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A New Estimate of Transaction Costs

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Abstract

Transaction costs are important for a host of empirical analyses from market efficiency to international market research. But transaction costs estimates are not always available; or where available, cumbersome to use and expensive to purchase. We present a model that requires only the time series of daily security returns to endogenously estimate the effective transaction costs for any firm, exchange, or time period and do so very inexpensively. The defining feature that allows for the estimation of transaction costs is the high incidence of zero returns. Incorporating these zero returns in the return generating process, the model provides continuous estimates of average round-trip transaction costs from 1963 to 1990 that are 1.2% and 10.3% for large and small decile firms, respectively. These estimates are highly correlated (87%) with the most commonly used transaction costs estimator: spread-plus-commissions as used by Stoll and Whaley (1989) and Bhardwaj and Brooks (1992).

Key Words: Transaction costs, Zero returns, Return generating process, Spread

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A New Estimate of Transaction Costs

How much does it cost to trade in common market securities? How large are transaction costs that include only the bid-ask spread and any applicable commission costs? The common notions that these costs are trivial, or, at worst, small in relation to a trade are mistaken. The Plexus Group (1996) estimates that these costs are at least 1.0% to 2.0% for institutions trading in the largest size decile of NYSE/AMEX firms. Such trades account for over 20% of reported trading volume. Stoll and Whaley (1982) reported quoted spread and commission costs of 2.0% to 9.0% for large and small decile NYSE firms, respectively. Bwardwaj and Brooks (1992) reported median quoted spread and commission costs between 2.0% to 12.5% for NYSE securities in price ranges greater than $20.00 and those less than $5.00, respectively. These costs are important in determining investment performance and "can substantially reduce or possibly outweigh the expected value created by an investment strategy (Keim and Madhavan 1995)." Despite the increasingly prominent role transaction costs are assuming in both practice and research, estimates of transaction costs are not always available or, where available, subject to considerable expense and error.

This paper presents a new model to obtain estimates of transaction costs regardless of time period, exchange, or firm. The primary strength of this model is that it requires only the time-series of daily security returns, which are almost universally available, to obtain continuous estimates of transaction costs. Hence, it is relatively easy and inexpensive to obtain continuous estimates of transaction costs for all firms and time periods for which daily security returns are available. The ease in obtaining this estimate of transaction costs will greatly alleviate the problems of incorporating transaction costs into a host of empirical studies that address issues such as market efficiency, market structure analysis, and international market research.[1] In addition, security traders can utilize these transaction costs estimates to judge the competitiveness of their realized trading costs or expected profits.

Researchers and traders who needed transaction cost estimates generally relied on one of two methods: proxy variables and the spread-plus-commission estimator. Studies such as Karpoff and Walkling (1988) and Bhushan (1994), used the proxy variables of price, trading volume, firm size, and the number of shares outstanding under the assumption that these variables are negatively related to transaction costs. Researchers have generally recognized that proxy variables cannot directly estimate the effects of transaction costs and that these variables may capture the effect of variables that are not related to transaction costs.

The most direct estimator of transaction costs is the spread-plus-commission, which is the sum of the proportional bid-ask spread, calculated using current specialist quotes, and a representative commission from a brokerage firm. However, several problems are apparent

[1] For example, international studies (Kato and Loewenstein 1995) where transaction cost estimates are often unavailable, market efficiency tests (Karpoff and Walkling 1988 and Bhushan 1994) that span long time periods before transaction cost data were collected, and market structure (Huang and Stoll 1996) analyses that are presently restricted to recent, single year periods where NYSE/AMEX cost data are more commonly available will benefit from this model. Additionally, inter-exchange studies are often hampered because "most trades for NASDAQ listed firms will not carry a commission fee, since the broker/dealer is compensated through *the buy-sell spread in the market (Plexus Group)" while NYSE/AMEX listed firms* carry a separate commission charge, if applicable. Even with intraday data (ISSM, TORQ, and TAQ) many empirical studies find these data cumbersome, and often impossible, to use due to the sheer volume of data and because it is provided on a year by year basis.

with the spread-plus-commission estimator. First, trades on the NYSE and AMEX are often consummated at prices that are inside the bid-ask quotes.[2] Lee and Ready (1991) and Petersen and Fialkowski (1994) provided evidence that many trades are inside the quoted bid-ask spread. Roll (1984) provided an estimate of the "effective spread," but his model cannot provide estimates for more than half of the firms listed on the NYSE/AMEX exchange (Harris 1990). Second, the commission schedule of brokers often reflects more than the costs of executing a trade. For example, Johnson (1994) argued that execution costs are often bundled with "softdollars" that pay for research which may or may not be related to the specific trade. In effect, the spread-plus-commission estimator, where available, overstates the effective transaction costs.

Despite these problems, the quoted spread-plus-commission is presently the best available estimator of transaction costs.[3] However, obtaining continuously quoted bid-ask spreads for all firms and time periods where security returns exist is difficult and, at times, impossible. The intraday Trades, Orders, Reports and Quotes (TORQ) and Trades and Quotes (TAQ) databases provide only monthly basis quotes from 1991 and 1993, respectively. Additional sources of quotes such as Fitch restrict quotes to only NYSE firms while the Institute in the Study of Security Markets (ISSM) intraday database provides quotes on an annual basis only from 1987 to 1991. The problems in estimating the spread

[2] Grossman and Miller (1988) argued that the quoted spread cannot serve as a measure of the cost of supplying immediacy for typical trading orders. They cite other "problems" with the spread such as the timing of trades or the likelihood that a buyer and seller will arrive in the market to transact at the same time and at the same price.

[3] It should be noted that the spread-plus-commission estimator is a narrow view of transaction costs. Merton (1987) argued that the cost of marginal traders' time used in developing a decision rule when information is released is a transaction cost. Berkowitz, Logue, and Noser (1988) argued that the impact on price when an order is executed is part of transaction costs.

are exemplified by Stoll and Whaley (1983) and Bhardwaj and Brooks (1992). Stoll and Whaley (1983) focused only on NYSE firms and used only the last trading day of the year to obtain the spread. Bhardwaj and Brooks (1992) used just 20 NYSE firms in each of five price ranges sampled once a year to represent the transaction costs of all NYSE/AMEX firms. Amihud and Mendelson (1986) relied on the annual Stoll and Whaley quotes.

In this paper, we propose a model of security returns that avoids the limitations of the transaction cost proxies and spread-plus-commission estimators because it incorporates the effects of transaction costs directly on daily security returns. In our model, this effect is modeled through the incidence of zero returns. The premise of this model is that if the value of the public (and private) information signal is insufficient to exceed the costs of trading then the marginal investor will either limit or not trade altogether thereby inhibiting information exchange and causing zero returns. The estimators' from this model are the marginal trader's effective transaction costs.

The model is rooted in the adverse selection framework of Glosten and Milgrom (1985) and Kyle (1985).[4] An integral aspect of this stream of literature is that the marginal (informed) investor will trade on new (or accumulated) information not reflected by the price of a security only if the trade yields a profit net of transaction costs. [5] The cost of transacting constitutes a *threshold* that must be exceeded before a security's return will begin to reflect new information. The price of a security with high transaction costs will

[4] Constantinides (1986), Merton (1987), and Dumas and Luciano (1991) model similar trading behaviors applied to portfolio returns.
[5] In these models, trading volume is used to represent the effects of transaction costs.

tend to move less frequently, and there will be more periods of zero returns, than the price of a security with low transaction costs. This paper provides evidence that security returns themselves demonstrate the effects of transaction costs through the incidence of zero returns.

We find that zero returns are very frequent. As much as 80 percent of the smallest firm's returns are zero and some of the largest firms have 30 percent zero returns. Using NYSE and AMEX data on individual securities for the period 1963 to 1990, we test two hypotheses related to the zero returns. First, that the frequency of zero returns is related to proxy variables commonly used to measure transaction costs and second, that the frequency of zero returns is inversely related to the market return, on an absolute value basis, which is used as a proxy for public information relevant to the pricing of assets. Consistent with the first hypothesis, we find evidence that the frequency of zero returns is inversely related to firm size, and directly related to the quoted bid-ask spread and Roll's measure of the effective spread. With respect to the second hypothesis, we find that the average proportion of zero returns is inversely related to the magnitude of the market's return. Only for larger absolute market returns is the transaction costs threshold exceeded for the marginal trader and the consequent frequency of zero return proportions diminished.

We use the limited dependent variable (LDV) model of Tobin (1958) and Rosett (1959)[6] to estimate transaction costs based on the relative frequency of zero returns. We apply the LDV model to daily security returns of all individual NYSE/AMEX securities from 1963

[6] The LDV model has been used in a variety of empirical studies in finance and accounting. See Maddala (1983, 1991) for a review of the applications.

to 1990. The LDV model's estimates of transaction costs show that the average round trip transaction costs range from 1.2% for the average firm in the largest size decile to 10.3% for the average firm in the smallest decile. This measure of transaction costs is significantly and positively correlated with the spread-plus-commission measure used by Stoll and Whaley over the period 1962 to 1979 and the spread-plus-commission measure used by Bhardwaj and Brooks over the period 1982 to 1986. Time-series analysis indicates that our estimates closely track these spread-plus-commission estimates with a correlation coefficient of 87%. However, on average, our estimates are 15% to 50% smaller than the spread-plus-commission estimates for small and large size decile firms, respectively. This is consistent with the findings of Lee and Ready (1991) and Petersen and Fialkowski (1994).

The paper is organized as follows. In section 1, we discuss the behavior of security returns in the presence of transaction costs. Section 2 presents the LDV model and introduces the LDV measure. Section 3 describes the data, Section 4 presents the results of testing the two LDV model hypotheses and Section 5 presents the tests of the LDV measures of transaction costs. The paper concludes with section 6.

1. Security Returns and Transaction Costs

As a limiting case, the absence of transaction costs allows investors the opportunity to continually trade in all securities. If transaction costs are not zero, the marginal investor will weigh the costs of trading against the expected gains (Constantinides 1986 and Dumas and Luciano 1991). Amihud and Mendelson (1986) analyze the effects of transaction costs (modeled using only the bid-ask spread)[7] on asset returns and consequent asset pricing. In their model, the gross return must be adjusted by transaction costs to determine a realized, or spread-adjusted, return. Transaction costs for the marginal investor constitute a threshold that must be exceeded by the absolute difference between the current return and the spread-adjusted return.[8]

The basic hypothesis of our model is that, on average, a zero return is observed if the transaction costs threshold is not exceeded. This implies that observed zero returns result from the effects that transaction costs have on the marginal investor. These marginal traders, who may be informed or uninformed, use the observable public information signal (which we proxy with the market return) to augment their private information in the trading decision. If the public-plus-private information is insufficient to exceed the costs of trading then these marginal investors will either limit or not trade[9] and there will be

[7] Financial economists have taken a variety of theoretical approaches to modeling the bid-ask spread which is a critical component of transaction costs. Demsetz (1968), Stoll (1978), and Ho and Stoll (1981) model the cost of trading in an asset market as the cost of carrying an inventory of the asset incurred by the market-maker. Bagehot (1971) directly modeled the adverse selection problem that market-makers face when trading with informed traders. Glosten and Milgrom (1985) and Kyle (1985) model the interaction between liquidity traders, defined as traders with no private information, and informed traders, defined as traders with private information. In these models the market-maker sets the price based on the flow of orders and on public information. The market for market-making is sufficiently competitive so that the expected profit is zero.

[8] Given that informed investors use the public information signal to augment their private information sets (Glosten and Milgrom, 1985) and are the agents that principally move the price through information exchange (Barclay and Warner 1993), the market-maker trades off his losses to the uninformed traders. If the market-maker, on average, is correct in his estimate of whether a particular trade is informed and if the information is not itself related to the transaction costs, then the discrepancy between the return with information and the return without will be bounded by the transaction costs of the informed investor.

[9] In most microstructure models, the market-maker must determine whether he is trading with an informed or uniformed trader. The market-maker makes a probability-weighted guess about whether the trader is informed based on the order flow. Glosten and Milgrom (1985) and Kyle (1985) argue that the flow of orders is not a sufficient statistic for transaction costs because of liquidity traders. Bhushan (1991) extends these models to show that the volume of trading in a security by all types of investors will tend to be inversely related to the investors' transaction costs. While trading volume and transaction costs are related, trading volume is also related to liquidity trading and this adds noise to any measure of transaction costs. As a result, any relationship between trading volume and transaction costs is difficult to specify empirically.

no price movement from the previous day. While we cannot observe whether the marginal trader is informed or uninformed or directly measure the transaction costs adjusted return we can observe both the market return and the occurrence of a zero return. We treat these zero returns as evidence that the transaction costs threshold has not been exceeded by the marginal trader.

The effect of transaction costs on daily security returns can be seen by considering plots of security returns versus the market return (equally-weighted index) for the calendar year 1989. Each circle represents a one day return. Figures 1 and 2 show the security return behavior for a small-firm security, Avnet Corporation, and a large-firm security, IBM Corporation, respectively. The striking feature of Figure 1 is the large number of zero returns exhibited by Avnet, especially in contrast to the paucity of zero returns exhibited by IBM in Figure 2. Of equal note for Avnet is that zero returns appear more frequently for small, rather than large, market returns. This is also apparent, though less so, for IBM.

There are other potential causes for zero returns that are not directly related to the marginal investor's transaction costs. First, liquidity or noise traders may trade at low volume levels, regardless of transaction costs, and not affect the price. Second, Admati and Pfleiderer (1988) theoretically argue that liquidity traders optimize their trades to minimize the effect on price. In effect, liquidity and noise traders trade at the existing price, typically at either the bid or ask quotes and with substantial volume, and do not move the price. Additionally, the market maker, in order to maintain an orderly market and protect himself from losses, matches trades from informed investors with those of liquidity or noise traders, who happen to be in the market at the same time, at an existing price. Finally, there may be little or no new information about a firm and the current price may equal the full information price with no trading volume.[10] These conditions will bias against finding an association between zero returns and transaction costs.

Conversely, non-zero returns may not always signal that a transaction costs threshold has been exceeded. This can be seen in Figure 1 where, for a given market return, there are a large number of both positive and negative returns along with zero returns. This may reflect a large firm-specific information event and, when augmented with a relatively small market return signal, will result in a consequent price movement. Additionally, since liquidity or noise traders may trade at either the bid or ask price for immediacy reasons, the resulting return will reflect the bid-ask bounce. Conrad, Kaul, and Nimalendran (1991) show that the 'true' return is zero in this case. In effect, liquidity or noise traders exhibit little relation between their trades and the general flow of information in the market as proxied by a market return.[11] Thus, we may observe non-zero returns for the same market returns that evidence zero returns. However, we will assume that these non-zero returns are idiosyncratic in nature and demonstrate little relation with the market return.[12] The observed zero returns will be used as evidence that marginal investor's transaction costs threshold has not been exceeded.

[10] This problem has been studied extensively in a series of papers by Arbel, Carvell and Strebel who modeled "neglected stocks." See Arbel and Strebel (1982), Arbel, Carvell and Strebel (1983) and especially Arbel (1985) and Strebel and Carvell (1987). Merton (1987) argued that that "cost of transmitting information to investors" is a cause of differential information affecting security prices.

[11] This is supported by Sias, Starks and Tinic (1995) who find that noise trading is not priced.

[12] In essence, we assume that the expected value of the asset pricing model's idiosyncratic term is zero or, $E(\epsilon) = 0$, which is a standard assumption in asset pricing relations.

In the next section we develop an empirical model of security returns that incorporates the effect of transaction costs as evidenced by zero returns. Our model assumes that the return on a market index is a significant factor used by marginal investors to augment their private information sets. The lower the absolute value of the market's return, the less likely the marginal investor will trade and the greater the probability that we will observe a zero return.

2. The LDV model

2.1 Background

The common 'market model' regression of the return, R^*_{jt}, on security j and period t, on the contemporaneous market return, R_{mt} is given as:

$$R^*_{jt} = \alpha_j + \beta_j R_{mt} + \epsilon_{jt} \tag{1}$$

We assume that the security's return is generated by price responses to both contemporaneous market-wide and firm-specific information through the terms $\beta_j R_{mt}$ and ϵ_{jt}, respectively. In a perfect market devoid of transaction costs, such information will be immediately reflected in the security's price. This will occur regardless of the magnitude of the effect of the information on the security's price, and thus R^*_{jt} represents the 'true' return on security j.

However, in the presence of transaction costs, the marginal informed investor will trade only if the value of the information exceeds transaction costs, thus justifying a trade at the existing market price (Glosten and Milgrom 1985). In this context, an informed investor trades with a market-maker, and transaction costs are given in terms of the bid and ask prices, B_{jt} and A_{jt}, respectively, for security j. If an informed investor arrives at time t with information set I_{jt} and associated value $Z_{jt}(I_{jt})$, the investor's decision is:

Buy if	$Z_{jt} > A_{jt}$
Sell if	$Z_{jt} < B_{jt}$
Do not trade if	$B_{jt} < Z_{jt} < A_{jt}$

While Glosten and Milgrom's model captures the basic behavior of the marginal informed investor in the presence of transaction costs, other researchers have modeled the consequences of this behavior on security returns. For instance, Cohen, Hawawini, Maier, Schwartz and Whitcomb (1983) and Amihud and Mendelson (1986) show that actual returns will deviate from true returns by an adjustment for the bid-ask spread. Their relation is stated as:

$$R_{jt} = R^{*}_{jt} - \mu S_j \tag{2}$$

where μS_j is the spread adjustment for security j, R_{jt} is the actual return and R^{*}_{jt} is the true return. The true and actual returns are related, but only after taking transaction costs into account. A more general model can be depicted as:

$$\begin{aligned} R_{jt} &= R^{*}_{jt} - \alpha_{1j} && \text{if} && R^{*}_{jt} < \alpha_{1j} \\ R_{jt} &= 0 && \text{if} && \alpha_{1j} < R^{*}_{jt} < \alpha_{2j} \\ R_{jt} &= R^{*}_{jt} - \alpha_{2j} && \text{if} && R^{*}_{jt} > \alpha_{2j} \end{aligned} \tag{3}$$

where $\alpha_{1j} < 0$ and $\alpha_{2j} > 0$. α_{1j} and α_{2j} are the total costs for selling and buying, respectively, for the marginal investor. Of course, α_{1j} may not be equal to α_{2j} since the cost of selling on information may not be equal to the cost of buying on information (Huang and Stoll 1994).

Equation (3) describes the observed returns for the marginal investor's trading behavior given transaction costs. If the true return exceeds the transaction costs, a marginal investor will trade and the price will adjust until the magnitude of the true return for the next trade is equal to the transaction cost. The marginal investor will not trade if the costs exceed the profits and we will observe a zero return. In this model, zero returns occur whenever the price effect of new information is insufficient to motivate trading by marginal investors, and zero returns are more likely to occur if transaction costs are high.

2.2 Specification of the LDV model

The model of security returns is based on the limited dependent variable (LDV) model of Tobin (1958) and Rosett (1959). The relationship between observed and true security returns is illustrated in Figure 3. The solid line relates the actual return to the true return. The actual return does not reveal the true returns of the marginal trader until transaction costs are exceeded.[13] However, the probability that the actual return will begin to reveal the true return is given by the expected return. As the transaction costs threshold is reached, there is a greater probability that the actual return will be non-zero.

The LDV model assumes that the market model, equation (1) with the intercept suppressed, is the correct model, but constrains the true return to reflect the effects of transaction costs on the observed security returns, equation (3). The LDV model representation of the return generating process relating actual returns, R_{jt}, to true returns, R^*_{jt}, is given

[13] A specification test was performed to determine whether the average return within the bounds of the LDV model's estimated transaction costs region was indeed zero. Lesmond (1995) found that the average return within this region for all size deciles was zero. Thus, the specification of the LDV model reflects the nature of the daily return data.

as:

$$R^*_{jt} = \beta_j R_{mt} + \epsilon_{jt} \tag{4}$$

where:

$$\begin{aligned} R_{jt} &= R^*_{jt} - \alpha_{1j} & \text{if} && R^*_{jt} < \alpha_{1j} \\ R_{jt} &= 0 & \text{if} && \alpha_{1j} < R^*_{jt} < \alpha_{2j} \\ R_{jt} &= R^*_{jt} - \alpha_{2j} & \text{if} && R^*_{jt} > \alpha_{2j} \end{aligned}$$

To illustrate this application, for firm j, the *threshold* for trades on negative information is α_{1j} and for trades on positive information is α_{2j}. If $\alpha_{1j} < \beta_j R_{mt} + \epsilon_{jt} < \alpha_{2j}$, the transaction costs exceed the value of the information, the actual return on the security will be zero. Thus, the marginal investor will make trading decisions on the basis of the observable contemporaneous market-wide information and all "other" information.[14] The "other" information may contain accumulated past market-wide and firm-specific information that has not yet been incorporated into the price. We assume that all information not contained in the contemporaneous market return is captured by the residual term.[15]

For each firm and each year, maximum likelihood estimates (MLE) of the parameters are obtained.[16] For our purposes, the critical parameters of the LDV model are the threshold terms, α_{2j} and α_{1j}. By definition, α_{2j} and α_{1j} are measures of proportional transaction costs for buying and selling, respectively. Their difference, $\alpha_{2j} - \alpha_{1j}$, is a measure of the

[14] We understand that the residuals of the LDV model may be serially correlated and the LDV model does not consider this information. The net effect of this misspecification is to over-estimate the transaction costs for the marginal investor since the informed trader is effectively assumed to trade on a larger difference than is actually there. We show that the LDV model's estimate of transaction costs is always smaller than the quoted spread-plus-commissions thus providing a very conservative estimate.

[15] This assumption follows Kyle's (1985) model, in which the informed investor's information set "consists of his private information...as well as past prices (p. 1315)." Also, Glosten and Milgrom's (1985) proposition 4 posits that the private information held by the informed investor will gradually be incorporated through a sequence of trades. This implies that at any given trade the informed trader assesses the extent to which the current price does not yet reflect past information.

[16] The derivation is contained in Appendix A.

proportional round-trip transaction costs for the competitive, informed investor. Since the informed investor will rationally trade only if the value of the accumulated information exceeds the transaction costs, $\alpha_{2j} - \alpha_{1j}$ is a measure of the total round-trip transaction costs associated with security j.

3. Data

The data for this study are taken from the NYSE/AMEX daily master file provided by the Center for Research in Security Prices (CRSP) for the 28-year period, 1963-1990. Firms are included in this study for a given calendar year if the security was listed on the exchange for the entire year.[17] In much of the analysis, we use the CRSP assignment for firm size deciles. These firms are sorted into size deciles according to the total market value of the firm's equity at the end of the previous year. If the previous year's ranking is unavailable, the current year's ranking is used. For separate NYSE or AMEX exchange size decile classifications, we use the same size decile procedure as CRSP except that we restrict the firms to that exchange to which they are listed. In addition, we take returns on the CRSP equally weighted index of NYSE/AMEX securities for use in the LDV model.

We also use two additional data sets in the analysis. The first set consists of daily closing specialists' bid and ask quotes for all NYSE/AMEX securities for the 3-year period 1988-1990, obtained from the Institute for Study of Security Markets (ISSM).[18] The second set includes the estimates of proportional spreads for NYSE securities for the period 1963-

[17] The LDV model required at least 25 daily security returns for an annual trading period (252 days) for convergence reasons.

[18] Although (opening and) closing spread tend to be slightly higher than mid-day spreads (Wood, McInish and Ord 1985), the difference does not appear to be large enough to compromise the analysis.

1979 that Stoll and Whaley (1983) used in their study, which consists of average closing specialist spreads for each security at the beginning and end of each year, as well as estimates of representative commission rates for securities in this sample.[19]

4. Empirical tests on the frequency of zero returns

4.1 Zero returns and transaction costs

We initially present tests of the relation between the relative frequency of zero returns and transaction costs in Table 1. We use firm size as an inverse proxy for transaction costs. This is based on evidence that transaction costs are inversely related to the size of the firm (Demsetz 1968, Benston and Hagerman 1974, Copeland and Galai 1983, Stoll and Whaley 1983, Roll 1984). We separate firms into size deciles, calculate the proportion of each firm's daily returns for the ensuing year that are equal to zero. Then, we calculate the overall proportion of zero returns for all firms in each decile. The results are shown for the period 1963-1990 in panel A of Table 1.

The evidence is consistent with a transaction costs effect on security returns. The proportions of zero returns are inversely related to firm size, and the relationship is monotonic. On average, firms in the smallest size decile experience 36.6% zero returns for an annual trading period. For an annual trading period, an average of more than one-third of the daily returns are equal to zero. Firms in the largest size decile, on average, experience only 11.9% zero daily returns.

We use Roll's (1984) measure of the "effective" bid-ask spread as a second proxy for

[19] We thank Hans Stoll for providing the spread data.

transaction costs. This measure, $2\sqrt{-cov}$, is estimated using the first-order autocovariance of security's returns. Roll shows that as trade prices bounce between bid and ask quotes, a negative return autocovariance is induced. The magnitude of the autocovariance depends on both the size of the spread and the probability that investors trade with the specialist at the bid or ask quotes as opposed to trading with others at intermediate prices. Thus Roll's statistic is a measure of the "effective" spread (Stoll 1989). A problem using Roll's measure is that the sample autocovariance (which we calculate for each security using a full year of returns) is frequently positive, rendering the estimate incalculable. To overcome this problem, we apply the approach developed by Harris (1990), who converts all positive autocovariances to negative. The averages of Roll estimates are shown in the final column of panel A. As expected, average effective spreads are inversely related to firm size, ranging from 0.31% for firms in the largest size decile to 4.34% for firms in the smallest size decile.

Our third proxy for transaction costs is the specialists' bid-ask spread. We calculate the average proportion of zero returns and the average annual specialist spread for individual NYSE/AMEX firms for the three-year period 1988-90. The results, sorted by firm size, are shown in panel B. Again, the proportions of zero returns are inversely related to firm size. The average specialist spreads are also inversely related to firm size, ranging from 0.60% for the largest firms to 10.05% for the smallest firms. Also reported in panel B are the average values of Roll's spread estimates for each size decile, as well as the average ratio of Roll's spread to the corresponding specialists' spread. Note that for all size deciles Roll estimates are approximately half as large as the specialist spreads. These results are roughly consistent with those of Harris (1990) as well as Petersen and Fialkowski (1994).

A closer examination of the behavior of security returns based on movements around the bid-ask spread for the period 1988-1990 is shown in Table B of Appendix B. These results indicate that the daily security returns provided by CRSP assesses accurately, but conservatively, the number of zero returns. As shown in Table B, the stated zero return proportions and those zero returns (i.e. *effective*) that would be registered if we controlled for the bid-ask bounce (Conrad, Kaul, and Nimalendran 1991) are closely related. For instance, the proportion of observed zero returns for the small size decile of firms is 43.7% while the *effective* proportion of zero returns is 54.7%. For the firms in the largest decile, the observed proportion of zero returns is 11.8% while the *effective* proportion of zero returns is 12.7%. Given the difficulty in obtaining bid-ask spreads for all time periods (1963 to 1990), these results show that using the CRSP closing daily returns can provide an accurate indicator of the effective number of zero returns.

We test the association between the frequency of zero returns and transaction costs by regressing the zero return proportions on specialists' spreads for firms in each size decile. The results are displayed in Table 2 using data for the period 1988 to 1990. Aggregate regression results include all observations. In all of the regressions, the spread coefficient is positive and highly significant even after controlling for firm size. The R^2 statistic is significant, rising from 15% to almost 40% for small and large firm size deciles, respectively. These results suggest that the proportion of zero returns, themselves, is a useful proxy for transaction costs.

4.2 Zero returns and market-wide information

The association between the frequency of zero returns and the range of market-wide information is tested by sorting the firms by both firm size and the size of the contemporaneous market return. We sort by firm size in order to hold transaction costs constant and allow the market-wide information to vary. The proportion of zero returns for firms in each size decile and market return interval are then examined. These zero return proportions are defined as the ratio of the zero returns divided by the non-zero returns each firm experiences for that market return interval. The market return intervals span 30 basis points and are chosen to allow for the transaction costs thresholds to be more clearly delineated for each size decile category. For the largest market returns (i.e. those greater than ±120 basis points) we use a 180 basis point span due to the reduced number of market returns that are experienced for these extreme regions. We use the CRSP equally-weighted index for the level of market-wide information.[20]

Higher levels of transaction costs will induce an increased level of zero return proportions for higher market returns (on an absolute market return basis) vis-a-vis lower levels of transaction costs. For a given level of transaction costs, which we proxy by firm size, the proportion of zero returns should be inversely related to the magnitude of the market return if the transaction costs threshold has been exceeded. In addition, a greater proportion of zero returns should be experienced by smaller firms for the same market return interval relative to larger firms. The market return intervals span the time period 1962

[20] Systematic risk is also important and is estimated by the proposed model. However, we control for systematic risk effects by partitioning by firm size thereby holding the systematic risk effect relatively constant.

to 1990. Market return intervals, -0.3% to 0.3%, encompass the smallest market returns. The results are displayed in Table 3.

The proportions of zero returns for the smallest market return interval, -0.3% to 0.0% and 0.0% to 0.3%, can be clearly seen to vary monotonically with firm size. The smallest firms experience over 100% zero return proportions while the largest firms experience only 13.0% zero return proportions. The remainder of the firms demonstrate zero return proportions between these two extremes. Given that transaction costs vary inversely with firm size, the results are consistent with a transaction costs argument.

Examining the relation between the market return interval and the proportion of zero returns, for each firm size decile, shows zero return proportions that are relatively constant with the market return interval. Only after relatively large market return intervals are reached do the zero return proportions decrease. Smaller firms that have higher transaction costs require an increased level of market-wide information to exceed the costs of trading. The market return interval that "induces" this reduction on the zero return proportion is seen to decrease as the firm size deciles increase.

A statistically significant[21] reduction in the zero return proportion has been delineated by the solid line the separates these market return intervals. Size decile one firms experience a relatively constant level of zero return proportions for all market return intervals except for the most extreme market return intervals. The zero return proportions are ap-

[21] A simple t-test is used to determine significance. For each size decile, each firm's zero return proportion is used to determine the size decile's standard error. The t-test then divides the mean zero return proportion by this standard error.

proximately 100% and then fall to 71.2% for market returns of 1.2% to 3.0% and 42.1% for market returns of -1.2% to -3.0%. For firms in size decile four, the zero return proportions are approximately 40.1% and then fall to 32.7% for market returns of 0.9% to 1.2% and 33.6% for market returns of -0.9% to -1.2%. Firms in size deciles nine and ten experience the same tendency, but for smaller market return intervals. For firms in size decile nine, the zero return proportions are approximately 16.9% and then fall to 14.3% for market returns of 0.6% to 0.9% and 13.4% for market returns of -0.6% to -0.9%. For firms in size decile ten, the zero return proportions are approximately 12.7% and then fall to 11.0% for market returns of 0.3% to 0.6% and 10.3% for market returns of -0.6% to -0.9%.

The F-statistics, shown in the last column of Table 3, reject the hypothesis of a constant zero return proportion distribution across the various market return intervals. This is found for all firm size deciles. These results suggest that marginal investors are less likely to move the price on market-wide information that has small valuation potential, but will move the price given a sufficiently high market return. All of the results are consistent with the LDV model's use of zero returns as an indication of whether the transaction costs threshold has been exceeded. Zero returns are more likely to be observed when the incremental value of market-wide information does not exceed the marginal investor's transaction costs. This level of transaction costs is greater for small firms than for large firms. The substantial zero return proportions observed across most of the market return intervals, for the small size decile firms, suggest that only for the largest market return intervals was the transaction costs threshold exceeded. The largest firm size decile firms, which have far smaller transaction costs, experience a vastly reduced zero return proportion and demonstrate a reduction in the zero return proportion for much smaller market return intervals than do the smaller firms.

5. LDV empirical estimates of transaction costs

5.1 LDV estimates of transaction costs

We use the LDV model to estimate transaction costs for NYSE and AMEX firms for the period 1963-1990. Panel A of Table 4 shows the average costs of sell trades, α_{1j}, buy trades, α_{2j}, and the round trip transaction costs, $\alpha_{2j} - \alpha_{1j}$. All results are shown for firms sorted by NYSE/AMEX size deciles.

As expected, the average values of the estimates of α_{1j} and α_{2j} are negative and positive, respectively. The average round trip transaction costs estimates, $\alpha_{2j} - \alpha_{1j}$, are significant for every size decile. Furthermore, as firm size increases, the sell, buy, and round trip transaction costs all decrease, as expected.

The average values of $\alpha_{2j} - \alpha_{1j}$ for the firms in the largest and smallest size deciles are 1.23% and 10.35%, respectively. Note that for each size decile the absolute, average value of α_{1j} is very close to, but tends to slightly exceed, the corresponding average value of α_{2j}, indicating that transaction costs are slightly greater for selling than for buying.[22] These results are consistent with those of Berkowitz, Logue and Noser (1988) and Huang and

[22] For all size deciles, the t-statistic of the difference in $\alpha_{2j} - \alpha_{1j}$ is highly significant.

Stoll (1994), who also find that transaction costs are greater for selling than for buying.

Since most empirical studies focus only on NYSE firms (e.g., Stoll and Whaley 1983 and Bhardwaj and Brooks 1992), we separately examine the LDV transaction cost estimates for firms listed on the NYSE exchange or AMEX exchange. AMEX firms are generally smaller than NYSE firms and we expect that AMEX firms will have greater transaction costs compared to NYSE firms. The results are displayed in panel B of Table 4.

The firm-year totals for the firms listed on the AMEX and NYSE exchanges are shown in columns 2 and 4, respectively. These totals reflect to the prevalence of relatively smaller firms listed on the AMEX exchange than on the NYSE exchange. For both exchanges, the average values of $\alpha_{2j} - \alpha_{1j}$ are again inversely related to firm size. Smaller firms, size deciles 1 through 3, show that the LDV estimates of transaction costs tend to be smaller for AMEX securities than for NYSE securities. Larger firms, size deciles 4 through 10, demonstrate smaller transaction costs for NYSE securities than AMEX securities. It should be mentioned that caution must be taken with a generalization of this result because of the disparity in the number of firms for each size decile.

A finer means of examining the total round trip transaction costs, $\alpha_{2j} - \alpha_{1j}$, for only NYSE firms is done by sorting against only other NYSE firms. The results are shown in the right-most columns of panel B. Again, the average values of $\alpha_{2j} - \alpha_{1j}$ are inversely related to firm size, ranging from 1.46% to 6.97% for the largest and smallest firms, respectively. For each size decile, the transaction cost estimates based on only NYSE firms are much smaller than the estimates obtained for both NYSE/AMEX firms. This is due to the relatively large size of only NYSE firms when compared to combined NYSE/AMEX firms.

5.2 Comparisons of LDV estimates with spread-plus-commission estimates

In this section we compare the LDV transaction costs estimates to the commonly used spread-plus-commissions used by Stoll and Whaley (1983) and Bhardwaj and Brooks (1992). These comparisons serve several purposes. First, we can determine if the LDV estimates of transaction costs are correlated to the commonly used spread-plus-commission estimates. Second, given that most trades occur within the quoted spread (Roll 1984 and Petersen and Fialkowski 1994), the spread-plus-commission may generally overstate the direct transaction costs facing the marginal investor. The LDV estimates of transaction costs will determine to what degree the spread-plus-commission estimates overstate the transaction costs for the marginal investor. This is important because Stoll and Whaley (1983) and Bhardwaj and Brooks (1992) spread-plus-commission estimates have been used as an explanation for the size effect and January anomalies. We begin with a comparison of Stoll and Whaley's estimates and conclude with Bhardwaj and Brooks' estimates.

The proportional spreads are obtained from Stoll and Whaley and include only NYSE securities and cover the period from 1963-1979. The spread-plus-commission estimates are determined by adding to each spread a commission cost. The commission is calculated in the same manner as Stoll and Whaley. We use the (fixed) minimum-commission schedules provided in various issues of The New York Stock Exchange Fact Book. The only exception is that we doubled each estimate of the commission to represent a round-trip commission. Firms were then sorted each year into size deciles using only other NYSE firms.

The graphical comparison of the time series for LDV estimates for the smallest (decile one) and largest firms (decile 10) is shown in Figure 4. The Stoll and Whaley spread-plus-commissions are restricted to the period 1963 to 1979, while the LDV estimates are shown for the entire period 1963 to 1990. For comparison with the LDV estimates for the period 1988 to 1990, we use the ISSM data for the spread only.

The most striking aspect of the results is the close correspondence of these estimates over time, especially for the smallest firms. Both estimates rose and then fell considerably in the mid-1970's, a period that corresponds with the switch from negotiated to competitive commissions (on May 1, 1975). However, other circumstances including pressure on computer facilities due to rising volume facing the NYSE may have contributed to temporarily higher transaction costs.[23] For the smallest firms, the correlation of the yearly values of the Stoll and Whaley and LDV estimates is 0.92 (significant at the 1% level). In addition, for both size deciles, the LDV estimates are consistently smaller than the spread-plus-commission estimates.

It is also interesting to note that the LDV estimates of transaction costs tend to rise at the end of the sample period, specifically from 1988-1990. Since we had spread data for this period, we calculated the average spread for each size decile and each year for NYSE firms to determine whether this component of transaction cost also rose. The results

[23] These pressures were alleviated with the development of a high-speed market data transmission line in January, 1976 and the Designated Order Turnaround (Dot) System in March, 1976.

are also displayed in Figure 4. For the smallest firms, the average specialist spread rose substantially in this period, and by approximately the same magnitude as the observed increase in the LDV estimates. These results provide further evidence indicating that LDV estimates closely track actual transaction costs, and changes in transaction costs over time.

Numerical results for the period 1963 to 1979 are provided in panel A of Table 5. Table 5 shows the average values of the LDV estimates and spread-plus-commission estimates for firms in each size decile. Note that for all firms the average LDV estimates are considerably smaller than the corresponding spread-plus-commission estimates. T-statistics shown in the last column of the panel indicate that the differences of these estimates are all highly significant. These results suggest that typically used spread-plus-commission estimates may generally overestimate the effective transaction costs for NYSE firms. This is consistent with Petersen and Fialkowski (1994) who found that most trades occur within the spread. Hence, the quoted spread generally overstates the effective spread facing the marginal trader. More to the point, spread-plus-commission estimate acts as an upper bound for the total effective transaction costs facing the marginal trader.

Panel B of Table 5 shows regression test results, for firms in each size decile, of the association between the LDV estimates and corresponding estimates of the bid-ask spread and commission costs. In all regressions the coefficients of both spread and commission are positive and significant at the 1% level, indicating that LDV estimates are highly associated with both the spread and commission costs. The adjusted R^2 statistics are generally quite high, although demonstrating inverse monotonicity with firm size. The R^2 statistics for the smallest size decile are 81.82%, but decrease to 30.47% for the largest firm decile. It is not immediately clear why the LDV estimates are not more closely related to spreads and commissions for larger firms.[24]

It does appears that LDV estimates are much more sensitive to commission rates for small firms than for large firms. An inverse relationship between the size of the coefficient of commissions and firm size is monotonic. For the smallest firms, the coefficient of commission is 1.7186 (standard error of 0.0378), while for the largest firms the coefficient is only 0.2746 (standard error of 0.0163). It is also possible that during the sample period the stated minimum commission rates were quite binding for trades of small firm securities, while for large firms the effective commission was much smaller than the stated minimum commission, due in part to soft-dollar arrangements between traders and their brokers.

In contrast to the behavior of the commission coefficient, the coefficient of spread appears to be unrelated to firm size, ranging from 0.4314 (standard error of 0.0259) and 0.4497 (standard error of 0.0234) for size deciles 5 and 1, respectively. This can be compared to a spread coefficient of 0.6498 (standard error of 0.0284) and 0.6661 (standard error of 0.0303) for firms in size deciles 4 and 7, respectively.

Finally, Table 6 provides a comparison of LDV and spread-plus-commission estimates for NYSE securities sorted by price for the periods 1982-1986 and 1988-1990. We use the same price categories as Bhardwaj and Brooks. For the 1982-1986 period, we borrow their estimates of the median specialist spread and round-trip commission for each price

[24] An explanation may be that the percentage of trades within the spread is greater for large firms relative to small firms.

category. Panel A of the table shows the price ranges for 1982-1986, including the sum of the median spread and commission costs. These total transaction costs are inversely related to price, ranging from 12.535% for securities priced at less than $5 to 2.095% for securities priced greater than $20. The last column of Panel A shows the average values of the LDV estimates of transaction costs for firms in the indicated price range. The average LDV costs are also inversely related to price level, ranging from 10.121% for the lowest-priced firms to 1.789% for the highest-priced firms. For every price range the average LDV estimate is smaller than the corresponding spread-plus-commission estimates. These results are similar to those reported for the Stoll and Whaley comparisons.

This indicates that the LDV estimates are consistently smaller than spread-plus-commission estimates of transaction costs. Similar results are obtained in panel B, where the analysis is extended to the 1988-1990 period. Here we calculate the median specialist spread for all NYSE firms in each price category, and again borrow Bhardwaj and Brooks' estimates of the median round-trip commission cost. As found in Panel A, for each price category, the sum of the median estimates of spread and commission for this period is greater than the median LDV estimate.

In summary, we find that the LDV estimates of transaction costs closely correspond to the spread-plus-commission estimates over time and cross-sectionally. Although the LDV estimates tend to be smaller than the spread-plus-commissions they are highly correlated. Researchers and traders who use the spread-plus-commission estimate of transaction costs should therefore consider the possibility that they may be overestimating the effective transaction costs facing the marginal investor.

5.3 Comparisons of LDV estimates with specialists' spreads

Further tests of the LDV measure of transaction costs are warranted due to the inherent problems of using a single, stated commission schedule for the marginal trader. The chosen commission schedule may not represent the execution costs of the marginal trader or the commission schedule may include soft dollars. In response, we conduct tests using only the quoted spread. This test is not only important for the validity of the LDV estimates, but allows the LDV model to be used as a vehicle for providing estimates for the quoted spread.

To test the association between the LDV estimates of $\alpha_{2j} - \alpha_{1j}$ and the average specialist proportional bid-ask spread, we regress these estimates of transaction costs for all NYSE/AMEX securities on the average specialist proportional bid-ask spread. These tests cover the period 1988-1990 for which we have complete daily spread data. We run separate OLS regressions for the observations in each NYSE/AMEX size decile, as well as an aggregate regression that combines all of the observations. The results are displayed in Table 7.

For every size decile, the slope coefficient of the regression is positive and significant at the 1% level. The adjusted R^2 for all regressions range from 46.46% to 91.76%. The aggregate regression also yields a highly significant positive slope coefficient and an adjusted

R^2 of 88.47%. These results indicate that the LDV estimates of transaction costs are very closely related to specialists' proportional bid-ask spreads. For all firm size deciles, the slope coefficient is reliably greater than one (though never greater than 2.3). Similar results are obtained from the aggregate regression. Ignoring the generally trivial intercepts, these results indicate that LDV model is quite good at estimating this *one* component of the transaction costs: the bid-ask spread.

The regression results in Table 7 contrast sharply with those of Table 2. In both tables, we use NYSE/AMEX data for the period 1988-1990, and the independent variable is the average specialist spread. Thus, the regressions differ only in terms of the dependent variable; zero returns in Table 2 versus LDV estimates in Table 7. For each size decile, the adjusted R^2 is much higher in Table 7 than in Table 2. This indicates that LDV estimates correspond much more closely to spreads than do the proportions of zero return. These results suggest that the LDV model extracts from the data a measure that is much more closely related to transaction costs than the simpler characteristic of zero return proportions. This is true even though both measures should be related to transaction costs.

For comparative purposes we also regressed Roll's model estimates on specialists' spreads for firms in each size decile using the data for 1988-90. The results are displayed in Table 8. In all the regressions, the slope coefficient is positive and highly significant. In most of the regressions the adjusted R-square statistic is substantial. This indicates a close correspondence between Roll model estimates and specialists' spreads. In addition, the slope coefficients are reliably less than one. This suggests that the "effective spread", as measured by the Roll model, is consistently less than the quoted spread, as expected. However, note that the R^2 statistics in Table 8 are much lower than the LDV based estimates of Table 7. This comparison indicates that the LDV model's estimates track specialist spreads better than do the Roll autocovariance based estimates.

6. Conclusions

In this paper we develop a model to continuously estimate total transaction costs for all firms listed on the NYSE and AMEX exchange over the time period 1963 to 1990. When compared to the commonly used measure of transaction costs, bid-ask spreads and commissions, the correlation is over 87%.

The model of transaction costs is based on patterns of daily security returns that demonstrate a large number of zero returns. These zero returns dominate the security return behavior of both small and large firms. For some of the smallest firms, over 80% of the daily security returns are zero for an annual trading period. Even for some of the largest firms, 40% of the daily security returns are zero for an annual trading period. The model of transaction costs utilizes a limited dependent variable (LDV) specification that endogenously estimates transaction costs through the incidence of zero returns.

We develop and test two hypotheses in relation to zero returns. Using firm size as an inverse proxy for transaction costs, we find the frequency of zero returns is much greater for small firms than for large firms. Regression tests indicate that the relative number of zero returns is highly associated with the quoted bid-ask spread. The adjusted R^2 is, on average, over 35%. The relative number of zero returns is also shown to be inversely related to the magnitude of the contemporaneous market return. This indicates that as the absolute market return decreases the probability of a zero return increases.

The estimates of transaction costs obtained from the LDV model range from 1.23% for large firms to 10.3% for small firms. The LDV transaction cost estimates demonstrate inverse monotonicity with respect to firm size. OLS regressions indicate that they correspond closely to estimates of proportional bid-ask spreads and broker commissions. Average R^2 statistics are 50%. The LDV estimates tend to be smaller than the commonly used estimate of transaction costs, spread-plus-commissions. We argue that this is because the LDV estimates reflect only the effective trading costs encountered by the marginal trader which are smaller than the quoted spread and a single commission schedule. Based on our findings, studies that use these two estimates for transaction costs overstate the effective trading costs from 15% for small firms to as much as 50% for large firms. This is consistent with Petersen and Fialkowski (1994) who find the same result for the effective spread versus the quoted spread. Additional regression tests using only the bid-ask spread indicate that the LDV measure is highly effective in estimating the quoted spread. The results indicate aggregate R^2 statistics of 88%. For comparison purposes, the Roll estimator produces R^2 statistics of only 77%. This is a significant improvement over Roll's model of effective spreads.

This conservative estimate of transaction costs requires only the time series of security returns. Hence, it is relatively easy and inexpensive to obtain estimates of the transaction costs for any time period and firm where daily security returns are available. It is important to note that this estimator of transaction costs is available even for firms and time periods where bid-ask spreads are *unobtainable* from common data sources. The need for comprehensive and complete transaction costs estimates in international, market efficiency, and market structure analyses studies underscores the importance of this model. Additionally, market studies that require transaction cost estimates for many firms over long time periods will benefit from this estimation method.

Appendix A

Linear Dependent Variable Maximum Likelihood Solution

The solution to the Limited Dependent Variable Maximum Likelihood regression model requires a likelihood function to be maximized with respect to $\alpha_1, \alpha_2, \beta$, and σ. In what follows, the summation $\sum_1$ reflects the N_1 observations for which R_t is less than α_1, the summation $\sum_2$ reflects the N_2 observations for which R_t is greater than α_2, and the summation $\sum_0$ reflects the N_0 observations for which R_t is zero. The subscript j is dropped for clarity. In addition, a normal distribution is assumed.

The log of the liklihood function is:

$$\begin{aligned} LogL = & \sum_1 Log\left[\frac{1}{(2\pi\sigma^2)^{\frac{1}{2}}}\right] - \frac{1}{2\sigma^2}\sum_1 (R_t + \alpha_1 - \beta\ Rm_t)^2 \\ & + \sum_2 Log\left[\frac{1}{(2\pi\sigma^2)^{\frac{1}{2}}}\right] - \frac{1}{2\sigma^2}\sum_2 (R_t + \alpha_2 - \beta\ Rm_t)^2 \\ & + \sum_0 Log\left[\Phi_2 - \Phi_1\right] \end{aligned} \tag{A1.0}$$

In preparation for solving the maximum likelihood relation, we first solve the following partial derivatives [1] with respect to β, σ^2, α_2, and α_1:

$$\frac{\partial \Phi_2}{\partial \beta} = f_2 Rm_t$$

$$\frac{\partial \Phi_1}{\partial \beta} = f_1 Rm_t$$

$$\frac{\partial \Phi_2}{\partial \sigma^2} = -\frac{1}{2\sigma^2}\left[\alpha_2 + \beta\ Rm_t\right] f_2$$

$$\frac{\partial \Phi_1}{\partial \sigma^2} = -\frac{1}{2\sigma^2}\left[\alpha_1 + \beta\ Rm_t\right] f_1$$

[1] Note that:

$$\Phi_i = \Phi(\alpha, \beta, \sigma, R_{mt}) = \int_{-\infty}^{(\alpha_i + \beta\ Rm_t)} f(u)du$$

$$f_i = f(\alpha, \beta, \sigma, R_{mt}) = \left[\frac{1}{(2\pi\sigma^2)^{\frac{1}{2}}}\right] e^{\frac{-(\alpha_i + \beta\ Rm_t)^2}{2\sigma^2}}$$

$$\frac{\partial \Phi_2}{\partial \alpha_2} = f_2$$

$$\frac{\partial \Phi_1}{\partial \alpha_1} = f_1$$

$$\frac{\partial f_2}{\partial \beta} = -f_2\left[\frac{(\alpha_2 + \beta\ Rm_t)}{\sigma^2}\right] Rm_t$$

$$\frac{\partial f_1}{\partial \beta} = -f_1\left[\frac{(\alpha_1 + \beta Rm_t)}{\sigma^2}\right] Rm_t$$

$$\frac{\partial f_2}{\partial \sigma^2} = \left[\frac{(\alpha_2 + \beta\ Rm_t)^2 - \sigma^2}{2\sigma^4}\right] f_2$$

$$\frac{\partial f_1}{\partial \sigma^2} = \left[\frac{(\alpha_1 + \beta\ Rm_t)^2 - \sigma^2}{2\sigma^4}\right] f_1$$

$$\frac{\partial f_2}{\partial \alpha_2} = -\left[\frac{(\alpha_2 + \beta\ Rm_t)}{\sigma^2}\right] f_2$$

$$\frac{\partial f_1}{\partial \alpha_1} = -\left[\frac{(\alpha_1 + \beta\ Rm_t)}{\sigma^2}\right] f_1$$

$$\frac{\partial f_2}{\partial \alpha_1} = 0$$

$$\frac{\partial f_1}{\partial \alpha_2} = 0$$

$$\frac{\partial \Phi_2}{\partial \alpha_1} = 0$$

$$\frac{\partial \Phi_1}{\partial \alpha_2} = 0 \qquad (A1.1)$$

Taking the first derivative of the log likelihood function given by Equation (A1.0) with respect to β, σ, α_1, and α_2 while substituting the relations (A1.1) into their respective partial derivatives for the maximum likelihood function yields:

$$\frac{\partial LogL}{\partial \beta} = \frac{1}{\sigma^2}\sum_1 (R_t + \alpha_1 - \beta\ Rm_t) Rm_t + \frac{1}{\sigma^2}\sum_2 (R_t + \alpha_2 - \beta\ Rm_t) Rm_t +$$

$$\sum_0 \left[\frac{(Rm_t \cdot f_2) - (Rm_t \cdot f_1)}{(\Phi_2 - \Phi_1)}\right] = 0 \qquad (A1.2)$$

$$\frac{\partial LogL}{\partial \sigma^2} = -\frac{N_1}{2\sigma^2} + \frac{1}{2\sigma^4}\sum_1 (R_t + \alpha_1 - \beta\ Rm_t)^2$$

$$-\frac{N_2}{2\sigma^2} + \frac{1}{2\sigma^4}\sum_2 (R_t + \alpha_2 - \beta\ Rm_t)^2$$

$$-\frac{1}{2\sigma^2}\sum_0 \frac{(\alpha_2 + \beta\ Rm_t)f_2}{(\Phi_2 - \Phi_1)}$$

$$+\frac{1}{2\sigma^2}\sum_0 \frac{(\alpha_1 + \beta\ Rm_t)f_1}{(\Phi_2 - \Phi_1)} = 0 \tag{A1.3}$$

$$\frac{\partial LogL}{\partial \alpha_2} = -\frac{1}{\sigma^2}\sum_2 (R_t + \alpha_2 - \beta\ Rm_t) + \sum_0 \left[\frac{f_2}{(\Phi_2 - \Phi_1)}\right] = 0 \tag{A1.4}$$

$$\frac{\partial LogL}{\partial \alpha_1} = -\frac{1}{\sigma^2}\sum_1 (R_t + \alpha_1 - \beta\ Rm_t) - \sum_0 \left[\frac{f_1}{(\Phi_2 - \Phi_1)}\right] = 0 \tag{A1.5}$$

Solving for α_1 from equation (A1.5) yields:

$$-\frac{1}{\sigma^2}\sum_1 (R_t + \alpha_1 - \beta\ Rm_t) = \sum_0 \left[\frac{f_1}{(\Phi_2 - \Phi_1)}\right]$$

$$N_1\alpha_1 + \sum_1 (R_t - \beta\ Rm_t) = -\sigma^2 \sum_0 \left[\frac{f_1}{(\Phi_2 - \Phi_1)}\right]$$

$$\text{Set:} \quad \gamma_1 = \sigma \sum_0 \left[\frac{f_1}{(\Phi_2 - \Phi_1)}\right]$$

Yields:

$$\alpha_1 = -\left(\frac{\sigma}{N_1}\right)\gamma_1 - \left(\overline{R}_1 - \beta\ \overline{Rm}_1\right) \tag{A1.6}$$

Where:

$$\overline{Rm}_1 = \text{Average market return in region 1}$$

$$\overline{R}_1 = \text{Average security return in region 1}$$

Solving for α_2 from equation (A1.4) yields:

$$-\frac{1}{\sigma^2}\sum_2 (R_t + \alpha_2 - \beta\ Rm_t) = -\sum_0 \left[\frac{f_2}{(\Phi_2 - \Phi_1)}\right]$$

$$N_2\alpha_2 + \sum_2 (R_t - \beta\ Rm_t) = \sigma^2 \sum_0 \left[\frac{f_2}{(\Phi_2 - \Phi_1)}\right]$$

$$\text{Set:} \quad \gamma_2 = \sigma \sum_0 \left[\frac{f_2}{(\Phi_2 - \Phi_1)}\right]$$

Yields:

$$\alpha_2 = \left(\frac{\sigma}{N_2}\right)\gamma_2 - \left(\overline{R}_2 - \beta\ \overline{Rm}_2\right) \tag{A1.7}$$

Where:

$$\overline{Rm}_2 = \text{Average market return in region 2}$$

$$\overline{R}_2 = \text{Average security return in region 2}$$

Solving for β by multiplying equation (A1.2) by σ^2 and utilizing the definitions of γ_1 and γ_2 results in:

$$\sum_1 (R_t + \alpha_1 - \beta\ Rm_t) Rm_t + \sum_2 (R_t + \alpha_2 - \beta\ Rm_t) Rm_t = \sigma \sum_0 \Big[(Rm_t \cdot \gamma_2) - (Rm_t \cdot \gamma_1) \Big]$$

Solving for β:

$$\beta = \left[\frac{\sum_1 (R_t \cdot Rm_t) + \sum_2 (R_t \cdot Rm_t)}{(\sum_1 Rm_t^2 + \sum_2 Rm_t^2)} \right] + \left[\frac{\alpha_1 \cdot \sum_1 Rm_t + \alpha_2 \cdot \sum_2 Rm_t}{(\sum_1 Rm_t^2 + \sum_2 Rm_t^2)} \right]$$
$$+ \sigma \sum_0 \left[\frac{(Rm_t \cdot \gamma_2) - (Rm_t \cdot \gamma_1)}{(\sum_1 Rm_t^2 + \sum_2 Rm_t^2)} \right] \qquad (A1.8)$$

Examination of equation (A1.8) reveals that the first term is from the straight OLS estimate of β obtained from the non–zero return observations. The second and third terms are the adjustment factors. The first adjustment factor, involving the intercepts α_1 and α_2, reflects the transaction costs induced regions of friction. The second adjustment factor reflects the probability of zero returns.

The final term to be derived is σ and this is determined by multiplying equation (A1.2) by $\beta/2\sigma^2$ and adding to equation (A1.3). The algebra is tedious so only the final form is presented. This is given by:

$$\sigma^2 = \frac{\sum_1 (R_t + \alpha_1 - \beta\ Rm_t) R_t + \sum_2 (R_t + \alpha_2 - \beta\ Rm_j) R_t}{(N_1 + N_2)} \qquad (A1.9)$$

These four equations, (A1.6), (A1.7), (A1.8), (A1.9), are solved iteratively using a Levenberg-Marquardt algorithm with a finite difference approximation to the Jacobian. The algorithm is a variant of Newton's method and uses the OLS estimates from the market model as the initial estimates for the parameters. The model's second derivative is negative semi-definite so convergence is assured.

Appendix B

A closer examination of the behavior of daily returns

This appendix presents evidence that the use of CRSP daily closing prices presents a conservative estimate of the number of zero returns. These zero returns do not account for all potential zero returns either because of zero trading volume or trades that reflect the bid-ask bounce (Conrad, Kaul and Nimalendran 1991).

A specialist acts as a monopolistic dealer for each security, and occasionally trades are executed with the specialist at either the bid or ask price. For a constant bid and ask quote structure, when closing trades occur at the bid one day and at the ask the next day, or vice versa, the recorded return for the day is non-zero. This is true even though it is likely that no value relevant information was exchanged, since the specialist did not change the quotes. Second, when a security does not trade for an entire trading day, there is no trade price to calculate the return on the security for that day. In such cases, CRSP uses the average of the specialist's closing bid and ask quotes in place of a trade price for the purpose of calculating the return on the security. This convention also affects the frequency of zero returns.

To get a clearer picture of the behavior of security returns, we delineate the following categories of daily returns on individual securities. The categories are created by first separating the trading days for a given security into two classes: days with positive volume and days with zero volume. Focusing initially on the days with positive volume, we identify four categories of daily returns on a security:

(1) The observed return is non-zero and successive closing bid and ask prices are different. These cases are consistent with the presence of information exchange;

(2) The observed return is non-zero, but closing prices move from bid to ask or vice versa and successive closing bid and ask prices are unchanged; these cases are consistent

with the absence of information exchange and evidence of a "true" return of zero (Conrad, Kaul and Nimalendran 1991);

(3) The observed return is zero as a result of successive closing trades at the bid price or ask price, where the bid and ask prices are unchanged; these cases also indicate the absence of information exchange or trading between liquidity traders and the specialist;

and (4) The observed return is zero, but successive closing trades are not at the bid or ask prices; these cases also indicate the absence of information exchange and trading between liquidity traders.

Next, we consider the cases with zero volume. The three possible categories are determined by the CRSP convention noted above and the tendency of the specialist to change bid and ask quotes in response to new information even in the absence of trading:

(5) The return is non-zero and successive bid and ask prices are changed; these cases indicate that the specialist changed his quotes in response to new information;

(6) The return is non-zero but successive bid and ask prices are unchanged; the non-zero return occurs because the prior day's trading volume was non-zero and the price was not at the mid-point of the spread, but there was no information exchange. However, this is again consistent with Conrad, Kaul and Nimalendran (1991), and evidences a "true" return of zero;

and (7) The return is zero; these cases occur only when volume on the previous day is also equal to zero, and the specialist did not change the bid and ask quotes.

We examine the frequency of cases in each of these categories using data on NYSE and AMEX securities for the period 1988-90. As before, we sort securities into size deciles, and for securities in each decile we compute the proportion of all returns that fit into each of the seven categories listed above. The results are shown in Table B. Shown in columns 2 through 8 are the proportions of all returns that conform to categories (1) through (7), respectively.

To provide internal validity for the results, we verify the proportion of zero returns that we derived using the CRSP actual returns of Table 1 for the period 1988 to 1990. This result is contained in the second last column of Table B and given as the absolute proportion of zero returns which is the sum of categories (3), (4), and (7). These results are identical to those of Table 1.

To determine the "effective" number of zero returns we sum the columns that correspond to the actual zero returns and those returns that would be zero if we accounted for the bid-ask bounce. The proportions in categories (2), (3) and (4) correspond to the positive volume case and categories (5) and (7) correspond to the zero volume case. Categories (2) and (5) correspond to those cases where the actual return is non-zero, but would be zero if we accounted for the bid-ask bounce. Adding categories (2), (3), (4), (5), and (7) will determine the "effective" number of zero returns.

As shown in the last column of Table B, the "effective" number of zero returns is always greater than the actual CRSP reported number of zero returns. However, the CRSP reported number of actual zero returns is a good indicator of the number of "true" zero returns. The difference between these two proportions is inversely related to firm size, ranging from 1.82% for the largest firms to 10.40% for the smallest firms. Remarkably, for the smallest firms the "effective" proportion of zero returns is greater then 50% (54.09%). While the bid-ask bounce in security returns or trading volume affects the number of zero returns, CRSP daily security returns provide an accurate indicator of the "effective" number of zero returns.

Table B

Daily Security Return Behavior: Bid and Ask Quote Basis

This table presents the proportions of zero and non-zero returns that are predicated on the bid and ask quotes. Seven categories are presented. The first four correspond to non-zero daily trading volume while the last three correspond to zero daily trading volume. Within the first four categories, categories (1) and (2) contain non-zero returns that pertain to successive trades at different bid and ask quotes, and successive trades at different extremes of the bid-ask spread or the bid-ask bounce, respectively. Categories (3) and (4) are observed zero returns because of successive closing trades at the bid or ask prices and successive closing trades that are not at the bid or ask prices, respectively. Categories (5) and (6) correspond to non-zero returns (but zero volume). Category (5) results from the specialist changing their quotes. Category (6) results from the trades at either the bid or ask prices the previous day and the average price recorded today. Category (7) corresponds to observed zero returns that result because of zero volume. The last two zero return calculations correspond to the sums of separate categories. The first zero return calculation is the sum of categories (3), (4), and (7). These are simply the observed zero returns as observed on the CRSP database, but aggregated from different daily volume cases. The last zero return calculation is termed the *effective* zero returns because it contains the proportions of zero returns that would result if in addition to the observed zero returns we included those days that exhibited non-zero returns related to the bid-ask bounce, categories (2) and (6). A (Zero) is included in categories (2) and (6) to signify an *effective* zero return. The size deciles are the NYSE/AMEX size deciles as taken from CRSP.

	Categories of Daily Return Proportions							Categories of Zero Return Proportions	
	Non-Zero Trading Volume				Zero Trading Volume				
Size Decile	Non-Zero (1) (%)	Non-Zero (Zero) (2) (%)	Zero (3) (%)	Zero (4) (%)	Non-Zero (5) (%)	Non-Zero (Zero) (6) (%)	Zero (7) (%)	Absolute Proportion of Zero Returns (3)+(4)+(7) (%)	*Effective* Proportion of Zero Returns (2)+(3)+(4)+(6)+(7) (%)
1	40.53	3.82	8.52	18.71	4.77	6.58	16.46	43.69	54.09
2	50.52	4.46	9.58	19.28	3.44	4.38	7.94	36.80	45.64
3	56.90	4.57	9.61	20.12	2.12	2.70	3.61	33.34	40.61
4	60.81	4.56	9.08	19.90	1.27	1.78	1.79	30.77	37.11
5	64.64	4.63	8.66	18.02	0.79	1.38	0.90	27.58	33.59
6	65.79	3.95	7.22	17.11	0.56	3.86	1.34	25.67	33.48
7	70.53	3.36	5.75	15.16	0.52	2.69	0.78	21.69	27.74
8	75.23	3.53	6.00	13.39	0.39	0.84	0.31	19.70	24.07
9	81.11	2.49	4.34	11.64	0.15	0.16	0.06	16.04	18.69
10	87.27	1.73	2.94	8.85	0.00	0.09	0.01	11.80	13.62

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Security Return Behavior

Avnet Corporation: 1989

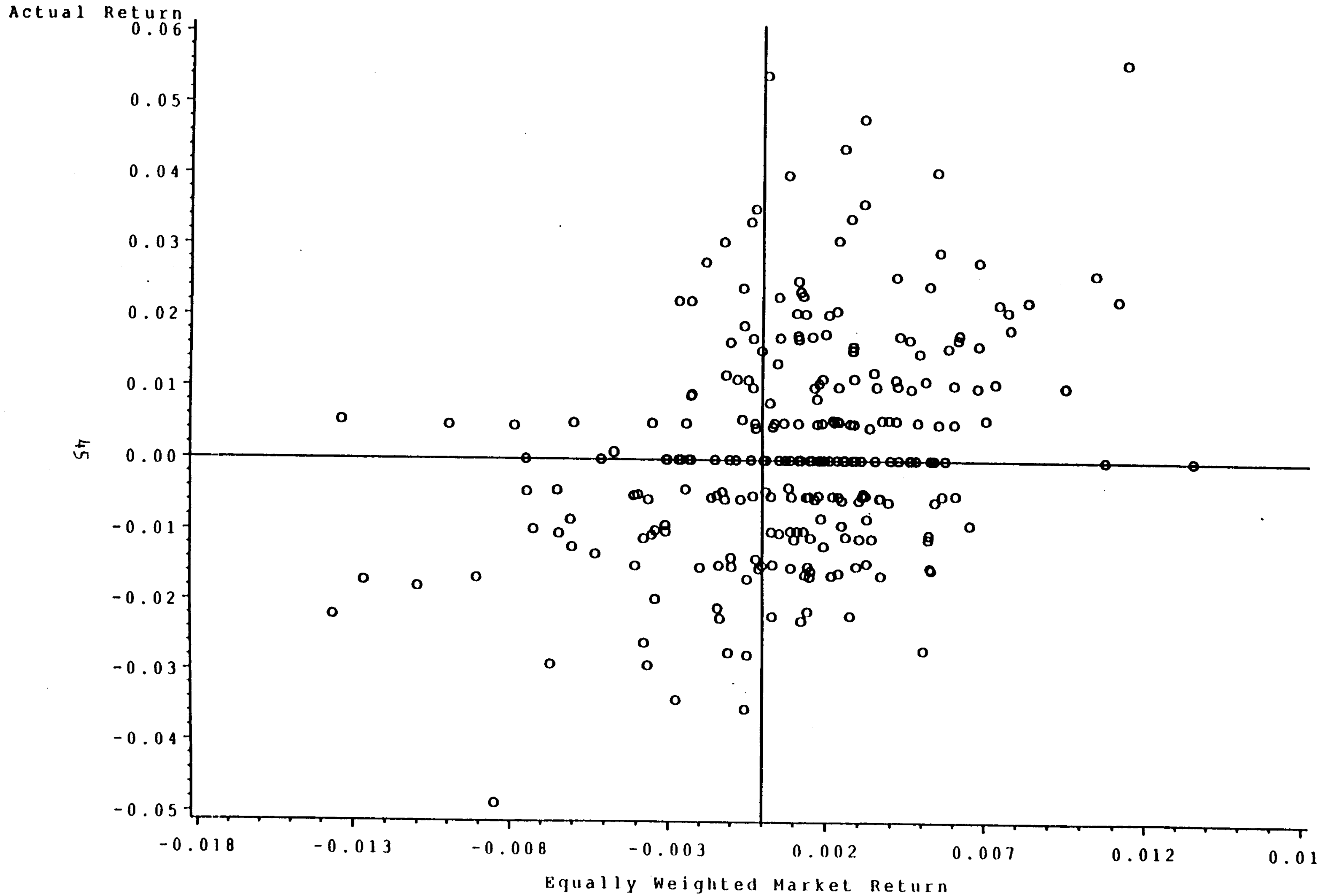
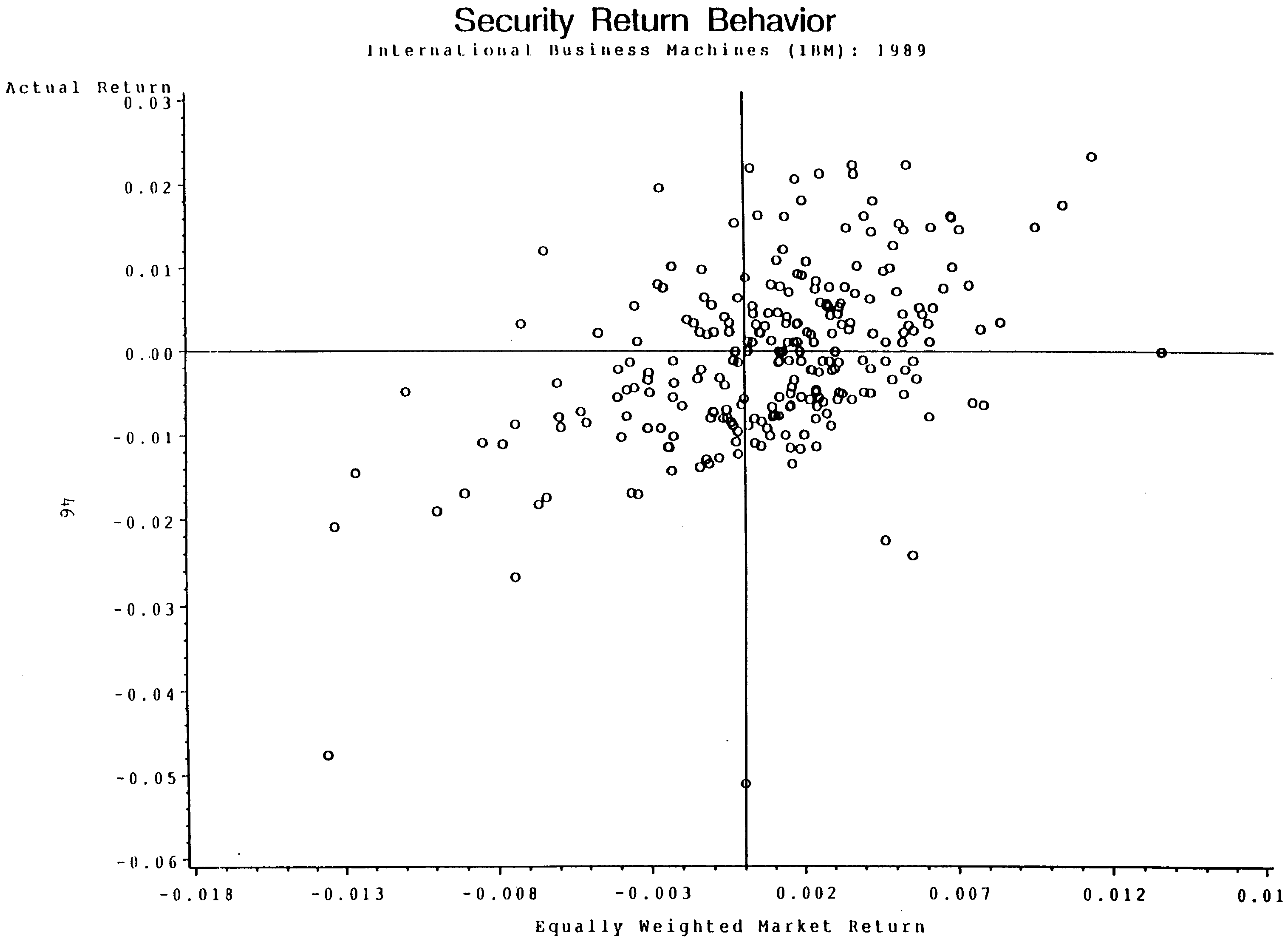


Figure 1



Security Return Behavior
International Business Machines (IBM): 1989
Actual Return
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.018
-0.013
-0.008
-0.003
0.002
0.007
0.012
0.017
Equally Weighted Market Return

Figure 2

LDV Model Specification
Econometric Structure and Nomenclature

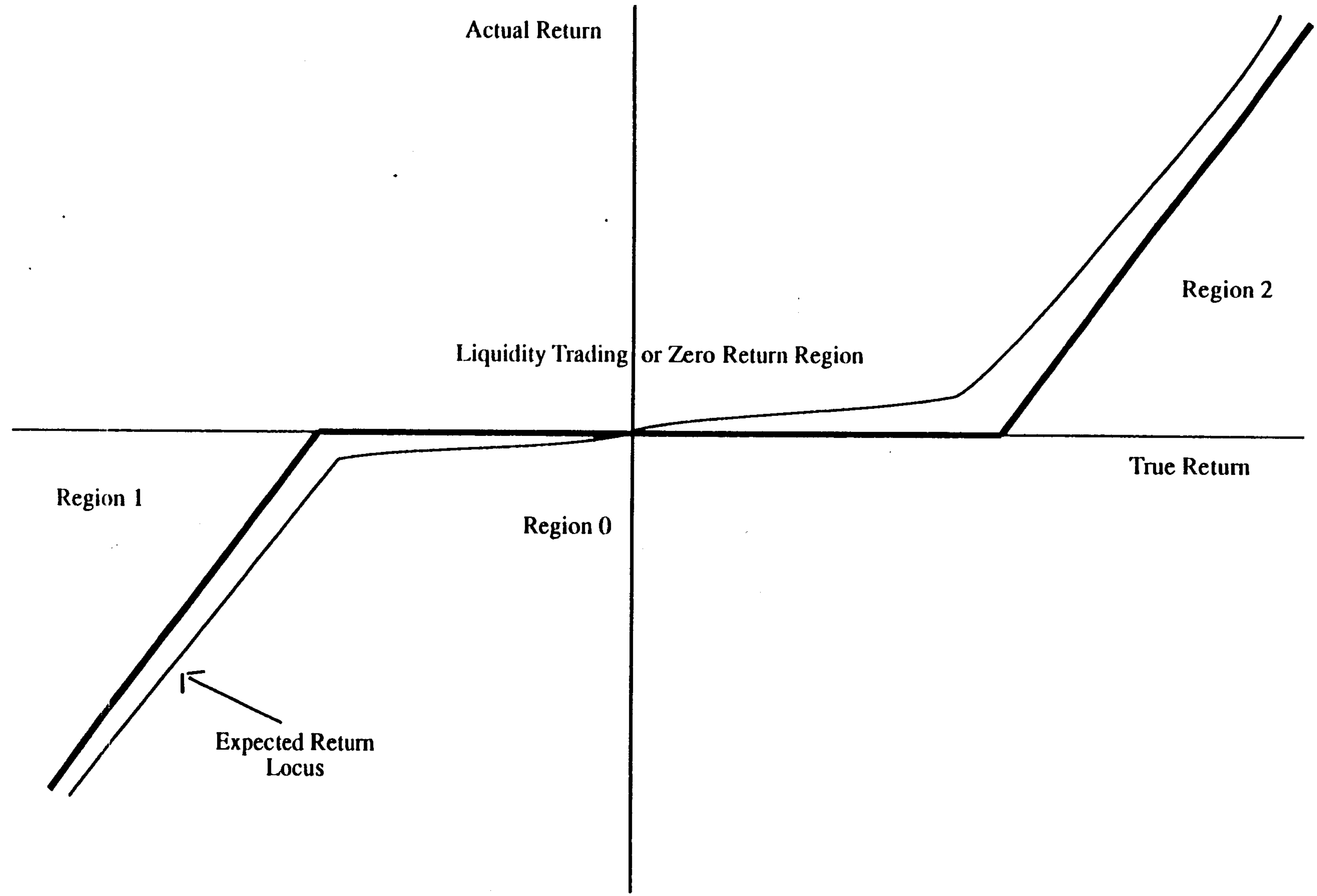


Figure 3

Transaction Costs Comparisons: LDV Estimates,

Spreads & Commissions

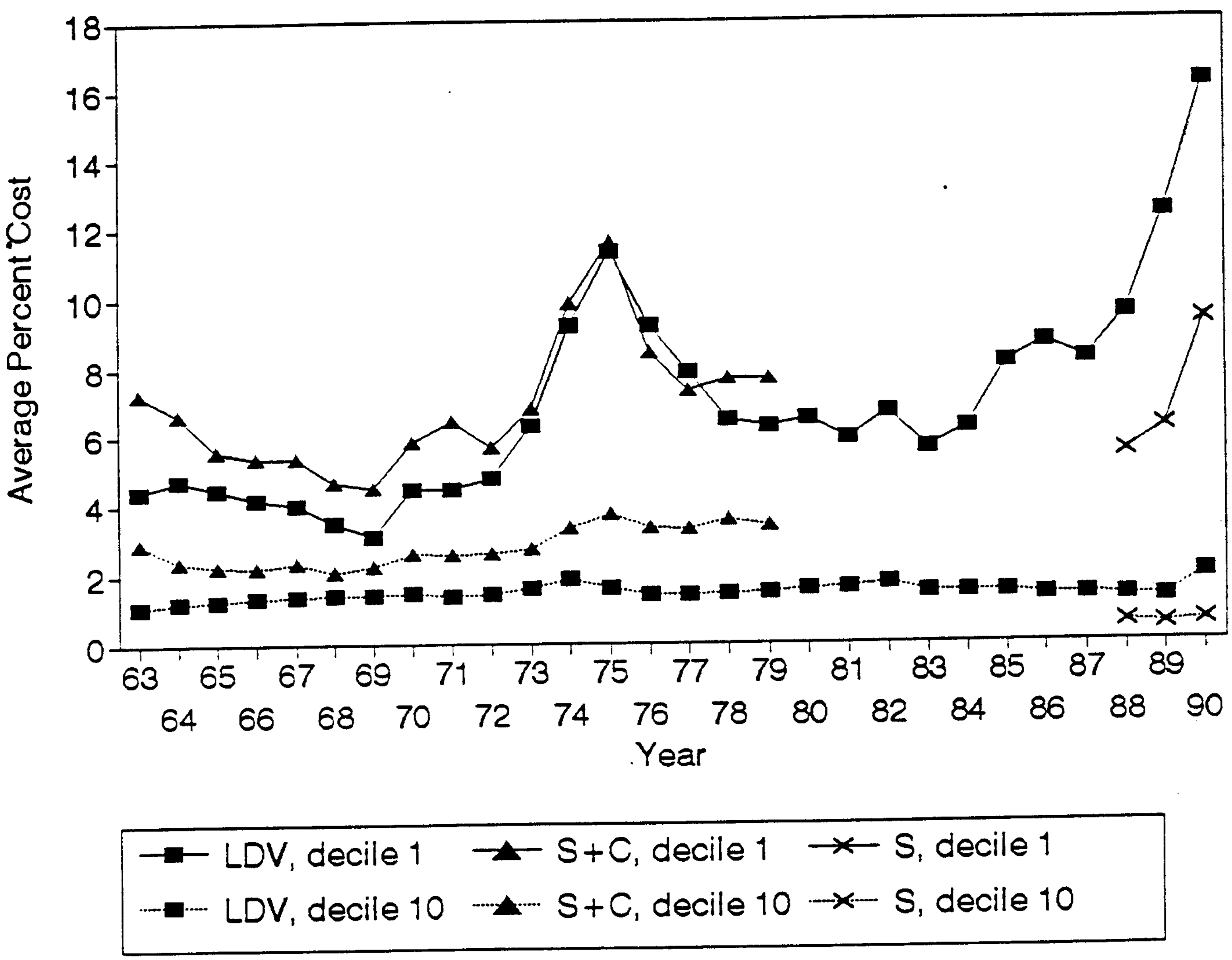


Figure 4. Mean percentage estimated transaction cost rates, using three measures, for selected size-sorted NYSE common stocks, annually for 1963-1990. The first measure is the limited dependent variable (LDV) estimate calculated for 1963-1990, the second is the sum of average proportional bid-ask spreads and round-trip commission rates (S+C) calculated for 1963-1979, and the third is the proportional bid-ask spread (S) calculated for 1988-1990. Firms are sorted annually into deciles by total market value of common equity, and the figure shows results for firms in decile 1 (smallest) and decile 10 (largest).

Table 1

Average Proportions of Zero Returns, Specialists' Spreads, and Roll Model Estimates by Firm Size

The results are based on a year-by-year analysis of daily returns for NYSE/AMEX stocks for the period 1963 to 1990 (Panel A) and the period 1988 to 1990 (Panel B). The size decile ranking is taken from CRSP with size deciles one and ten corresponding to the smallest and largest firms, respectively. For each firm and year the proportion of daily returns equal to zero is calculated and the average of these proportions is computed for stocks in each size decile. These zero returns are scaled by the total number of available trading days to determine the proportion of zero returns. Roll's spread is defined as $2\sqrt{-cov}$, where cov is the first order serial autocovariance of daily security returns. Roll's 'effective' spread is estimated using the serial autocovariance of returns based on data for a full year. The given Roll's spread measure forces all positive serial autocovariance measures negative as outlined in Harris (1990). The specialists' spread of Panel B is the average of each day's closing bid and ask quotes, defined as $\frac{(Ask-Bid)}{(Ask+Bid)/2}$ over an annual trading period. Firm-Years refers to the number of observations for the proportions of zero daily returns, specialists' spreads, and Roll's estimate.

Panel A: Period 1963 to 1990

Size Decile	Firm Years	Proportion of Zero Daily Returns (%)	Maximum Proportion of Zero Daily Returns (%)	Roll's Spread (%)
1	5928	36.6	84.5	4.34
2	5867	31.1	77.4	2.88
3	5806	27.8	69.8	1.67
4	5875	25.0	82.5	1.31
5	5851	22.6	67.1	1.16
6	5938	20.2	76.9	0.76
7	6005	18.6	78.6	0.56
8	6173	16.7	69.9	0.52
9	6368	14.6	65.1	0.34
10	6540	11.9	49.2	0.31

Panel B: Period 1988 to 1990

Size Decile	Firm Years	Proportion of Zero Daily Returns (%)	Specialists' Spread (%)	Roll's Spread (%)	Roll's Spread ÷ Specialists' Spread (%)
1	521	43.7	10.05	5.25	52.24
2	537	36.8	5.03	2.68	53.28
3	533	33.4	3.48	1.76	50.58
4	511	30.8	2.61	1.21	46.36
5	520	27.6	2.20	1.02	46.36
6	508	25.7	1.72	0.68	39.54
7	523	21.7	1.45	0.56	38.62
8	606	19.7	1.14	0.48	42.11
9	581	16.0	0.87	0.35	40.23
10	520	11.8	0.60	0.36	60.00

Table 2

Results of Regressions of Zero Returns on Specialists' Spread

Regressions of the proportion of zero returns on the average proportional specialists'spread. The results are based on the aggregate as well as size decile rankings of all NYSE/AMEX firms for the period 1988 to 1990. The specialist's spreads are based on closing bid and ask quotes obtained from ISSM. Firms are analyzed on a daily basis from January to December to obtain the proportion of zero returns (*Propzero*) and the average proportional spread (*Spread*). *Spread* is the average daily proportional spread, defined as $\frac{(Ask-Bid)}{(Ask+Bid)/2}$. The size decile ranking is taken from CRSP with size deciles one and ten corresponding to the smallest and largest firms, respectively. Any firm-year that had a zero market capitalization or either began or ceased trading mid-year was deleted. The regression equation is $Propzero_{jf} = \zeta_1 + \zeta_2 Spread_{jf} + \epsilon_{jf}$, where j and f are size decile and firm-year indicators, respectively. Standard errors are in parentheses.

Size Decile	Firm-Years	*Intercept* $\hat{\zeta}_1$	*Spread* $\hat{\zeta}_2$	$\%R^2$
1	520	0.3912**	0.4565**	15.12
		(0.0069)	(0.0471)	
2	536	0.3070**	1.2117**	24.96
		(0.0068)	(0.0912)	
3	532	0.2677**	1.8814**	30.10
		(0.0057)	(0.0134)	
4	510	0.2286**	3.0530**	34.97
		(0.0066)	(0.2038)	
5	519	0.2034**	3.3149**	29.93
		(0.0064)	(0.2490)	
6	507	0.1790**	4.4968**	24.81
		(0.0074)	(0.3856)	
7	521	0.1421**	5.1814**	27.76
		(0.0064)	(0.3667)	
8	605	0.1064**	7.8761**	27.80
		(0.0063)	(0.5167)	
9	580	0.0635**	11.1471**	25.71
		(0.0071)	(0.7876)	
10	519	0.0285**	14.8578**	30.76
		(0.0074)	(0.9791)	
Aggregate	5359	0.2093**	1.9454**	37.50
		(0.0011)	(0.0341)	

** Significant at the 1% level

Table 3

Average Proportions of Zero Returns by Firm Size and Market Return Intervals

The proportions of zero returns are shown for each market return interval and firm size decile. The proportions of zero returns are the ratio of the number of zero returns divided by the non-zero returns for each specified market return interval and are given as a percentage. The size decile ranking is taken from CRSP with size deciles one and ten corresponding to the smallest and largest firms, respectively. Note that the most extreme market return intervals span 180 basis points while the remainder span 30 basis points. The delineated area separates a statistically reduced proportion of zero returns. The market return is the equally weighted index as provided by CRSP for the years 1963 to 1990. The F-statistic tests the null hypothesis that the proportion of zero returns (for a given size decile) are equal across the market return intervals.

	Proportions of Zero Returns (%)										
	Market Return Interval (%)										
Firm Size Decile	-3.0 to -1.2	-1.2 to -0.9	-0.9 to -0.6	-0.6 to -0.3	-0.3 to 0.0	0.0 to 0.3	0.3 to 0.6	0.6 to 0.9	0.9 to 1.2	1.2 to 3.0	F
1	42.1	103.2	105.4	114.4	107.8	101.1	95.9	100.0	101.5	71.2	15**
2	20.7	52.9	57.5	61.8	60.7	58.3	56.5	56.2	57.3	32.8	54**
3	15.9	42.1	47.0	49.8	50.3	48.3	46.0	44.5	43.2	24.1	67**
4	12.4	33.6	38.4	41.6	42.5	41.4	39.4	37.3	32.7	18.7	73**
5	10.4	27.4	31.6	35.0	35.9	35.3	34.0	31.6	28.8	16.1	75**
6	8.9	23.8	27.1	29.6	31.2	31.2	29.3	26.9	24.1	13.8	84**
7	7.4	19.2	22.4	25.7	26.3	26.6	24.7	22.3	19.7	10.9	93**
8	6.3	15.2	17.4	20.1	22.4	22.9	20.7	18.4	15.2	8.1	101**
9	4.4	11.3	13.4	16.0	17.6	17.6	16.3	14.3	13.2	6.5	113**
10	3.2	7.6	10.3	12.1	13.0	12.9	11.0	9.9	9.1	4.5	130**

** Significant at the 1% level

Table 4

Average Values of LDV Model Estimates for NYSE/AMEX Stocks

The results are based on a year-by-year analysis of firm data for NYSE/AMEX stocks for the period 1963 to 1990. The size decile ranking is taken from CRSP with size deciles one and ten corresponding to the smallest and largest firms, respectively, for combined and separated NYSE/AMEX firms of Panels A and B. Panel B also uses a NYSE firm grouping that relies on only NYSE firms that are sorted into decile rankings for each year from 1963 to 1990. The LDV model intercept estimates, $\hat{\alpha}_1$ and $\hat{\alpha}_2$, are based on a full year of data, regressing stock returns on the equally weighted market index. If a firm began or ceased trading during the year that firm was deleted for that year.

Panel A: NYSE/AMEX firms combined

Size Decile	Firm Years	$\hat{\alpha}_1(\%)$	$\hat{\alpha}_2(\%)$	$\hat{\alpha}_2 - \hat{\alpha}_1(\%)$	$t(\hat{\alpha}_2 - \hat{\alpha}_1)$
1	4365	−5.34	4.31	10.35	28.3
2	5911	−3.68	3.41	7.09	24.6
3	5888	−2.92	2.67	5.59	25.7
4	5945	−2.35	2.14	4.49	30.1
5	5963	−1.97	1.86	3.83	29.9
6	6074	−1.65	1.54	3.19	32.6
7	6118	−1.43	1.33	2.76	31.2
8	6256	−1.19	1.09	2.28	35.6
9	6191	−0.97	0.87	1.84	33.1
10	5356	−0.73	0.50	1.23	27.7

Panel B: NYSE and AMEX firms separated

NYSE/AMEX Size Decile	Firm Years	*Only AMEX* $\hat{\alpha}_2 - \hat{\alpha}_1(\%)$	Firm Years	*Only NYSE* $\hat{\alpha}_2 - \hat{\alpha}_1(\%)$	NYSE Size Decile	Firm Years	*NYSE* $\hat{\alpha}_2 - \hat{\alpha}_1(\%)$
1	4076	10.26	289	15.91	1	3656	6.97
2	5101	6.94	810	8.58	2	3881	4.12
3	4076	5.56	1812	5.78	3	3885	3.45
4	2996	4.67	2949	4.41	4	3847	3.02
5	1999	4.06	3964	3.73	5	3808	2.69
6	1299	3.57	4775	3.11	6	3781	2.43
7	864	3.21	5254	2.71	7	3732	2.15
8	547	2.81	5709	2.28	8	3637	1.91
9	329	2.35	5862	1.90	9	3481	1.70
10	156	1.94	5200	1.55	10	2916	1.46

Table 5

Spread-plus-Commission and LDV Transaction Costs Comparisons

Period 1963 to 1979

Panel A shows mean percentage spreads (S), round-trip commissions (C), and LDV estimates of transaction costs based on a year-by-year analysis of data for NYSE firms for the period 1963 to 1979. The size decile rankings are computed using only NYSE firms where size deciles one and ten correspond to the smallest and largest NYSE firms, respectively. Shown as Stoll and Whaley's (1983) proportional spread (S) data and the NYSE stated minimum round-trip commission (C) expressed in percentages for each size decile. The mean percentage spread are a point estimate taken at December 31 of each year from 1963 to 1979. It should be noted that in Stoll and Whaley's (1983) paper they present one-half of the round-trip commission whereas we present the full round-trip commission. The LDV model estimates, $\alpha_2 - \alpha_1$, are based on a full year of data, regressing stock returns on the equally weighted market index. The t-statistic of Panel A is from a means test for the difference between spread (S) plus round-trip commissions (C) and the LDV transaction costs estimates for each size decile. The regressions of Panel B for each size decile are stated as $\alpha_{2f} - \alpha_{1f} = \zeta_1 + \zeta_2 Spread_{jf} + \zeta_3 Commission + \epsilon_{jf}$.

Panel A: Comparisons of Spread-plus-Commission and LDV Estimates of Total Transaction Costs

NYSE Size Decile	Mean (%) Spread (S)	Mean (%) Round-Trip Commission (C)	Mean (%) S+C	Mean (%) $\alpha_2 - \alpha_1$ LDV Estimate	Difference t-stat
1	2.93	3.84	6.77	5.82	34.83
2	2.05	3.18	5.23	4.02	45.58
3	1.68	2.96	4.64	3.34	44.19
4	1.47	2.78	4.25	2.95	61.45
5	1.33	2.64	3.97	2.64	71.52
6	1.19	2.52	3.71	2.35	73.80
7	1.10	2.44	3.54	2.12	58.54
8	0.99	2.40	3.99	1.87	69.49
9	0.89	2.26	3.15	1.69	59.97
10	0.69	2.02	2.71	1.43	70.97

Overall Correlation: 87%

Panel B: Regressions of LDV Estimates of Transaction Costs on the Specialists' Spread and Commission Estimates

Size Decile	Firm-Years	*Intercept* $\hat{\zeta}_1$	*Spread* $\hat{\zeta}_2$	*Commission* $\hat{\zeta}_3$	$\%R^2$
1	1980	−2.5851**	0.4314**	1.7186**	81.82
		(0.1102)	(0.0259)	(0.0378)	
2	2090	−2.1292**	0.5031**	1.5103**	74.48
		(0.0957)	(0.0235)	(0.0353)	
3	2125	−1.7943**	0.4613**	1.4096**	65.71
		(0.0945)	(0.0246)	(0.0362)	
4	2121	−1.5293**	0.6498**	1.1999**	65.59
		(0.0845)	(0.0289)	(0.0354)	
5	2129	−1.0967**	0.4497**	1.1347**	56.73
		(0.0803)	(0.0234)	(0.0321)	
6	2124	−0.6050**	0.5456**	0.8726**	51.97
		(0.0698)	(0.0264)	(0.0291)	
7	2116	−0.2544**	0.6661**	0.6532**	46.82
		(0.0613)	(0.0303)	(0.0262)	
8	2076	0.0555	0.5171**	0.5373**	37.52
		(0.0553)	(0.0286)	(0.0231)	
9	1995	0.2699**	0.5172**	0.4180**	33.56
		(0.0473)	(0.0314)	(0.0195)	
10	1614	0.4691**	0.5138**	0.2746**	30.47
		(0.0386)	(0.0316)	(0.0163)	

** Significant at the 1% level

Table 6

Spread-plus-Commission and LDV Transaction Costs Comparisons

Periods 1982 to 1990 and 1988 to 1990

Panel A shows median percentage spreads (S), commissions (C) as given by Bhardwaj and Brooks (1992) for five price groupings and 20 NYSE firms for the period 1982 to 1986. Median values, as opposed to means, are given as the medians are much smaller than the means as presented by Bhardwaj and Brooks (1992). The commissions stated are round trip commission costs (C). The LDV model estimates of total transaction costs, $\alpha_2 - \alpha_1$, are based on a full year of data, and are determined by regressing stock returns on the equally weighted market index. Panel B shows the period 1988 to 1990 where the Bhardwaj and Brooks commission schedule from 1982 to 1986 is used along with NYSE spread data from the period 1988 to 1990 to determine the spread plus round trip commission cost.

Panel A: Period 1982 to 1986 Comparisons of Spread-plus-Commission and LDV Estimates of Total Transaction Costs

Price Range Group	Median (%) Spread (S)	Median (%) Round-Trip Commission(C)	Median (%) S+C	Median (%) $\alpha_2 - \alpha_1$
$P \leq \$5$	5.128	7.407	12.535	10.121
$\$5 < P \leq \$10$	2.548	2.674	5.222	4.809
$\$10 < P \leq \$15$	1.827	2.917	4.744	3.311
$\$15 < P \leq \$20$	1.389	2.027	3.416	2.623
$\$20 > P$	0.806	1.289	2.095	1.789

Panel B: Period 1988 to 1990 Comparisons of Spread-plus-Commission and LDV Estimates of Total Transaction Costs

Price Range Group	Median (%) Spread (S)	Median (%) Round-Trip Commission(C)	Median (%) S+C	Median (%) $\alpha_2 - \alpha_1$
$P \leq \$5$	6.441	7.407	13.848	12.056
$\$5 < P \leq \$10$	2.299	2.674	4.973	4.404
$\$10 < P \leq \$15$	1.603	2.917	4.520	3.006
$\$15 < P \leq \$20$	1.278	2.027	3.305	2.330
$\$20 > P$	0.724	1.289	2.013	1.522

Table 7

Results of Regressions of LDV Model Estimates on the Specialists' Spreads

Regression tests of $\alpha_2 - \alpha_1$ on the average proportional spread. The results are based on the aggregate as well as size decile rankings of all NYSE/AMEX firms for the period 1988 to 1990. The specialists' spreads are based on closing bid and ask quotes obtained from ISSM. The resulting firms are analyzed on a daily basis from January to December to obtain an average proportional spread. The proportional spread, shown as *Spread*, is the average of each day's spread, and defined as $\frac{(Ask-Bid)}{(Ask+Bid)/2}$ over an annual trading period. The size decile ranking is taken from CRSP with size deciles one and ten corresponding to the smallest and largest firms, respectively. Any firm-year that had a zero market capitalization or either began or ceased trading mid-year was deleted. The regressions for each size decile and in aggregate are stated as $\alpha_{2f} - \alpha_{1f} = \zeta_1 + \zeta_2 Spread_{jf} + \epsilon_{jf}$. Standard errors are in parenthesis.

Size Decile	Firm-Years	*Intercept* $\hat{\zeta}_1$	*Spread* $\hat{\zeta}_2$	$\%R^2$
1	520	0.0054 (0.0040)	1.5595** (0.0319)	82.15
2	536	−0.0049** (0.0023)	1.9097** (0.0351)	84.72
3	532	−0.0072** (0.0012)	2.0531** (0.0267)	91.76
4	510	−0.0020 (0.0012)	1.9595** (0.0382)	83.79
5	519	0.0004 (0.0013)	1.9589** (0.0499)	74.86
6	507	−0.0043** (0.0008)	2.1608** (0.063)	82.99
7	522	−0.0029** (0.0008)	2.2371** (0.0507)	78.89
8	605	−0.0028** (0.0008)	2.2763** (0.0595)	70.75
9	580	0.0040** (0.0007)	1.6734** (0.0743)	46.46
10	519	0.0053** (0.0004)	1.4664** (0.0674)	47.72
Aggregate	5359	0.0047** (0.0004)	1.6495** (0.0081)	88.47

** Significant at the 1% level

Table 8

Results of Regressions of Roll's "Effective" Bid-Ask Spread Estimate on the Specialists' Spread

Regression tests of Roll's estimates "effective" spread estimator, on the average proportional spread. The results are based on the aggregate as well as size decile rankings of all NYSE/AMEX firms for the period 1988 to 1990. The restricted period corresponds to the available closing bid and ask quotes obtained from ISSM. The resulting firms are analyzed on a daily basis from January to December to obtain Roll's effective spread measure and the average proportional spread. For those firm-years where the serial autocovariance is positive, the covariance is forced negative but used as if a negative covariance was obtained. The proportional spread, shown as *Spread*, is the average of each day's spread, defined as $\frac{(Ask-Bid)}{(Ask+Bid)/2}$ over an annual trading period. The size decile ranking is taken from CRSP with size deciles one and ten corresponding to the smallest and largest firms, respectively. Any firm-year that had a zero market capitalization or did not trade for the entire year (i.e. that began or ended trading mid-year) was deleted. The regressions for each size decile and in aggregate are stated as $2\sqrt{-cov} = \zeta_1 + \zeta_2 Spread_{jf} + \epsilon_{jf}$. Standard errors are in parenthesis.

Size Decile	Firm-Years	*Intercept* $\hat{\zeta}_1$	*Spread* $\hat{\zeta}_2$	$\%R^2$
1	520	−0.0067**	0.6223**	73.57
		(0.0021)	(0.0164)	
2	536	−0.0061**	0.7295**	76.94
		(0.0012)	(0.0172)	
3	532	−0.0035**	0.7497**	73.46
		(0.0009)	(0.0196)	
4	510	−0.0002	0.6766**	64.92
		(0.0007)	(0.0220)	
5	519	0.0018**	0.6517**	52.99
		(0.0008)	(0.0269)	
6	507	0.0002	0.7446**	50.05
		(0.0006)	(0.0330)	
7	522	0.0019**	0.7514**	45.31
		(0.0006)	(0.0362)	
8	605	0.0030**	0.6984**	27.06
		(0.0006)	(0.0466)	
9	580	0.0075**	0.3133**	3.53
		(0.0006)	(0.0680)	
10	519	0.0072	0.2865**	1.45
		(0.0006)	(0.1039)	
Aggregate	5359	−0.0038**	0.6265**	77.31
		(0.0002)	(0.0046)	

** Significant at the 1% level