure 1: The Regression Approach to Controlling for Selection Bias