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Bid-ask Spreads: An Examination Of Systematic Behavior Using Intraday Data On Canadian And Us Exchanges

David Carlyle Porter

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BID-ASK SPREADS: AN EXAMINATION OF SYSTEMATIC BEHAVIOR USING INTRADAY DATA ON CANADIAN AND U.S. EXCHANGES

by

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Submitted in partial fulfilment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Graduate Studies
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LIST OF TABLES cont'd

12 F Tests for Equality of SUR Regression Time Dummy Coefficients 86

ABSTRACT

Recently, many authors have noted anomalies in risk adjusted returns as measured by the Capital Asset Pricing Model (CAPM). The majority of these studies are based implicitly or explicitly on two assumptions:

A) there are no systematic cross-sectional or time-series differences in the probability of a trade occurring at the bid or at the ask, and

B) there are no systematic time-series movements in proportional bid-ask spreads.

In this thesis, I test the validity of these two Assumptions by testing four subsets of Assumption A, using LOGIT regressions and a single subset of Assumption B, using a SUR regression. The Canadian data include time and date stamped intraday bid-ask quotes, transaction prices, and volumes on every security listed on the Toronto Stock Exchange (TSE) over the period January 1979 to December 1987. The U.S. data consists of all securities interlisted on the TSE, NYSE and AMEX during the period January 1984 to December 1987, and includes many active securities such as IBM, GM, Mobil Oil, and American Express.

I find systematic differences in the probability of a bid and ask across days of the week, price stratified portfolios, and times of day. I also find proportional spreads are not stable during the day. Based on these results, I conclude Assumptions A and B are not valid.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

Page

CERTIFICATE OF EXAMINATION ii
ABSTRACT iii
ACKNOWLEDGEMENTS v
TABLE OF CONTENTS vi
LIST OF TABLES viii
LIST OF FIGURES x

CHAPTER 1 - INTRODUCTION 1

CHAPTER 2 - THE DAY-OF-THE-WEEK AND END-OF-THE-DAY EFFECTS: PREVIOUS RESEARCH 7

2.1 Evidence of the Day-of-the-Week Effect 7
2.2 Evidence of the End-of-the-Day Effect 10
2.3 Explanations for the Day-of-the-Week and End-of-the-Day Effects 13
2.3.1 Settlement Day Hypothesis 13
2.3.2 Measurement Error Hypothesis 15
2.3.3 Trading Slows Towards the End of the Day Hypothesis 17
2.3.4 Closing Prices are Manipulated Hypothesis ... 17
2.3.5 Bid-Ask Bias Hypothesis 18
2.4 Summary 19

CHAPTER 3 - EXAMINING THE FREQUENCY OF BIDS AND ASKS INTERDAY AND INTRADAY: TESTING THE VALIDITY OF ASSUMPTION A: 21

3.1 Data 21
3.2 Measuring a Trades Placement Within the Bid-Ask Spread 22
3.3 Examining the Frequency of Bids and Asks Across Days of the Week 24
3.3.1 Method 25
3.3.2 Results 27
3.4 Examining the Frequency of Bids and Asks Across Price Stratified Portfolios 30
3.4.1 Method 31
3.4.2 Results 33
3.5 Examining the Frequency of Bids and Asks Across Times of the Day, Holding the Day of the Week Constant 37
3.5.1 Method 38
3.5.2 Results 40
3.6 Examining the Frequency of Bids and Asks Across Days of the Week, Holding the Time of the Day Constant 42
3.6.1 Method 43
3.6.2 Results 44
3.7 Summary 46

TABLE OF CONTENTS cont'd

CHAPTER 4 - DETERMINANTS OF BID-ASK SPREADS: PREVIOUS RESEARCH 47

4.1 Early Empirical Studies 47
4.2 Theoretical Models 54
4.3 Summary 60

CHAPTER 5 - EXAMINING THE TIME-SERIES BEHAVIOR OF INTRADAY PROPORTIONAL BID-ASK SPREADS: TESTING THE VALIDITY OF ASSUMPTION B 61

5.1 Measuring Intraday Proportional Bid-Ask Spreads 61
5.1.1 Method 62
5.1.2 Results 67
5.2 Summary 70

CHAPTER 6 - CONCLUSIONS AND IMPLICATIONS 71

6.1 Conclusions 71
6.2 Implications for Future Research 72

TABLES 74

FIGURES 87

BIBLIOGRAPHY 92

LIST OF TABLES

Table	Description	Page
1	Trading Summary of Canadian-Based Securities Interlisted on U.S. Exchanges During 1987	74
2	Trading Summary of U.S.-Based Securities Interlisted on Canadian Exchanges During 1987	76
3	Summary of Volume and Value of Canadian-Based and U.S.-Based Interlisted Securities for the Year Ended December 31, 1987	77
4	Difference of Means Tests, Means, and Variances for LOGIT Regression Coefficients Across Days of the Week Using Canadian Data 1979-1987 and U.S. Data 1984-1987	78
5	Difference of Means Tests, Means, and Variances for LOGIT Regression Coefficients Across Price Portfolio Quintiles Using Canadian Data 1979-1987	79
6	Difference of Means Tests, Means, and Variances for LOGIT Regression Coefficients Across Times of the Day, All Days Combined Using Canadian Data 1979-1987	80
7	T Statistics for Difference of Means Tests for LOGIT Regression Coefficients Across Days of the Week for Seven Time Periods During the Day Using Canadian Data 1979-1987 and U.S. Data 1984-1987	81
8	Means and Variances of LOGIT Regression Coefficients Across Days of the Week for Seven Time Periods During the Day Using Canadian Data 1979-1987 and U.S. Data 1984-1987 ..	82
9	SUR Regression Coefficients (T Stats) for Canadian Data by Time of Day and Price Stratified Quintiles from 1979-1987	83
10	SUR Regression Coefficients (T Stats) for Canadian Data by Time of Day, Volume, and Price Stratified Quintiles from 1979-1987	84
11	SUR Regression Coefficients (T Stats) for Canadian Data by Time of Day, Variance, Volume, and Price Stratified Quintiles from 1979-1987	85

LIST OF TABLES cont'd

12 F Tests for Equality of SUR Regression Time Dummy Coefficients 86

LIST OF FIGURES

Figure	Description	Page
1	Probability of the Last Trade of the Day Occurring at the Ask Across Five Price Stratified Portfolios Using Canadian Data 1979-1987	87
2	Probability of a Trade Occurring at the Ask Across Times of the Day, For Days of the Week Using Canadian Data 1979-1987	88
3	Probability of a Trade Occurring at the Ask Across Times of the Day, For Days of the Week Using U.S. Data 1984-1987	89
4	Probability of a Trade Occurring at the Ask Across Days of the Week, For Seven Time Periods During the Day Using Canadian Data 1979-1987	90
5	Probability of a Trade Occurring at the Ask Across Days of the Week, For Seven Time Periods During the Day Using U.S. Data 1984-1987	91

CHAPTER 1

INTRODUCTION

Bid-ask spreads and the statistical biases they can create in computed returns and variances have interested researchers for at least two decades. Niederhoffer and Osborne (1966) show the existence of bid-ask spreads leads to negative autocorrelation in stock price changes. Fisher (1966) demonstrates the bid-ask spread can result in an upward bias in computed returns. More recently, many authors, including Blume and Stambaugh (1983), Stoll and Whaley (1983), Lakonishok and Smidt (1984), and Amihud and Mendelson (1986), examine the bid-ask spread as a possible explanation of several anomalies in risk adjusted returns as measured by the Capital Asset Pricing Model (CAPM). These anomalies include the small firm effect, the day-of-the-week effect, and the end-of-the-day effect. The majority of these papers are based implicitly or explicitly on two assumptions:

A) there are no systematic cross-sectional or time-series differences in the probability of a trade occurring at the bid or at the ask, and

B) there are no systematic time-series movements in proportional bid-ask spreads (measured as the percentage difference between bid and ask prices).

The significance of these two assumptions is demonstrated with the following examples.

1) Gibbons and Hess (1981) find, on average, weekend returns are negative when returns are measured Friday close to Monday close. Keim and Stambaugh (1984) note returns are usually measured with closing prices and closing prices often represent a specialist's bid or ask price rather than the "true" price at which a security would trade in the absence of the specialist. They then show relatively small variations in the frequency of trades at the bid or ask during the week can create an effect similar to the effect found by Gibbons and Hess. For example, if a $50.00 stock has a spread of $0.25, and if there is a 15% greater probability of a closing trade at the ask on Friday and a 15% greater probability of a closing trade at the bid on Monday, then the calculated weekend return would be -0.075% even though the "true" return is zero. This negative return is similar in size to the negative returns found in studies of the weekend effect.

2) Terry (1986), when studying the end-of-the-day effect, finds that hourly returns variances for the Dow Jones 30 are approximately 160% higher in the last hour of the day than in any other hour of the day. To examine what portion of

this difference may be the result of computing variances using transaction prices, consider the following example. Assume the average price of a Dow Jones 30 stock is $50.00; the average spread during the hour 11:00 to 12:00 is 1/8; the average spread during the hour 3:00 to 4:00 is 1/4. The variance of returns for 30 stocks, half moving from the bid to the ask and half moving from the ask to the bid, is 6.25E-06 in the earlier hour and 24.95E-06 during the last hour of the day, or an increase of 300%. This example shows the variance differences found by Terry could be the result of the spread widening toward the end of the day.

3) Blume and Stambaugh (1983) suggest part of the small firm effect may be the result of an upward bias in computed daily returns resulting from the existence of specialist's bid and ask prices. They propose that observed price, $\hat{P}_{it}$, is a function of the true price, P_{it}, and a bid-ask bias:

$$\hat{P}_{it} = [1 + \delta_{it}]P_{it} \tag{1}$$

where $E[\delta_{it}] = 0$ and δ_{it} is independently distributed through time and is independent of $P_{i\tau}$ for all τ. They then show that expected observed return is a function of expected true return and the variance of δ:

$$E\{\hat{r}_{it}\} \approx E\{r_{it}\} + \sigma^2\{\delta_{i,t-1}\}. \tag{2}$$

To show the size of the bias, they assume the observed price is an ask price, P_a, or a bid price, P_b, with equal probability. This assumption implies expected closing price, $E\{P_c\}$ is:

$$E\{P_c\} = \Sigma_{\text{all } i} \; \pi_i P_i = (P_a + P_b)/2 \qquad (3)$$

which is assumed equal to the true price P. It then follows that δ_i is plus or minus $(P_a - P_b)/2P$ and the variance of δ_i is:

$$\sigma^2\{\delta_i\} = \Sigma_{\text{all } i} \; \pi_i[\delta_i - E(\delta_i)]^2 = \frac{(P_a - P_b)^2}{(P_a + P_b)^2} \qquad (4)$$

For a stock with a bid of \$1.00 and an ask of \$1.05, $\sigma^2\{\delta_i\}$ computes to 0.059%, which is a substantial portion of Blume and Stambaugh's computed daily return for small firms of 0.141%

If the same analysis is repeated with the assumption that 60% of the trades take place at the ask and 40% at the bid, rather than 50% at each boundary, then $E\{P_c\}$ becomes:

$$E\{P_c\} = \Sigma_{\text{all } i} \; \pi_i P_i = (3P_a + 2P_b)/5 \qquad (5)$$

which is also assumed equal to the true price P. It then follows, in this case, that δ_i is plus or minus $2(P_a - P_b)/5P$ and the variance of δ_i is:

$$\sigma^2\{\delta_i\} = \Sigma_{\text{all } i} \quad \pi_i[\delta_i - E(\delta_i)]^2 = \frac{4(P_a - P_b)^2}{(3P_a + 2P_b)^2} \qquad (6)$$

For a stock with a bid of \$1.00 and an ask of \$1.05, $\sigma^2\{\delta_i\}$ computes to 0.037%, or almost 40% less than the number calculated based on the assumption of equal probability of trades at the bid and the ask.

In summary, the violation of Assumption A or B can create statistical biases in measured returns and variances which may result in empirical researchers drawing incorrect conclusions from their studies.

In this thesis, I test the validities of Assumptions A and B using intraday Canadian and U.S. data. Four subsets of Assumption A are tested based on a review of the day-of-the-week and end-of-the-day anomalies. A single subset of Assumption B is tested based on a review of the determinants of bid-ask spreads. The results of these tests imply that both Assumptions A and B are invalid. The major implication of these findings is conclusions drawn from empirical studies based on the these assumptions may also be invalid. For example, the returns and variance patterns found by Wood, McInish and Ord (1985) will virtually disappear if returns and variances are calculated using the mean of the bid ask spread, rather than transaction prices.

The remainder of this thesis is organized as follows. In Chapter 2, I review the literature on the day-of-the-week and end-of-the-day effects. One explanation of these anomalies is bid-ask bias.[1] This explanation casts doubt on the validity of Assumption A. In Chapter 3, I describe and test four hypotheses that bear directly on the validity of Assumption A. This Chapter also includes a description of the data. In Chapter 4, I review the literature on the determinants of bid-ask spreads. During the analysis, I argue that cross-sectional theory and results from cross-sectional empirical studies imply time-series movements in bid-ask spreads. This implication casts doubt on the validity of Assumption B. In Chapter 5, I describe and test one hypothesis that bears directly on the validity of Assumption B. Chapter 6 contains a summary of the conclusions and the implications for future research.

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[1] In this thesis, I refer to bid-ask bias as a general class of biases which results when computed returns, variances, correlations, etc., differ from the "true" parameters because of the existence of the specialist's bid-ask spread.

CHAPTER 2

THE DAY-OF-THE-WEEK AND END-OF-THE-DAY EFFECTS: PREVIOUS RESEARCH

In this Chapter, I review the empirical evidence on the day-of-the-week and end-of-the-day anomalies. Then, I review explanations of the anomalies. One of these explanations, bid-ask bias, implies Assumption A may be invalid.

2.1 Evidence of the Day-of-the-Week Effect

Cross (1973) documents the differences in the distribution of prices on Fridays and Mondays by counting advances and declines, measured close to close. He finds, for the S&P 500 index (January 2, 1953 through December 21, 1970), there is a significantly greater number of advances on Fridays than on Mondays. He also finds, following a Friday advance, there is a 50% chance of a Monday advance or decline, whereas following a Friday decline, there is a 75% chance of a Monday decline. This pattern is significantly different from the relationship of price changes found on other successive trading days.

French (1980) extends the research of Cross (1973) by testing two specific returns hypotheses: the trading time hypothesis and the calendar time hypothesis. The trading time hypothesis implies returns on Mondays should, on average, be equal to returns on the other trading days since each day includes equivalent trading time. The calendar day hypothesis implies returns are generated in calendar time; therefore, Mondays returns should, on average, be three times larger than returns on other trading days since they include a weekend. Using the regressions:

$$R_t = \alpha + \delta_2 d_{2t} + \delta_3 d_{3t} + \delta_4 d_{4t} + \delta_5 d_{5t} + e_t \qquad (7)$$

$$R_t = \alpha(1 + 2d_{1t}) + \delta_2 d_{2t} + \delta_3 d_{3t} + \delta_4 d_{4t} + \delta_5 d_{5t} + e_t \qquad (8)$$

where:

d_{1t} to d_{5t} = dummy variables for Monday to Friday respectively, and

e_t = a random error term.

French finds average Monday returns are not equal to the other trading days' average returns and Monday returns are significantly negative. Therefore, he rejects both the calendar and trading time hypotheses.

Keim and Stambaugh (1984) provide evidence that the weekend effect is size related. Using size deciles based on the daily CRSP tape (January 2, 1963 to December 31, 1979) and the system of regressions:

$$R_{pt} = \Sigma_{i=1}^{5} a_{pi} d_{it} + e_{pt} \quad p = 1,\ldots,10;\ t = 1,\ldots,T \quad (9)$$

where:

d_{it} = a dummy variable which equals 1 for day i and zero otherwise, and

e_{pt} = a random error term,

they find average returns tend to increase as the week progresses and the effect is most prominent for the smallest size decile. A systematic relationship between Monday returns and size is not found but Friday returns exhibit a strong relationship to size.

Jaffe and Westerfield (1985a, 1985b) show the weekend effect is international in nature and the effect is more appropriately named the day-of-the-week effect. Using index data from the U.K., Japan, Canada, Australia, and the U.S., they find some form of the day-of-the-week effect exists in all countries. The U.S., Canada, and the U.K. have low Monday returns. Japan has low Tuesday returns. Australia has both low Monday and low Tuesday returns with Tuesday's returns being more pronounced. The highest return day in Japan is Saturday, not Friday as usually found using NYSE data.[2] Therefore, the weekend effect occurs Saturday to

---

[2] This result confirms the results of Keim and Stambaugh (1984). They (Footnote Continued)

Tuesday in Japan and Friday to Tuesday in Australia but Friday to Monday in the U.S., the U.K., and Canada.

In summary, the day-of-the-week effect has been shown to exist internationally and, in the U.S., on several indices and across size portfolios. Evidence of the end-of-the-day effect is also convincing.

2.2 Evidence of the End-of-the-Day Effect

Wood, McInish and Ord (1985) find an intraday returns pattern for stocks listed on the NYSE, both in the period September 1971 to February 1972 and in the period January 1982 to December 1982. They calculate returns as:

$$r_t = \ln[(p_t + d_t)/p_{t-1}] \qquad (10)$$

where:

P_t = the price of the security during the minute t,

P_{t-1} = the price of the security during the minute t-1, and

d_t = any dividend declared since the last trade.

(Footnote Continued)
find that when the NYSE is open on Saturday, Saturday has the highest return of the week. When the exchange is closed on Saturday, Friday becomes the highest return of the week.

An equally weighted index is developed by summing each return for each minute and dividing by the total number of firms (946 in 1971-1972 and 1138 in 1982). A typical trading pattern for each day is then computed by averaging across days for each trading minute. The results show the average return for all days declines in the first three minutes of the day and has a substantial increase during the last three minutes of the day. Returns in the remainder of the day fluctuate around zero.

Terry (1986) calculates returns for the Dow Jones 30 based on the last two transactions of each stock in each trading hour. For example, if the last two transactions in the hour 3:01 to 4:00 are P_t and P_{t-1}, then the return over the 4:00 hour will be $\ln(P_t - P_{t-1})$. Overnight returns are adjusted for dividends. This method results in the last hour returns being significantly larger than the other trading hours for 28 of the 30 firms.

Terry proceeds by examining the last ten transactions of the day to determine when the large returns occur. He finds most of the end-of-the-day effect is concentrated in the last trade of the day. Some of the effect is also present in the second last trade. In contrast to Harris (1986), Terry finds that Friday appears to have the largest end-of-the-day effect.

Harris (1986) confirms the end-of-the-day pattern is evident across all trading days. He also finds a beginning-of-the-day pattern which is positive from Tuesday through Friday but negative on Monday. Similar patterns occur when firms are stratified by size.

Harris calculates returns using time weighted averages and the assumption that returns accumulate linearly between trades. He always uses the first transaction price of the day as the denominator in the returns calculations stating "this seemingly unusual denominator is used in lieu of the normal lagged price to control the upward bias in arithmetic mean returns which results when prices jump back and forth between bid and ask" (p. 117).

Harris' results contrast with Terry's (1986), who finds the last two transactions of the day are positive and make up a large portion of the end-of-the-day effect. Harris finds the last transaction is positive but the second last transaction is negative.

In summary, evidence has been forwarded showing the existence of the day-of-the-week and end-of-the-day effects. These effects ~~exist~~ cross-sectionally and intertemporally. In the next section, explanations for the two anomalies are discussed.

2.3 Explanations for the Day-of-the-Week and End-of-the-Day Effects

2.3.1 Settlement Day Hypothesis

Gibbons and Hess (1981) propose mean returns differences between Friday and Monday may be the result of settlement day differences. Prior to February 10, 1968, Monday's settlement period consisted of only four business days whereas Tuesday's to Friday's included six business days. Since Monday's returns included two less days interest, its returns would appear lower than the returns of the other trading days. Gibbons and Hess propose, if Monday's negative returns are due to settlement day differences, then Tuesday's returns should be high enough to offset exactly Monday's low returns. They test their hypothesis using the regression:

$$R_{it} = \alpha_{0i} + \alpha_{1i}D_{1t} + \alpha_{2i}D_{2t} + \alpha_{4i}D_{4t} + \alpha_{5i}D_{5t} + v_{it} \quad (11)$$

where:

D_{1t} to D_{5t} = dummy variable for Monday through Friday respectively, where Wednesday's dummy is arbitrarily excluded, and

v_{it} = a random error term.

Since the coefficients in this equation represent the differences between the mean returns of each day and Wednesday's mean, Gibbons and Hess test the offsetting means hypothesis by testing: $(\alpha_{1t} + \alpha_{2t}) = 0$. They find the sum of the coefficients is significantly different from zero leading to rejection of the settlement day hypothesis.

Lakonishok and Levi (1982) test the settlement day hypothesis using a different method. They note stocks purchased on Fridays do not have the check clear for ten days after the purchase. However, stocks purchased on Mondays have the check clear eight days after the purchase. Therefore, investors who purchase stock on a Friday should be prepared to pay more for the stock by the amount of two days interest. Similarly, they suggest, "the equilibrium rate of return on Mondays should be lower by two days interest than the expected return from either a trading time or calendar time view" (p. 884). They correct for the settlement procedure by adding two days interest (measured at the prime rate) to Monday's returns and subtract two days interest from Friday's returns. The results show the weekend effect still remains in the period 1968 - 1973 but disappears by 1974.[3]

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[3] Jaffe and Westerfield (1985a) find similar corrections for the settlement procedure do not fully remove the day-of-the-week effect in the U.K., Japan, Canada, or Australia. Corrections for the foreign

(Footnote Continued)

2.3.2 Measurement Error Hypothesis

Gibbons and Hess (1981) note security prices are not measured without error. Therefore, "if Monday's negative results are explained by upward biased prices on Friday, the deviation of Monday's return from the overall mean should be exactly offset by Friday's" (p. 591). Using equation (11), they test the hypothesis that the sum of Monday's and Friday's coefficient is not significantly different from zero. They reject the null hypothesis at the 0.01 significance level.

Keim and Stambaugh (1984) submit that Gibbons and Hess incorrectly adjust for the difference of means by arbitrarily dropping Wednesday's coefficient. They suggest that if Wednesday's mean differs from the mean of other days, the test will be biased. The correct procedure, they propose, is to measure deviations from the mean of all days. Retesting the hypothesis with the corrected procedure, they find for individual size portfolios, Friday's mean and Monday's mean are offsetting. However, for the entire sample, the two means are not offsetting.

(Footnote Continued)
currency settlement procedure are also found to have a negligible effect on correcting the anomaly.

Keim and Stambaugh (1984) suggest a more powerful test for measurement error is a correlation test. Based on the assumption that Friday's closing prices and Friday's returns are subject to random errors that are on average positive, then Monday would be subject to random errors that are on average negative. If the assumption is correct, then larger than average positive errors on Friday should be followed by larger than average positive errors on Monday. The hypothesis predicts Friday returns should be negatively correlated with Monday returns, or at the least, the correlation between Friday and Monday returns should be lower than the correlation of returns on any other set of successive trading days. Using the Dow Jones 30, Keim and Stambaugh reject the hypothesis finding the correlation between Friday and Monday returns are higher than those of other successive trading days.[4]

Harris (1986) notes that if high closing Friday prices are the result of measurement error, then average last transaction returns should be higher on Fridays than on the other trading days. His findings, which contrast with the findings of Terry (1986), do not support this hypothesis. Harris (1986) also correlates Friday's average last

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[4] Since Keim and Stambaugh (1984) also show the weekend effect is size related, the use of the Dow Jones 30 seems inappropriate since it contains only large firms.

transaction return with the Friday-close to Monday-open return based on the arguments made by Keim and Stambaugh (1984). Again, the results are inconsistent with the measurement error hypothesis.

2.3.3 Trading Slows Towards the End of the Day Hypothesis

If transactions are more widely spaced towards the end of the day, then returns toward the end of the day should be larger to reflect the longer holding period. Terry (1986) finds the average length of time between transactions decreases towards the end of the day suggesting, when returns are controlled for time, end of day returns would be even larger. This result is confirmed by Wood, McInish and Ord (1985), who compute minute by minute returns and find average returns increase substantially in the last two minutes of the trading day.[5]

2.3.4 Closing Prices are Manipulated Hypothesis

Portfolio managers who have part of their performance evaluation based on the market value of their portfolios have the incentive, just before their evaluation, to attempt to raise stock prices. This hypothesis implies the managers place buy orders at or above the market quote to attempt to have the closing price of the day executed at the ask price or simply to drive up the last transaction price. Since the manipulation is artificial, it is expected that only small volumes will be traded, implying volume will decrease at the end of the day. Terry (1986) finds volume increases towards the end of the day leading him to reject the manipulation hypothesis.

2.3.5 Bid-Ask Bias Hypothesis

Bid-ask biases may occur if there are systematic patterns in the frequency of bid and asks across days of the week or times of the day. If such patterns occur, Assumption A is invalid.

Keim and Stambaugh (1984) test for bid-ask bias by computing bid to bid returns for fifty of the most actively traded NASDAQ over the counter stocks.[5] After forming the bid to bid returns into an equally weighted index, they find a returns pattern similar to the pattern for close to close returns: negative Monday returns and high Friday returns. The authors suggest this result is evidence "the day-of-the-week effect is not due to systematic differences between true prices and closing prices recorded on the exchanges" (p. 384). However, this test does not explicitly

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[5] Bid prices are required for the entire year on each stock so that their actual sample varied from 37 to 45 firms over the years 1978 to 1982

test for frequencies of bids or asks. Therefore, this test cannot be considered a direct test of Assumption A.

Terry (1986) discusses several hypotheses that may explain the end-of-the-day effect. He believes the end-of-the-day effect cannot be the result of a few outliers, information increases at the end of the day, or a disproportionate amount of good news arriving at the end of the day. He suggests, of the hypotheses he considered, the only hypothesis supported by his data is an increase in buying by liquidity traders at the end of the day, resulting in closing trades being executed at the ask price. Tests for systematic end-of-the-day bid-ask patterns were not completed.

2.4 Summary

In summary, satisfactory explanations for the end-of-the-week and the end-of-the-day effect have not been developed. The bid-ask bias hypothesis implies part of the explanation may be due to a violation of Assumption A. Terry (1986) does not complete a test of the Assumption and Keim and Stambaugh (1984) do not explicitly test the Assumption.

In the next chapter, four subsets of Assumption A are tested. One test is completed across days of the week, motivated by evidence of the weekend effect. A second test is completed across price portfolios, motivated by evidence that the weekend effect is size related.[6] The final two tests are completed across days of the week and times of the day, motivated by evidence of intraday patterns of returns. Rejecting any one of the four null hypotheses implies Assumption A is invalid.

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[6] Blume and Stambaugh (1983) and Stoll and Whaley (1983) show stratifying by price or size produce very similar results. I use price in this thesis to conform with the theories on the determinants of bid-ask spreads discussed in Chapter 4.

CHAPTER 3

EXAMINING THE FREQUENCY OF BIDS AND ASKS INTERDAY AND INTRADAY: TESTING THE VALIDITY OF ASSUMPTION A

In this Chapter, I describe the four hypotheses used to test the validity of Assumption A. Descriptions of the data and the test results are also contained in this chapter.

3.1 Data

The Toronto Stock Exchange (TSE) made available extensive data for use in this thesis. The Canadian data include time and date stamped intraday bid-ask quotes, transaction prices, and volumes on every security listed on the TSE over the period January 1979 to December 1987. The U.S. data consists of all securities interlisted on the TSE, NYSE, and AMEX during the period January 1984 to December 1987, and includes many active securities such as IBM, GM, Mobil Oil, and American Express.[7] Tables 1, 2, and 3 contain a list of the interlisted securities and a summary of their trading activity. Table 1 contains the Canadian-based interlisted securities, Table 2 the U.S. based

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[7] U.S. data for October 19 and October 23, 1987 are only available during the last half hour of trading. During the earlier part of these two days, the TSE's computers required the processing power and the U.S. feed was disconnected.

interlisted securities, and Table 3 a summary of volume and value traded for both the Canadian and U.S. based interlisted securities.

3.2 Measuring a Trade's Placement Within the Bid-Ask Spread

Tests of hypotheses in this chapter require a statistic measuring the placement of a trade within the bid-ask spread. Since the tests completed in this chapter are tests of frequencies of bids and asks, the following definition is selected:[8]

$$\Omega = \begin{cases} 1 & \text{if trade takes place above the mean of the spread} \\ 0 & \text{if trade takes place below the mean of the spread} \end{cases}$$

The estimate of Ω also includes the following restriction: a transaction must be preceded by a valid bid-ask quote. Without the restriction, it would not be possible to determine if a transaction is above or below the mean of the spread. A valid bid-ask quote is defined as one where both the bid and ask prices exist, the ask price is

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[8] Approximately 1.5% of closing trades took place at the mean of the spread. Exclusion of these observations was not considered sufficient to alter the results.

above the bid price, and the spread is less than $2.00.[9] Less than 1.0% of the trades fail to meet the restriction.[10]

Ω is distributed dichotomously. Appropriate methods for analyzing such a distribution include LOGIT, PROBIT, and linear probability models.[11] Of the three models, LOGIT and PROBIT are preferred because the estimated probabilities generated by the models are constrained between zero and one. PROBIT requires evaluation of the cumulative normal distribution. LOGIT requires evaluation of the cumulative hyperbolic-secant-square distribution. The two distributions are similar in shape but the former is more difficult to evaluate because it involves the evaluation of an integral. Regressions in this thesis often contain 10,000 observations. Therefore, the computational advantages of the LOGIT model are preferred and LOGIT is selected for use in this thesis.

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[9] Although all the data are provided directly from the TSE computers and very few errors exist, $2.00 was arbitrarily chosen as a filter to remove possible errors in recording the bid or ask price.

[10] The majority of the omitted transactions occurred early in the morning and on actively traded stocks where trades occurred prior to quotes being recorded.

[11] See Madalla (1983) for a comprehensive explanation of these three techniques.

3.8 Examining the Frequency of Bids and Asks Across Days of the Week

Tests of the weekend effect by authors such as Jaffe and Westerfield (1985a), are completed under the assumption of equal frequency of bids and asks, on the closing trade of the day, across days of the week. Terry (1986), proposes that part of the weekend effect may be the result of systematic patterns in the number of closing trades occurring at the bid and ask across days of the week. Terry's proposition implies that Assumption A is not valid.

To examine if systematic patterns exist in the frequency of bids and asks on the last trade of the day, across days of the week, I test the following hypothesis:

$$H_0: AFC_i = AFC_j \quad \text{for all } i,j = 1,\ldots,5 \quad i \neq j$$
$$H_1: AFC_i \neq AFC_j \quad \text{for any } i,j = 1,\ldots,5 \quad i \neq j$$

where AFC_i is Average Frequency of Closing trades, above or below the mean of the bid-ask spread, on each of the five trading days; i = 1 for Monday, 2 for Tuesday, etc. The null hypothesis implies equal frequency of bids and asks across all trading days. The null hypothesis is rejected if the frequency of bids and asks on any trading day is significantly different from the frequency of bids and asks on any other trading day.

3.3.1 Method

Ω is calculated for each closing trade of the day for every stock and for every day for which data are available. Stocks not trading on a particular day are not included in the analysis. Computer memory limitations makes running the entire sample (about 1,000,000 observations in the Canadian sample) in a single LOGIT regression impossible. Consequently, several regressions must be run. The hypothesis tests are completed under the assumption that the set of regression coefficients estimated in each regression is an independent "sample". Means and variances of the regression coefficients are used to complete difference of means tests. A trade off is made between the number of observations used in each LOGIT regression and the number of "samples" used to calculate the means and variances for the hypothesis tests. Monthly samples are used in all tests and several tests are repeated with the Canadian data using biannual, triannual and annual samples to determine if the results are dependent on the monthly sample sizes. Regressions are also run on a random sample of forty Canadian stocks across the full nine year data period to determine if the results are dependent on the large cross-section, short time period (monthly) samples. In all cases, the results are qualitatively the same as the results reported in this thesis.

In this test, the following LOGIT regression is run on each monthly sample:

$$\Omega_{it} = \delta_1 D_{1it} + \delta_2 D_{2it} + \delta_3 D_{3it} + \delta_4 D_{4it} + \delta_5 D_{5it} + e_{it} \quad (12)$$

i = 1,...,number of stocks having a closing trade on day t;

t = 1,...,number of trading days in the month;

where:

Ω_{it} = { 1 if the closing trade for stock i, on day t is above the mean of the spread, 0 if the closing trade for stock i, on day t is below the mean of the spread,

D_1 to D_5 = dummy variables for the day of the week,

D_{1it} = 1 if the closing trade for stock i on day t occurs on a Monday and zero otherwise,

D_{2it} = 1 if the closing trade for stock i on day t occurs on a Tuesday and zero otherwise,

etc.,

e_{it} = a random error term.

All Ω's in each month are stacked and regressed on the five dummy variables. One hundred and eight monthly LOGIT regressions (12 months x 9 years) are run for the Canadian sample and forty-eight (12 months x 4 years) for the U.S. sample. The average number of observations in a regression is 10043 using the Canadian sample and 2045 using the U.S.

sample. The smallest monthly sample size is 7107 for the Canadian and 1690 for the U.S. sample.

The LOGIT regression coefficients can be rewritten to represent the estimated probability of a trade occurring at the ask using:

$$\hat{p} = \exp(x\beta) / (1 + \exp(x\beta)). \qquad (13)$$

The probability interpretation is often more intuitive than the regression coefficients and both are used interchangeably.

3.3.2 Results

All regressions are tested for significance at the 0.05 level using a likelihood ratio (LR) test. The test statistic is:

$$-2 \ln L = -2[\ln l(W) - \ln l(w)] \qquad (14)$$

where l(W) is the value of the likelihood function evaluated with a constant and four dummy variables and l(w) is the value of the likelihood function with a constant only. Asymptotically, the test statistic is distributed chi-square with four degrees of freedom. Approximately 35% of the regressions using monthly samples are significant at this level.[12] When the regressions are repeated using semi-annual and annual sample sizes, the percentage of significant regressions increases to approximately 70% and 90% respectively.

Means and variances of the five regression coefficients are calculated based on the 108 Canadian regressions and a second set of five means and variances based on the 48 U.S. regressions. Difference of means tests are then completed across all days, Monday versus Tuesday, Monday versus Wednesday , . . . , Thursday versus Friday.

Panel A in Table 4 shows, for the Canadian sample, the average Friday coefficient is significantly above the average Monday, Tuesday and Thursday coefficient at the 0.05 significance level. This finding implies closing trades on Fridays occur significantly more at the ask than closing trades on Monday, Tuesday and Thursday. Based on this finding, I reject the null hypothesis of no difference in the frequency of bids and asks, on the last trade of the day across days of the week, for the Canadian sample.

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[12] Monthly samples contain an average of four observations on each day of the week. Therefore, it is not surprising that only 35% of the monthly regressions are significant when using day of the week dummies.

Finding systematic differences in the frequency of bids and asks across days of the week implies part of the Canadian day-of-the-week effect may be the result of this phenomenon. It is possible to determine rough estimates of the explanatory power of these findings using the estimated probabilities derived from the LOGIT regression coefficients. For example, an average Canadian stock sells for about $12.00. Assuming an average bid of $11.875 and an ask of $12.125, the Canadian weekend effect, due to differences in the frequencies of bids and asks, is -0.03%, or about 25% of the total Canadian weekend effect.

Panel A of Table 4 also shows the difference of means tests for the U.S. sample. None of U.S. coefficient means are significantly different at the 0.05 level. This finding contrasts with the Canadian results just discussed. However, three similarities between the Canadian and U.S. results are notable. First, Panel B of Table 4 shows both samples have a similar pattern of increasing mean coefficient from Monday to Friday. Second, in both samples, the Thursday coefficient is less than the Wednesday and Friday coefficients. Third, even though none of the difference of means tests are significant in the U.S. sample, the difference between the mean Monday and Friday U.S. regression coefficients is more than twice as large as the same difference for the Canadian sample. These similarities suggest a larger U.S. sample may result in significant differences in the frequency of bids and asks across days of the week.

In summary, I reject the null hypothesis of equal frequency of bids and asks on the last trade of the day, in the Canadian sample but not in the U.S. sample. The patterns of the mean LOGIT coefficients are very similar across the two samples but the variances of the U.S. coefficients are about ten times larger than the Canadian coefficients. These findings do not support the validity of Assumption A but do support Terry's proposition that part of the day-of-the-week effect may be the result of systematic variations in the frequency of bids and asks.

3.4 Examining the Frequency of Bids and Asks Across Price Stratified Portfolios

Keim and Stambaugh (1984) find systematic patterns in the day-of-the-week effect across size portfolios.[13] To examine if systematic patterns exist in the frequency of bids and asks on the last trade of the day, across price stratified portfolios, I test the following hypothesis:

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[13] In this thesis, portfolios are grouped by price rather than size to be consistent with the findings discussed in Chapter 4. In this chapter, the theory presented suggests that bid-ask spreads are a function of stock price, not firm size.

H_0: $AFDP_{ij} = AFDP_{ik}$

$i = 1,\ldots,5;$ for all $j,k = 1,\ldots,5$ $j \neq k$

H_1: $AFDP_{ij} \neq AFDP_{ik}$

$i = 1,\ldots,5;$ for any $j,k = 1,\ldots,5$ $j \neq k$

where $AFDP_{ij}$ is Average Frequency of closing trades, above or below the mean of the bid-ask spread, during Day i for Portfolio j. The null hypothesis implies equal frequency of bids and asks across all five price stratified portfolios, while holding the day of the week constant. The null hypothesis is rejected if the frequency of bids and asks for one portfolio is significantly different from the frequency of bids and asks in any other portfolio, holding the day of the week constant.

3.4.1 Method

To test this hypothesis, I use the same set of Ω's described in section 3.3.1 and the LOGIT regression:

$$\Omega_{it} = \delta_1 d_{1it} + \delta_2 d_{2it} + \delta_3 d_{3it} + \delta_4 d_{4it} + \delta_5 d_{5it} + e_{it} \quad (15)$$

$i = 1,\ldots,$number of stocks having a closing trade on day t;

$t = 1,\ldots,$number of days in the month;

where:

$\Omega_{it} = \{$ 1 if the closing trade for stock i, on day t is above the mean of the spread,
0 if the closing trade for stock i, on day t is below the mean of the spread.

d_1 to d_5 = dummy variables for price stratified portfolios,

d_{1it} = 1 if the closing trade on day t and stock i is on a stock in the lowest priced quintile and zero otherwise,

d_{2it} = 1 if the closing trade on day t and stock i is on a stock in price portfolio two and zero otherwise, etc., and

e_{it} = a random error term.

To be consistent with the findings of empirical studies and theoretical research on the determinants of bid-ask spreads discussed in Chapter 4, stocks are stratified by price, rather than by market value. The theories imply proportional spreads are a function of "raw" prices, not prices adjusted for dividends and stock splits. Therefore, the prices used in this study are not adjusted for dividends or stock splits.

Portfolios are formed based on the last traded price in December of the preceding year and are rebalanced annually. December is selected based on the analysis of Lakonishok and Smidt (1984). They find December is the most active month for low priced stocks. Since stocks with no trades in

December are omitted from the analysis for the following year, the use of December trades allows maximum sample sizes. Portfolios are formed to have, as closely as possible, equal numbers of stocks in each portfolio.[14] For example, in 1987 each portfolio quintile contains approximately 210 securities. The price ranges for the five portfolios are:

$ 0.06 to $ 1.00
$ 1.00 to $ 4.20
$ 4.25 to $ 9.50
$ 9.50 to $ 17.50
$17.50 to $375.00

The LOGIT regressions are run with monthly samples and the means and variances of the monthly coefficients are used to determine if there are significant differences between the means of the five coefficients.

3.4.2 Results

Means and variances of the five regression coefficients are calculated based on the 108 (12 months x 9 years)

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[14] Because the actively traded U.S. stocks are all high price stocks in comparison to the average price of a Canadian stock, the U.S. stocks would mainly fall into price portfolio five. Therefore, I concluded that little additional knowledge would be gained by stratifying the U.S. securities by price and price portfolio tests were not completed on the U.S. data.

regressions using Canadian data. Panel A in Table 5 shows the average LOGIT coefficients for all portfolios are significantly different at the 0.01 level excluding two comparisons: portfolio two with portfolio three and portfolio four with portfolio five. Portfolio four is significantly different from portfolio five at the 0.05 level.

Examination of Panel B in Table 5 reveals a monotonically increasing probability of a trade at the ask across the five price stratified portfolios. The size of the difference in the probability of a trade at the ask from the smallest to the largest price portfolio is approximately 250% larger than the difference reported when examining the probability of an ask across days of the week.

The monotonically increasing pattern of trades occurring at the ask is similar to the monotonically increasing pattern of returns across price and size stratified portfolios reported by several researchers including Keim (1983), Stoll and Whaley (1983) and Morgan and MacBeth (1983). The similarity of the patterns suggests part of the returns effect may be the result of incorrectly assuming equal frequency of bids and asks across price and size stratified portfolios.

To further characterize the results of this test, I use the following LOGIT regression:

$$\Omega_{it} = \Sigma_{j=1}^{25} \delta_j D_{jit} + e_{it} \qquad (16)$$

where:

D_1 to D_{25} = dummy variables for day of the week and price portfolio,

D_{1it} = 1 if the closing trade is on a Monday and stock i is in the smallest price portfolio, and zero otherwise,

D_{2it} = 1 if the closing trade is on a Monday and stock i is in price portfolio two, and zero otherwise

D_{3it} = 1 if the closing trade is on a Monday and stock i is in price portfolio three, and zero otherwise, etc., and

e_{it} = a random error term.

The results of running equation (16) with monthly samples are shown graphically in Figure 1. The figure shows the findings across portfolios persist across days of the week and are not the result of an aggregation bias. The pattern of increasing probabilities of a trade at the ask across the five price stratified portfolios is consistent across all days of the week. The probability of a trade at the ask is 13.9% higher for the Friday high priced portfolio than for the Monday low price portfolio. This difference is more than 300% larger than the effect found when considering only days of the week but only 20% larger than found when considering only price stratified portfolios. Based on these differences, I conclude that systematic patterns in the frequencies of bids and asks, on the last trade of the day, is more a price than a day-of-the-week phenomenon.

The pattern of bids and asks found in this study is not identical to the returns pattern found by Keim and Stambaugh (1984) but the conclusions are similar. Keim and Stambaugh conclude returns calculated using the last trade of the day are size and day related. I find the systematic patterns of bids and asks, based on the last trade of the day are price and day related.

In summary, I reject the null hypothesis of no difference in the frequency of bids and asks, on the last trade of the day, across price stratified portfolios at the 0.05 significance level. This finding implies Assumption A is not valid.

3.5 Examining the Frequency of Bids and Asks Across Times of the Day, Holding the Day of the Week Constant

Wood, McInish and Ord (1985) find average calculated returns increase significantly in the last three minutes of the day and decrease significantly in the first three minutes of the day. They calculate returns using transaction prices that usually reflect the specialist's bid and ask price rather than the "true" price at which a security would trade in the absence of the specialist. If Assumption A is not valid, then systematic patterns in intraday returns may be the result of systematic patterns in the frequency of bids and asks.

To examine if systematic patterns exist in the frequency of bids and asks across times of the day, holding the day of week constant, I test the following hypothesis:

$$H_0: AFDT_{ij} = AFDT_{ik}$$
$$i = 1,\ldots,5; \quad \text{for all } j,k = 1,\ldots,7 \quad j \neq k$$
$$H_1: AFDT_{ij} \neq AFDT_{ik}$$
$$i = 1,\ldots,5; \quad \text{for any } j,k = 1,\ldots,7 \quad j \neq k$$

where $AFDT_{ij}$ is Average Frequency of trades, above or below the mean of the bid-ask spread, during Day i, in Time period j. The null hypothesis implies, holding the day of the week constant, equal frequency of bids and asks across time of the day. The null hypothesis is rejected if the frequency of bids and asks in one time period is significantly different from the frequency of bids and asks in any other time period, holding the day of the week constant.

3.5.1 Method

To test this hypothesis, a new set of Ω's are calculated. First, I define seven intraday time periods:

the opening three minutes of the day,[15]
the three minutes from 11:00 to 11:03,
the three minutes from 12:00 to 12:03,
the three minutes from 1:00 to 1:03,
the three minutes from 2:00 to 2:03,
the three minutes from 3:00 to 3:03, and
the closing three minutes of the day.

The three minute time period is chosen for comparison of the U.S. results to the findings of Wood, McInish and Ord, who find anomalous returns patterns during the first and last three minutes of the trading day.

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[15] The opening three minutes of the day is defined as 10:00 to 10:03 prior to the first trading day in October, 1985 and 9:30 to 9:33 thereafter. Both the TSE and NYSE began opening at 9:30 on September 30, 1985.

Then, for each of the seven three minute time periods, I calculate Ω for any transaction during the period that meets the restriction of a preceding valid quote. I repeat the procedure for each day of the 2260 trading days of Canadian data and the 1004 trading days of U.S. data.

I then run the following LOGIT regression:

$$\Omega_{nd} = \delta_1 D_{1nd} + \delta_2 D_{2nd} + \delta_3 D_{3nd} + \delta_4 D_{4nd} + \delta_5 D_{5nd} + \delta_6 D_{6nd} + \delta_7 D_{7nd} + e_{nd} \quad (17)$$

$n = 1, \ldots,$ the number of observations in day d, across all seven time periods of the day;

$d = 1, \ldots, 5,$ the number of days of the week;

where:

D_1 to D_7 = dummy variables for each hourly time period,

D_{1nd} = 1 if observation n, on day d occurs in the first three minutes of the day and zero otherwise,

D_{2nd} = 1 if observation n, on day d occurs in the period 11:00 to 11:03 and zero otherwise, etc.,

e_{nd} = a random error term.

This regression is run monthly with the Canadian data and in triannual samples using both the U.S. and Canadian data. The purpose of using the triannual samples is to keep a similar number of observations in each LOGIT regression across all tests. The monthly and triannual results are qualitatively identical and the triannual results are reported. For example, for the 27 Canadian triannual samples, the regression is run for all observations that occurred on a Monday, yielding 27 sets of Monday, time dummy coefficients on which difference of means tests are completed across times of the day. The procedure is then repeated for Tuesday, Wednesday, Thursday and Friday data, yielding 27 sets of coefficients for each day. Means and variances are also calculated for all days combined. The entire procedure is repeated for each of the twelve, triannual samples for the U.S. data.

3.5.2 Results

Figures 2 and 3 show, on all five trading days, the last three minutes of the day has significantly more trades occurring at the ask than any other time period of the day in both the Canadian and U.S. samples. Table 6 shows the results for both samples when all data is aggregated. In the Canadian sample, the open is significantly below all other time periods and the close is significantly above all other time periods, both measured at the 0.01 significance level. None of the remaining periods are significantly different at the 0.05 level.

In the U.S. sample, the probability of an ask across times of the day forms a bid-ask pattern similar to the returns pattern found by Wood, McInish and Ord (1986). The close has significantly more asks than any other time period. The open has significantly more asks than all time periods excluding the close. With one exception, none of the remaining time periods are significant at the 0.05 level.

To examine the explanatory power of these findings, the regression coefficients are converted to estimated probabilities. Then, if an average NYSE stock has a bid of $50.00 and an ask of $50.125, the pattern found by Wood, McInish and Ord (1985), using 1982 intraday data, can be totally explained with bid-ask frequencies in the first three minutes of the day and reduced by 28% in the last three minutes of the day. In their 1972 data, the pattern in the first three minutes of the day can be reduced by 50% and the pattern in the last three minutes of the day can be totally explained with bid-ask frequencies.

In summary, in both the Canadian and U.S. samples, I reject the null hypothesis of no difference in the frequency of bids and asks across times of the day. The closing time period has significantly more trades occurring at the ask than any other time period in both countries when measured at the .001 level. Further, both the open and the close are significantly different from the remaining time periods during the day when all data is aggregated. In Canada, the open has significantly fewer asks than the midday time periods and in the U.S. the open has significantly more asks than the midday observations.

3.6 Examining the Frequency of Bids and Asks Across Days of the Week, Holding the Time Period Constant

Harris (1986) finds returns patterns differ across days of the week during the same time of day. He calculates returns using transaction prices under the implicit assumption of no systematic patterns in the frequency of bids and asks. To examine if systematic patterns exist in the frequency of bids and asks across days of the week, holding the time of day constant, I test the following hypothesis:

$$H_0: AFDT_{ij} = AFDT_{mj}$$

$$\text{for all } i,m = 1,\ldots,5 \quad i \neq m; \quad j = 1,\ldots,7$$

$$H_1: AFDT_{ij} \neq AFDT_{mj}$$

$$\text{for any } i,m = 1,\ldots,5 \quad i \neq m; \quad j = 1,\ldots,7$$

where $AFDT_{ij}$ is Average Frequency of Trades, above or below the mean of the bid-ask spread, during Day i, in Time period j. The null hypothesis implies, holding the time of day constant, equal frequency of bids and asks across days of the week. The null hypothesis is rejected if the frequency of bids and asks for one day of the week is significantly different from the frequency of bids and asks for any other day of the week, holding the time of the day constant.

3.6.1 Method

To test this hypothesis, I use the same set of Ω's described in section 3.5.1 and the LOGIT regression:

$$\Omega_{nt} = \delta_1 D_{1nt} + \delta_2 D_{2nt} + \delta_3 D_{3nt} + \delta_4 D_{4nt} + \delta_5 D_{5nt} + e_{nt} \quad (18)$$

n = 1,..., to the number of observations in time period t across all days of the week;

t = 1,..., 7, the number of daily time periods;

where:

D_1 to D_5 = dummy variables for the day of the week,

D_{1nt} = 1 if observation n, in time period t is on a Monday and zero otherwise,

D_{2nt} = 1 if observation n, in time period t is on a Tuesday and zero otherwise, etc.,

e_{nt} = a random error term.

The regression is run monthly, once for each month and time period giving 756 (12 months x 7 time periods x 9 years) sets of regression coefficients for the Canadian sample and 336 (12 months x 7 time periods x 4 years) sets of coefficients for the U.S. sample. Means and variances for the Monday open coefficients through the Friday close coefficients are then calculated and significance tests for differences in means among the seven time periods are completed. For example, for the Monday test, in each of the 108 months of the Canadian sample, the means and variances of the Monday open coefficients through the Monday close coefficients are calculated. These means and variances are then used to complete difference of means tests. The procedure is repeated for Tuesday through Friday on the Canadian data and the entire procedure is repeated for the 48 months of the U.S. data.

3.6.2 Results

Table 7 shows the difference of means tests and Table 8 shows the means and variances of the regression coefficients for both the Canadian and U.S. samples. Similar to the results across days of the week, the Canadian, but not the U.S. sample, shows several significant results.

Panel A of Table 7 shows the Monday open is significantly different from the open on all other days at the 0.05 level. At 12:00, 1:00, and the close, the frequency of bids and asks on Monday and Tuesday is significantly different from the frequency on Friday. At

1:00 and the close, Wednesday's frequencies are also significantly different from Friday's.

Based on these results, I reject the null hypothesis of equal frequency of bids and asks across days of the week, while holding the time period constant. The Canadian coefficients, converted to probabilities are shown graphically in Figure 4.

In the U.S. sample, one of the difference of means tests is significant at the 0.05 level, Monday open is significantly below the Friday open. As concluded for the Canadian sample, I reject the null hypothesis of equal frequency of bids and asks across days of the week, holding the time of the day constant. The U.S. coefficients, converted to probabilities are shown graphically in Figure 5.

The bid-ask frequency patterns I find in this study during the first hour of the day do not resemble the returns patterns found by Harris (1986) during the first hour of the day. He finds Monday returns decline but Tuesday through Friday returns increase. I find an increase in the frequency of bids across all five days. These results suggest that the returns patterns found by Harris may not be the result of systematic differences in bid-ask frequencies.

In summary, in both the Canadian and U.S. samples show differences in the frequency of bids and asks across days of the week, holding the time period constant. These results again imply Assumption A is not valid.

3.7 Summary

In this chapter, I test the validity of Assumption A using four hypothesis tests. I reject the hypothesis of equal frequency of bids and asks across days of the week, across price stratified portfolios, and across times of the day. The overall conclusion is Assumption A is not valid. This result implies that conclusions drawn from empirical studies not correcting for the existence of the bid-ask spread may also be invalid.

CHAPTER 4

DETERMINANTS OF BID-ASK SPREADS: PREVIOUS RESEARCH

In this Chapter, I review the literature on the determinants of bid-ask spreads. Both theoretical and empirical support are given to the hypothesis that bid-ask spreads vary cross-sectionally. During the review, I argue that cross-sectional theory and the results of cross-sectional empirical studies imply the existence of systematic time-series movements in proportional bid-ask spreads. These arguments are inconsistent with Assumption B: there are no systematic time series movements in proportional bid-ask spreads.

4.1 Early Empirical Studies

In his seminal article on the determinants of bid-ask spreads, Demsetz (1968) generates interest in an area mostly neglected in the previous literature. Using both supply and demand theory and the role of the specialist, Demsetz develops his main argument "that under competitive conditions the bid-ask spread, or markup will measure the cost of making transactions without delay" (p. 39). He suggests that typical supply and demand theory omits the possibility that a seller (buyer) will not be available when a buyer (seller) enters the market. Therefore, if someone is willing to stand ready to immediately buy or sell shares at stated prices, this individual will take on the waiting costs associated with the expected time between the initial order and the receipt of a following offsetting order. These waiting costs are reflected in the bid-ask spread of the specialist or market maker. It follows that the main determinants of the spread should be those factors that affect the time rate of transactions.

Demsetz continues by submitting that secondary factors affecting the spread should appear in two other forms: competitive forces on the specialist and the price per share. Standard economic theory would predict increases in competition would result in narrower spreads. Price is proposed as a determinant of the spread since the "spread will tend to increase in proportion to an increase in the price per share so as to equalize the cost of transaction per dollar exchanged. Otherwise those who submit limit orders will find it profitable to narrow spreads on those securities for which spread per dollar exchanged is larger" (p. 45).

To empirically test his hypothesis, Demsetz uses the regressions:

$$S_i = \beta_0 + \beta_1 P_i + \beta_2 T_i + \beta_3 M_i + e_i \qquad (19)$$

$$S_i = \beta_0 + \beta_1 P_i + \beta_2 N_i + \beta_3 M_i + e_i \qquad (20)$$

where:

S_i = the bid-ask spread for security i measured in dollars per share,

P_i = the price of security i,

T_i = the average number of transactions for security i over the two day observation period,

M_i = the number of markets on which security i is listed,

N_i = the number of shareholders of security i measured in hundreds, and

e_i = a random error term.

The regressions are run using both linear and logarithmic forms and he finds the best fitting equations are linear in price but logarithmic in number of shareholders and transactions.

Even though the data set used is quite limited and specialist risk is mentioned only in passing, Demsetz's research is instrumental in initializing study in the area and in developing the beginnings of a cross-sectional theory on the determinants of bid-ask spreads.

Tinic and West (1972) continue the development of cross-sectional theory by criticizing Demsetz (1968) both for his lack of discussion on dealer[16] risk and for his choice of proxy for competition. Tinic and West believe, for over-the-counter (OTC) securities, the number of dealers quoting on a stock is a more appropriate measure of competition than the number of markets on which a security is listed.

Using a data set comprised of a single observation (January 18, 1962) on each of 68 OTC stocks, they regress:

$$S_i = \alpha_0 + \alpha_1 A_i + \alpha_2 P_i + \alpha_3 R_i + e_i \qquad (21)$$

where:

S_i = the average bid-ask spread for security i,

A_i = 0.93750 Z_v + 0.37500 Z_n, derived from a principal components analysis on V_i, the total sales and purchases for security i, and N_i, the number of dealers quoting bid and ask prices on security i. Z_v and Z_n are the standardized variables of V_i and N_i respectively,

P_i = average price of security i in 1961,

R_i = $(P_{high} - P_{low}) / P_i$, and

e_i = a random error term.

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[16] In this thesis, dealer, specialist, market maker and designated market maker are used as synonymous terms

They find their proxy for dealer risk, R_i is statistically insignificant. This result suggests that OTC market makers may be able to eliminate risk through diversification, since spreads are not related to Tinic and West's proxy for risk. However, Pinches and Kinney (1971) show Tinic and West's risk proxy is not stable over time, making such a conclusion difficult to support.

Tinic (1972) extends equation (21) to include further cross-sectional variables. These include the number of institutions holding the stock, trading continuity, standard deviation of stock price, and two variables describing individual specialist units. The additional explanatory variables result in the following multiple regression:

$$S_i = \alpha_0 + \alpha_1 P_i + \alpha_2 \ln(V_i) + \alpha_3 M_i + \alpha_4 I_i + \alpha_5 N_j + \alpha_6 C_i + \alpha_7 \sigma_{pi} + \alpha_8 (K_j/T_i) + u_i \qquad (22)$$

where:

S_i = average bid-ask spread of security i,

P_i = average price of security i,

V_i = average number of shares of security i traded per day,

M_i = index of competition for security i,

I_i = number of institutional investors holding security i,

T_i = average number of transactions in security i per day,

C_i = trading continuity of security i (number of days traded/number of days sampled).

N_j = total number of specialty stocks carried by the unit registered in security i,

σ_{pi} = standard deviation of the price of security i,

K_j = total purchasing capacity of specialist unit j in thousands, and

u_i = a random error term.

The additional variables are included in the regression based on arguments of dealer risk. Tinic argues that inventory variables reflecting the risks inherent in the carrying, borrowing and liquidity costs of inventory should be major factors in the determinants of spreads. These risks, he suggests, will be a function of trading activity, stock price volatility, and the purchasing power and diversification of the dealer. Using 80 securities and nineteen trading days in March, 1969 (averaged to give a single observation for each stock) Tinic finds the regression equation is significant at the 0.001 level. Excluding σ_{pi} and (K_j/T_i), all the independent variables are significant at the 0.05 level.

Tinic uses a second cross-sectional regression to test the hypothesis that active, continuously traded stocks have their bid-ask spreads altered less often than inactively traded stocks. The hypothesis is developed on the assumption that dealers may systematically vary their bid-ask quotations to vary their inventory positions. Tinic suggests such a practice would be more common for infrequently traded stocks, thus the variance of the bid-ask spread should be higher for inactive stocks. The regression:

$$\sigma_{si} = \beta_0 + \beta_1 C_i + \beta_2 T_i + \beta_3 P_i + \beta_4 (K_j / N_j) + v_i \qquad (23)$$

where:

σ_{si} = the standard deviation of the bid-ask spread on the ith stock, and

v_i = a random error term,

is used to validate the hypothesis. β_0, C, T, and P are found to be significant at the 0.05 level. The F test is significant at the 0.001 level.

Logical extensions to Tinic's (1972) cross-sectional analysis result in the prediction of time-series variations in spreads. If inventory risk is a major determinant of spreads and if during certain time periods, such as periods when the exchange is closed, the inventory risk of the dealer systematically increases, then one would expect to find systematic time-series variations in the size of bid-ask spreads as the dealer attempts to control this risk.

Since the dealer holds a non-diversified portfolio, any restriction in the ability to alter inventory position could significantly increase dealer risk. Therefore, one would expect increased risk over non-trading periods such as weekends and year-ends. This extension is inconsistent with Assumption B.

4.2 Theoretical Models

Stoll (1978) introduces explicit theory to the supply side of dealer services. Drawing on the insights of Demsetz (1968), he describes the role of dealers as one of providing the service of immediacy. He believes the cost of immediacy takes three forms: holding costs, which include the risk of price movements and the opportunity cost of holding securities; order costs, which include the costs of arranging trades, recording and clearing transactions; and information costs, which include costs which arise when investors trade on the basis of superior information.

Using these three concepts and the assumption of utility maximization, Stoll (1978) derives a dealer cost function which is quadratic in dollar spread but linear in proportional spread. He finds that holding costs are dependent on size of transaction, the variance of the return of the stock being traded, the size of the initial holdings of all stocks in the dealer's trading account, and the covariance between the return on the stock being traded and the return on the trading account.

Stoll's theory is extended to continuous time and to include the demand side of the dealer cost equation by Ho and Stoll (1981). They find the dealer's bid and ask prices depend on the return characteristics of the stock, the stochastic demand for dealer services, and the dealer's utility function. Their theory predicts wider spreads for larger transactions and the bid and the ask are always altered to the point where the dealer is indifferent between a purchase or a sale. For example, if the probabilities of a purchase or a sale are equal, then the bid and ask prices are changed equally. If the probabilities are not equal, the bid and ask prices will not change the same amounts but the final setting will leave the dealer indifferent between a sale and a purchase.

Following Tinic's (1972) research, Ho and Stoll's (1981) prediction that dealers will manipulate the bid and ask prices to control inventory sizes and thereby control inventory risk leads directly to the hypothesis of time-series variations on bid-ask spreads. Assuming a positive probability of the arrival of new, relevant information over a non-trading period, inventory risk must increase over the non-trading period since it is not possible for the dealer to alter the securities' inventory position. The larger the probability of the information arrival, the greater the increase in inventory risk. Further, assuming the probability of the information arrival is an increasing function of time, longer non-trading periods should result in wider bid-ask spreads. This hypothesis is again inconsistent with the assumption of no systematic time-series movements in bid-ask spreads.

Copeland and Galai (1983) show the spread can be expressed as a combination of call and put options. The advantage of this model, over the models of Stoll (1978) and Ho and Stoll (1981), is the dealer's utility function does not enter into the equation.

As introduced by Bagehot (1971) and empirically tested by Benston and Hagerman (1974), Copeland and Galai (1983) emphasize two types of trading, the first for liquidity reasons and the second based on superior information. Copeland and Galai state the dealer can never gain from trades with investors having superior information but does gain from trades with liquidity motivated traders. Therefore, they model the spread as a trade-off between expected losses to informed traders and expected gains from liquidity traders.

Several comparative static results are predicted by this model. First, as the variance of a stock's rate of return increases, the competitive, equilibrium ask price will be raised. Second, if the probability of an informed trade is higher for thinly traded stocks, the spread will be wider for such securities.[17] Third, if large price changes are the result of informed trading, there should be a contemporaneous relationship between large price changes and the size of the bid-ask spread.

As with previous theoretical models, Copeland and Galai's model can also be applied to support the hypothesis of time-series movements in spreads. In their model, the probability that the next trader is informed is a major determinant in the setting of the spread. Therefore, if the probability that the next trader is informed is a function of the length of time between trades, then one would expect the average proportional spread to be a function of the length of the non-trading period. For example, if information arrivals are modelled using a Poisson distribution:

$$\delta = \frac{e^{-\phi t} \ \phi t^{k}}{k!} \qquad (24)$$

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[17] The probability of an informed trade may be higher for thinly traded stocks because they are more closely held or because there is a longer time period between trades.

where:

ϕ = the expected number of information arrivals per time period

t = the number of time periods between trades

then δ, the probability of k information arrivals in t time periods, must be an increasing function of time.[18] The model predicts, on average, opening spreads should be wider than closing spreads and opening spreads following weekends should be wider than opening spreads followed by overnight non-trading periods. These predictions are inconsistent with Assumption B.

Glosten and Milgrom (1985) continue with the assumption of two groups of traders, one group trading for liquidity and the other trading with proprietary information. The authors make three critical assumptions: that all investors and specialists are risk neutral; that the specialist knows the probability distribution of trade arrivals; and the specialist earns zero profits. They then prove several propositions, one of which shows that the width of the spread is a positive function of the quality of insider information, the proportion of informed to uninformed trades, and the "desire of the uninformed to trade."

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[18] The distribution parameters are assumed stable over the period in question.

Glosten and Milgrom use their theory to support the hypothesis of cross-sectional variations in bid-ask spreads but do not extend their theory to include time-series movements in spreads. However, it seems logical to assume that longer periods between trades would allow informed traders more time to verify the quality of their information. If the assumption is valid, support is again given to the hypothesis of systematic time series movements in spreads around non-trading periods.

Finally, in support of Assumption B, Terry (1986) argues that because bid and ask prices move in 1/8 dollar increments, the optimal strategy for the specialist may be to avoid adjusting the width of the spread regardless of the expected number of informed traders. He suggests if the specialist widens the spread in period t, in expectation of the arrival of informed traders, then liquidity traders will delay their trade to a period where the spread is narrower. If such a delay tactic occurs, then the proportion of informed traders in period t will be even larger, requiring the specialist to widen the spread even further. This widening will result in more liquidity traders delaying their trades and the cycle will repeat.[19] To avoid such a

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[19] Terry (1986) does not consider the goal spread of the specialist which would effectively end the cycle when the specialist could no longer widen the spread. The existence of interlisted securities would (Footnote Continued)

cycle, Terry (1986) suggests specialists will only partially adjust their spreads in reaction to expected informed traders. The partial adjustment may be within the 1/8 dollar increment implying no adjustment would occur and that time-series movements in spreads do not exist.

4.3 Summary

In this chapter, I cite theoretical and empirical evidence linking cross-sectional variations in bid-ask spreads to cross-sectional variations in risk adjusted returns. I argue, based on the theoretical and empirical research, that systematic time-series movements in bid-ask spreads should exist. I propose, if such movements do exist, they will be found surrounding periods of non-trading. Spreads, I argue, should be widest following periods of non-trading and may also be a function of the length of the non-trading period. These arguments imply Assumption B may not be valid. In the next chapter, I complete a direct test of the validity of Assumption B.

(Footnote Continued)
also weaken the argument unless all specialists widened and narrowed their spreads simultaneously.

CHAPTER 5

EXAMINING THE TIME-SERIES BEHAVIOR OF INTRADAY PROPORTIONAL BID-ASK SPREADS: TESTING THE VALIDITY OF ASSUMPTION B

In this chapter, I describe the hypothesis used to test a subset of Assumption B. Then, I discuss the methodology and results of the test. I reject the null hypothesis at the 0.05 level and conclude that Assumption B is not valid.

5.1 Measuring Intraday Proportional Bid-ask Spreads

In the previous chapter, propositions are forwarded suggesting that cross-sectional studies on the determinants of bid-ask spreads imply time-series movements in bid-ask spreads. These propositions imply proportional spreads may systematically vary across days of the week and across times of the day. The propositions are based on empirical and theoretical evidence suggesting that proportional bid-ask spreads are a function of the specialists's inventory control, the potential for informed traders and the quality of the informed traders information. If systematic patterns in proportional bid-ask spreads exist, then Assumption B is invalid.

To examine if systematic patterns in proportional bid-ask spreads exist intraday, I test the following hypothesis:

$$H_0: APS_{ij} = APS_{ik}$$

$$i = 1,\ldots,5; \quad \text{for all } j,k = 1,\ldots,7;\ j \neq k$$

$$H_1: APS_{ij} \neq APS_{ik}$$

$$i = 1,\ldots,5; \quad \text{for any } j,k = 1,\ldots,7;\ j \neq k$$

where APS_{ij} is Average Proportional Spread in day i during time period j. The null hypothesis implies, holding the day of the week constant, average proportional spread is constant throughout the day. The null hypothesis is rejected if average proportional spread in one time period is significantly different from average proportional spread in any other time period. The seven time periods are the same as those described in section 3.5.1.

5.1.1 Method

The discussion in the previous chapter implies that, at a minimum, proportional bid-ask spreads are a function of stock price, stock price variance and stock activity. Therefore, any correct test for changes in average proportional spreads during the trading day must, at a minimum, include control variables for these three factors.

Similar to earlier studies, such as Blume and Stambaugh (1983), I control for price by placing all stocks into one of five portfolios using the same method described in Chapter 3.[20] Similar to earlier studies, such as Tinic (1972), I use volume to control for trading activity. I use variance of the mean of the bid-ask spread to control for stock price variance. This method is chosen based on the findings of Marsh and Rosenfeld (1985) who show that biases may occur if stock price variances are estimated using transaction prices.

To calculate the volume variable, I record volumes for all transactions meeting the restriction of a preceding valid quote, during each of the seven three minute time periods, and during each day of the nine year period for which data are available. The volumes are aggregated by averaging monthly within each time period and price portfolio, and the log of the average is calculated. This procedure yields 35 observations per month, one for each of the seven time periods in each of the five price portfolios. For example, in month m, a transaction occurs at 11:01 on stock i and stock i is in portfolio one. Then, the volume on that transaction is added to the volumes of all previous transactions occurring in month m between 11:00 and 11:03 on

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[20] Since price portfolios are used in this test, U.S. comparisons are not completed for the same reasons discussed earlier.

stocks in the lowest price portfolio. At the end of the month, the arithmetic average of the volumes is determined and the log of the average is calculated.[21]

Option pricing studies, by researchers such as Geske (1979), imply that stock price variances change over time. Since this thesis deals with three minute time periods, it is desirable to use estimates of three minute variances to capture the movement of the variances through time. Regrettably, there are insufficient quotes on any stock in a three minute time period to calculate a three minute variance. Consequently, to estimate the variance variable I assume variances are stable within a month.[22]

To estimate the variance variable, I record the mean of all valid quotes during each month and for each stock. The variance of these means is then used as the estimate of stock price variance for each individual stock. Variances are not calculated when a stock has fewer than five quotes in a month. These monthly variances are then averaged within each of the five price portfolios. For example, if

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[21] The regression is also completed without logs. The results are qualitatively the same on the difference of means tests.

[22] Other methods of estimating the variances were considered such as estimates of variances based on implicit variances derived from Black-Scholes option pricing model. All were discarded because of intractability or the assumptions were considered less acceptable than the assumption of constant variance within a month.

stock i has seventy quotes in July, seventy observations are used to calculate the variance of the mean of the bid-ask spread. If stock i is in price portfolio one, its July variance is added to the July variances of all price portfolio one stocks and an average July, portfolio one variance is calculated.

The dependent variable, proportional bid-ask spread, is defined as:

$$\Gamma = (ask - bid) / ((ask + bid)/2). \tag{25}$$

As with volume, I calculate this statistic for every transaction meeting the restriction, in each of the seven three minute time periods during the trading day and for each of the trading days during the nine year period of the Canadian data. Γ's are not calculated if a stock does not trade during the time period or the trade is not preceded by a valid quote. The Γ's are averaged in the same manner as described for volume. The averaging yields 35 observations for proportional spread in each month.

These three proxies for proportional spread, volume and variance, are then combined with seven dummy variables in the following system of regressions:

$$\Gamma_{pt} = \Sigma_{j=1}^{7} \delta_j D_{jpt} + \delta_8 \overline{\sigma^2}_{p\tau} + \delta_9 \ln(\bar{V}_{pt}) + e_{pt} \qquad (26)$$

$p = 1, \ldots, 5$, the number of price portfolios;

$t = 1, \ldots, T$;

$\tau = 1, \ldots, 108$, the number of months in the sample;

where:

Γ_{pt} = arithmetic average of proportional spreads in portfolio p during time t,

D_1 to D_7 = dummy variables for each hourly time period,

D_{1pt} = 1 if the observation on portfolio p is during the first three minutes of the day and zero otherwise,

D_{2pt} = 1 if the observation on portfolio p is during 11:00 to 11:03 and zero otherwise, etc.,

$\ln(\bar{V}_{pt})$ = log of average volume for portfolio p during time period t,

$\overline{\sigma^2}_{p\tau}$ = average variance for portfolio p during month τ, and

e_{pt} = a random error term.

At least two models are appropriate for estimating these equations simultaneously: pooled cross-section time-series[23] and Seemingly Unrelated Regression (SUR). The advantage of SUR is the method makes use of the information contained in the contemporaneous correlation of the residuals across equations. Analysis of the data, using standard OLS grid search techniques, shows the individual equation regression residuals have an average rho of greater than 0.5 when testing for first order autocorrelation. Therefore the data is transformed equation by equation prior to running the SUR regression.[24] Evidence presented on the day-of-the-week effect suggests differences in intraday proportional bid-ask spreads may exist across days of the week. Therefore, the system of equations is run daily as well as with all data combined. The regression is also run with and without the variance and volume variables to determine if the significance of the time coefficients is the result of the proxies chosen.

5.1.2 Results

The results are virtually identical for the six regressions; therefore, only the regression for the total

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[23] See Judge et. al. (1982, Ch 16) for an explanation of pooled cross-section time-series.

[24] See Kmenta (1986, Sec 12-3) for a discussion on using SUR in the presence of autocorrelation.

sample is reported. The SUR regression coefficients and t statistics for the regression with the time coefficients only are shown in Table 9. Table 10 contains the results of the regression with the time and volume coefficients and Table 11 contains the results of running equation (26). The results of the F tests for equality of the time coefficients for equation (26) are shown in Table 12.

With one exception (Table 11, p=1, t=close), in all cases and in every equation, the time dummies are significant at the 0.05 level. Examination of Tables 11 and 12 show the spread is the widest at the opening of the Exchange, narrows to midday and, for all portfolios excluding the low price portfolio, significantly widens in the last two hours of trading. Therefore, I reject, at the 0.05 significance level, the null hypothesis of constant proportional spreads within the trading day. The interpretation of the time coefficients shown in Table 11 is the mean of proportional spread for portfolio p, during time period t, after controlling for the effects of variance and volume.

These results imply that Assumption B is not valid. Terry's (1986) proposition that spreads will not widen throughout the day because of Exchange requirements is also not supported by the results of this study. The data does support the time-series extensions presented in the previous chapter.

Finding spreads are widest in the morning, narrow to midday, and widen again to the close of trading implies variances calculated with transaction prices will vary systematically throughout the day. Variances will be largest in the morning, decrease to midday and increase to the close of trading. This is exactly the pattern found by Wood, McInish and Ord (1985). The similarity of the two patterns implies part of the variance pattern may be the result of intraday movements in proportional bid-ask spreads.

The coefficients on the volume and variance variables are not consistent with previous theory or empirical studies. Only the coefficients on the first and fifth portfolios are significant for the variance variable and the first, fourth, and fifth portfolios for the volume variable. The signs and patterns of the coefficients are counter intuitive. Based on the discussions in the previous chapter, the expected sign on the volume variable is negative and positive on the variance variable. Table 11 shows a the volume coefficient starts positive for portfolio one, monotonically decreases to the fourth portfolio, where it becomes negative, and then increases but remains negative for the fifth portfolio. The pattern is almost the reverse for the variance variable. The variance pattern may be the result of assuming constant variances across months but the explanation for the patterns is left for future research.

5.2 Summary

In this chapter, I test the validity of Assumption B by testing a subset of the Assumption. I reject the null hypothesis of equal proportional spreads across times of the day while controlling for stock price, stock price variance, and volume. Based on this result I conclude that Assumption B is not valid.

CHAPTER 6

CONCLUSIONS AND IMPLICATIONS

6.1 Conclusions

In this thesis I test the validity of two Assumptions:

A) there are no systematic cross-sectional or time-series differences in the probabilities of a trade being at the bid or at the ask, and

B) there are no systematic time-series movements in proportional bid-ask spreads.

Two conclusions result from the tests:

1) Assumption A and Assumption B are invalid. Null hypotheses of equal frequency of bids and asks across days of the week, across price stratified portfolios, and across time of the day are all rejected at the 0.05 significance level. The null hypothesis of no difference in proportional spreads across time of the day is also rejected at the 0.05 level.

2) There are similarities between the systematic patterns in the frequency of bids and asks found in this thesis and

returns anomalies such as the day-of-the-week, end-of-the-day and small firm effects. Bid-ask patterns occur at the beginning and end of the day, as do the intraday returns patterns found by Harris (1986) and Terry (1986). Bid-ask patterns occur across days of the week as do the returns patterns found by authors such as Gibbons and Hess (1981). Bid-ask patterns occur across price portfolios as do the returns patterns found by Blume and Stambaugh (1983).

6.2 Implications for Future Research

The major implication of the findings in this thesis is: conclusions drawn from empirical studies not correcting for variations in bid-ask frequencies and for variations in proportional bid-ask spreads may be erroneous. Because of the size of the "biases" found, the implication has more relevance in daily and intraday studies than studies using data with less frequent observations. Blume and Stambaugh (1983) suggest the convention of using the mean of the bid and the ask rather than transaction prices would help remove bid-ask biases. Lakonishok and Smidt (1983) suggest this method may not be appropriate due to Exchange continuity requirements. The results of the studies in this thesis suggest transaction prices may not be the most accurate proxy for calculating "true" returns and variances. The derivation of a better proxy is left for future research.

The examples given in this thesis show the use of the mean of the bid-ask spread, rather than transaction prices, to compute returns and variances can substantially reduce several returns and variance anomalies.

An explanation for the existence of systematic variations in the frequency bids and asks interday, intraday, and across price portfolios is also left for future research. Since the specialists set the bid and ask prices, part of the explanation may be found in a study of specialist activity during the day and across securities.

TABLE 1
TRADING SUMMARY OF CANADIAN-BASED SECURITIES INTERLISTED ON U S EXCHANGES DURING 1987

SECURITY NAME	ALL MARKETS		%S A % OF TRADED VALUE				
	VOLUME	VALUE ($000)	TSE	CDN TOTAL	NYSE	AMEX	U.S TOTAL[a]
ABITIBI PRICE	17,236,435	562,652	65.5	83.3	16.7	0.0	16.7
ACCUGRAPH CL A J	428,515	670	99.5	99.5	0.0	0.0	0.5
AGNICO-EAGLE MINES	22,677,965	711,610	20.8	30.3	0.0	0.0	69.7
ALCAN ALUMINIUM	240,104,087	10,291,197	29.8	38.4	61.6	0.0	61.6
AMCA INTL	10,303,502	114,295	62.5	91.7	8.3	0.0	8.3
AMERICAN BARRICK	73,373,156	2,429,706	50.4	54.9	45.1	0.0	45.1
ARC INTL	2,695,517	13,636	29.0	29.0	0.0	71.0	71.0
ASAMERA INC	50,048,459	609,604	36.8	43.7	0.0	56.3	56.3
BANISTER CONTENTL	2,567,306	27,259	58.3	58.4	0.0	41.6	41.6
BCE INC	102,799,458	4,094,343	53.1	78.5	21.5	0.0	21.5
BOW VALLEY IND	47,204,239	842,603	77.7	89.8	0.0	10.2	10.2
BRALORNE RES	4,543,329	8,446	71.0	83.1	0.0	0.0	16.9
BRASCAN LTD CL A	25,779,545	877,597	66.0	82.5	0.0	17.5	17.5
BREAKWATER RES J	42,885,632	351,407	61.0	62.4	0.0	0.0	37.6
CALIFORNIA GOLD J	4,600,061	12,284	5.4	5.9	0.0	0.0	94.1
CAMPBELL RED LAKE	28,626,676	1,047,943	22.6	22.6	77.4	0.0	77.4
CAMPBELL RESOURCES	26,967,927	75,214	24.5	31.1	68.9	0.0	68.9
CAN SOUTHERN PET	3,780,690	14,453	18.9	18.9	0.0	0.0	81.1
CARLING OKEEFE	3,934,451	63,346	54.3	64.6	35.4	0.0	35.4
CDC LIFE SCIENCES	16,665,995	401,315	47.3	53.5	0.0	0.0	46.5
CDN MARCONI	6,072,226	120,264	60.7	80.4	0.0	19.6	19.6
CDN OCCIDENTAL	6,735,168	200,946	94.5	94.5	0.0	5.5	5.5
CDN PACIFIC LTD	305,133,344	7,206,083	45.5	56.2	43.8	0.0	43.8
CENTRAL FUND A NV	16,473,176	141,965	32.4	32.4	0.0	67.6	67.6
CHIEFTAIN DEV	2,984,821	38,539	47.0	47.0	0.0	53.0	53.0
CINEPLEX ODEON	14,620,465	248,544	57.5	57.5	42.5	0.0	42.5
CITADEL GOLD J	2,533,929	10,413	79.7	79.8	0.0	0.0	20.2
COGNOS INC	5,585,082	64,329	27.1	27.1	0.0	0.0	72.9
COMINCO LTD	58,157,576	1,029,336	84.2	94.1	0.0	5.9	0.0
CONS MERCANTILE J	1,393,197	2,609	53.3	53.3	0.0	0.0	46.7
CONS PROFESSOR J	9,021,268	18,654	91.6	91.7	0.0	0.0	8.3
DAVIDSON TISDALE J	3,918,314	11,730	40.6	40.6	0.0	0.0	59.4
DEVELCON	979,623	3,427	78.5	78.5	0.0	0.0	21.5
DICKENSON CL A SV	9,025,686	114,707	79.9	79.9	0.0	20.1	20.1
DICKENSON CL B	1,603,806	21,517	74.1	74.1	0.0	25.9	25.9
DOME MINES	111,225,838	1,999,401	36.2	40.0	60.0	0.0	60.0
DOME PETROLEUM	180,144,080	222,132	43.4	47.6	0.0	52.4	52.4
DOMTAR	44,194,237	1,216,085	30.8	50.1	49.9	0.0	49.9
DUMAGAMI MINES J	4,204,596	55,531	43.6	67.6	0.0	0.0	32.4
DUNE RES CL A J	799,350	443	94.6	94.6	0.0	0.0	5.4
EASTMAQUE GOLD JR	1,842078	20,199	64.0	96.8	0.0	0.0	3.2
ECHO BAY	123,476,397	4,638,716	24.4	29.4	0.0	70.6	70.6
ENERGEX MARL J	17,188,101	20,580	56.3	98.2	0.0	0.0	1.8
ENSCOR INC	127,167	202	7.0	7.0	0.0	0.0	93.0
FALCONBRIDGE LTD	104,220,189	2,390,838	81.3	88.0	0.0	0.0	12.0
FEDERAL EXPRESS	6,629,199	349,620	0.0	0.0	100.0	0.0	100.0
FORD MOTOR CANADA	240,000	40,657	58.1	58.1	0.0	41.9	41.9
GALACTIC RES J	54,306,918	809,683	32.6	33.2	0.0	0.0	66.8
GALVESTON	16,365,233	163,963	44.9	99.2	0.0	0.0	0.8
GALVESTON CL A SV	429,129	2,568	47.9	77.2	0.0	0.0	22.8
GALVESTON CL B	186,770	1,094	47.6	97.4	0.0	0.0	2.6
GANDALF TECH	12,374,616	124,440	37.0	37.0	0.0	0.0	63.0
GEMINI TECH J	11,071,781	45,707	58.7	78.9	0.0	0.0	21.1
GEODOME RES J	7,152,524	29,097	31.6	41.7	0.0	0.0	58.3
GIANT BAY J	8,574,833	12,154	65.2	66.0	0.0	0.0	34.0
GIANT YELLOWKNIFE	7,157,419	177,645	11.3	11.3	0.0	88.7	88.7
GLAMIS GOLD	17,748,986	182,309	38.3	38.3	0.0	0.0	61.7
GOLDEN KNIGHT J	12,208,895	166,774	87.5	93.4	0.0	0.0	6.6
GOLDEN NORTH J	919,032	6,741	53.8	73.6	0.0	0.0	26.4
GOLDENBELL J	8,686,849	43,703	90.1	95.4	0.0	0.0	4.6
GRANDVIEW RES J	2,778,240	20,776	22.3	35.5	0.0	0.0	64.5
GRANGES EXPL	20,752,957	276,059	81.9	81.9	0.0	18.1	18.1
GULF RES	73,904,311	1,699,790	44.4	50.8	0.0	49.2	49.2
GW UTILITIES	4,743,347	114,643	79.0	87.5	0.0	12.5	12.5
HIGHWOOD RES J	4,213,328	23,775	66.5	66.5	0.0	0.0	33.5
HUSKY OIL	27,231,148	313,191	61.6	66.3	0.0	33.7	33.7
IMPERIAL OIL CL A	44,184,771	2,830,813	45.8	55.3	0.0	44.7	44.7
INCA RES J	7,589,155	15,577	58.2	75.6	0.0	0.0	24.4
INCO LTD	171,629,614	4,062,586	38.1	44.6	55.4	0.0	55.4
INTER-CITY GAS	6,528,521	115,041	82.5	82.5	0.0	17.5	17.5
INTERPROV PIPE LINE	3,863,307	182,515	68.9	96.8	0.0	0.0	3.2
KERKHOFF IND	260,905	772	0.0	0.0	0.0	100.0	100.0
LAC MINERALS	66,643,422	1,598,023	64.2	70.6	29.4	0.0	29.4
LACANA MINING	23,347,230	385,312	69.2	73.0	0.0	0.0	27.0

TABLE I cont'd
REVIEW OF INTERLISTED TRADING FOR THE YEAR ENDED DECEMBER 31, 1987
CANADIAN-BASED INTERLISTED ISSUES

SECURITY NAME	ALL MARKETS		AS A % OF TRADED VALUE				
	VOLUME	VALUE ($000)	TSE	CDN TOTAL	NYSE	AMEX	U S TOTAL
LAIDLAW	13,796,180	292,620	88 4	96 2	0 0	0 0	3 8
LAIDLAW CL B NV	144,170,854	2,918,165	57.5	64 5	0 0	0.0	35 5
LAWSON MARDON A SV	10,952,161	169,068	53 3	53.3	0 0	46.7	46 7
LEVON RES J	4,276,953	18,443	40.9	63 6	0 0	0 0	36 4
MACMILLAN BLOEDEL	88,758,160	2,594,792	49 8	55 3	0 0	0 0	44 7
MAGNA INTL CL A SV	54,629,423	1,178,504	35 9	35 9	0 0	0 0	64 1
MCINTYRE MINES	765,313	36,908	56.3	59 4	40 6	0.0	40 6
MIRTONE CL A NV	1,610,764	2,364	74 9	74 9	0.0	0.0	25 1
MIRTONE INTL	2,160,007	3,420	70 5	70 5	0 0	0 0	29 5
MITEL CORP	33,418,213	203,356	56 2	65 0	35 0	0 0	35.0
MOORE CORP	58,809,837	1,833,287	61 0	70 4	29 6	0 0	29 6
MSR EXPL	2,857,693	7,965	15 8	15 9	0 0	84 1	84.1
MURGOLD RES J	229,800	192	24 5	45 8	0 0	0 0	54 2
MUSCOCHO EXPL	17,877,530	90,336	52 9	63.1	0 0	0 0	36.9
MUSTO EXPL J	25,003,341	47,009	26.5	26 9	0 0	0.0	73 1
NAT BUSINESS SYS	16,892,418	293,848	75 4	75 4	0 0	0.0	24 6
NELSON HOLDINGS J	11,889,944	40,630	97 7	98.9	0.0	1 1	1 1
NORTH CDN OILS	11,154,433	208,227	77 0	81.0	0 0	19.0	19.0
NORTHERN TELECOM	123,395,514	4,262,082	34 4	43.7	56 3	0 0	56 3
NORTHGATE EXPL	22,024,289	209,489	36.3	39 2	60 8	0.0	60 8
NOWSCO WELL	21,082,999	387,516	57 8	57.8	0.0	0.0	42 2
NUMAC OIL & GAS	17,023,754	182,190	82.0	82 0	0 0	18.0	18 0
PAPERBOARD INC	5,342,545	60,374	88.4	94.7	0.0	0.0	4 3
PARKSIDE PETE	1,384,200	1,778	45.5	91.7	0.0	0.8	8.3
PEGASUS GOLD	74,705,663	1,839,101	26 2	26.2	0.0	0.8	73 8
PENNANT RES J	9,370,709	3,213	99.8	99.8	0.0	0.0	0.8
PLACER DEVELOPMENT	48,143,986	1,535,010	64.3	77 5	0.0	22.5	22 5
PLACER DOME	94,442,281	2,049,166	46.2	59.8	40.2	0.0	40 2
PLEXUS RES J	6,244,794	26,078	71 4	71.4	0.0	0.0	28 6
PRAIRIE OIL ROYALTY	549,331	4,983	35 1	35.1	0 0	64.9	64 9
QUEBEC STURGEON J	4,449,578	27,696	92.6	92.6	0.0	0.0	7 4
QUEBECOR CL Z	4,867,604	89,319	24 0	88 3	0 0	11.7	11.7
RANGER OIL	82,410,269	575,191	40.7	40 7	59 3	0.0	59 3
REA GOLD J	22,974,861	117,810	70.7	89 2	0 0	0.0	10 8
REDLAW IND J	272,100	1,064	0 0	0 0	0.0	100.0	100.0
RENABIE GOLD TR UN	1,494,802	556	93 5	93.5	0.0	0 0	6 5
RIO,ALGOM	12,79,312	262,448	88.2	96.4	0.0	3.6	3.6
SCEPTRE RESOURCES	17,826,266	76,300	87 9	92.8	0 0	7.2	7.2
SCURRY RAINBOW	359,070	7,551	39.7	39.7	0.0	60.3	60.3
SEAGRAM CO	77,728,240	7,118,890	27 5	34 9	65.1	0.0	65.1
SHL SYSTEMHOUSE	36,531,989	918,016	7.4	7 8	0.0	0.0	92.2
SILVERSIDE RES J	758,245	817	94.8	94.8	0.0	0.0	5.2
SONORA GOLD J	15,700,385	154,198	40.6	40.6	0.0	0.0	59.4
STERIVET-LAB	424,617	3,404	53.6	53.6	0.0	0.0	46.4
TERRA MINES J	15,302,254	32,852	55.6	59.9	0.0	0.0	40.1
TEXACO CANADA INC	19,286,671	647,994	66.9	84.1	0.0	15 9	15.9
TOTAL ERICKSON	14,573,412	70,739	49.0	50.6	0.0	0.0	49.4
TOTAL PETE NT AM	18,427,861	470,476	32.5	38.3	0.0	61.7	61.7
TRANSCAN PIPELINES	46,313,669	842,661	67.4	88.6	11.4	0.0	11.4
TRILOGY RES	63,911,980	72,447	7.1	7.8	0.0	0.0	92.2
U S PREC METAL J	6,548,762	11,278	7.6	24.5	0.0	0.0	75.5
UNITED CANSO	2,874,588	2,666	88.4	88.4	0.0	0.0	11.6
VARITY CORP	136,010,612	450,929	15.1	17.0	83.0	0.0	83.0
VINER EA CL A NV	6,836,293	27,518	85.1	85.1	0.0	0.0	14.9
VULCAN PACKAGING	4,682,412	13,390	78.3	78.3	0.0	0.0	21.7
WESTBURNE INTL	4,233,863	88,285	22.8	28.6	0.0	71.4	71.4
WESTCOAST TRANSMISSN	21,022,298	237,572	72.6	84.1	15.9	0.0	15.9
WHARF RES	37,958,384	252,327	83.6	83.6	0.0	0.0	16.4
ZYTEC SYSTEMS J	492,105	402	1.4	6.6	0 0	0.0	93.4
TOTAL CDN-BASED INTLST	4,055,126,504	89,574,891	43.8	52.4	30 3	8.6	47.6

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[a] Totals reflect trading on all exchanges in each country.

TABLE 2
TRADING SUMMARY OF U S -BASED SECURITIES INTERLISTED ON CANADIAN EXCHANGES DURING 1987

SECURITY NAME	ALL MARKETS VOLUME	ALL MARKETS VALUE ($000)	AS A % OF TRADED VALUE TSE	CDN TOTAL	NYSE	AMEX	U.S TOTAL[a]
ALLIED SIGNAL	138,134,722	7,566,222	0.0	0.0	100.0	0.0	100.0
AMAX GOLD	6,941,567	239,043	3.4	3.4	96.6	0.0	96.6
AMAX INC	101,005,266	2,861,690	0.0	0.0	100.0	0.0	100.0
AMERADA HESS	118,031,260	4,970,756	0.0	0.0	100.0	0.0	100.0
AMERICAN EXPRESS	355,871,219	20,142,120	0.0	0.0	100.0	0.0	100.0
AMOCO CORP	117,405,366	12,113,725	0.0	0.0	100.0	0.0	100.0
BANCO CENTRAL ADS	14,756,295	405,087	2.4	2.4	97.6	0.0	97.6
BARNWELL IND INC	343,200	4,881	0.0	0.0	0.0	100.0	100.0
BATTLE MTN A SV	84,642,131	3,178,002	3.4	3.4	96.6	0.0	96.6
BET PUBLIC	3,515,458	81,219	8.2	12.6	87.4	0.0	87.4
BRITISH AIR INSTL	21,958,360	591,552	13.2	13.2	86.8	0.0	86.8
BRITISH AIRWAY ADS	4,189,768	163,691	7.6	7.6	92.4	0.0	92.4
BRITISH GAS INSTL	17,517,700	633,130	5.4	5.4	94.6	0.0	94.6
BRITISH PET INSTL	29,029,068	628,903	0.5	0.5	99.5	0.0	99.5
BRITISH PETRO ADS	13,803,786	1,034,511	0.1	0.1	99.9	0.0	99.9
BRITISH TEL ADS	14,286,667	791,619	0.3	0.3	99.7	0.0	99.7
CHALLENGER RV	880,021	3,005	2.0	2.0	0.0	0.0	98.0
CHRYSLER CORP	269,728,705	13,278,266	0.1	0.1	99.9	0.0	99.9
CITICORP	84,963,138	3,697,662	0.0	0.0	100.0	0.0	100.0
COLECO INC	23,528,374	289,604	0.2	0.2	99.8	0.0	99.8
COLUMBIA GAS	31,490,986	2,022,314	0.0	0.0	100.0	0.0	100.0
CONTROL DATA	74,202,767	2,920,791	0.0	0.0	100.0	0.0	100.0
DOW CHEMICAL	208,302,469	23,011,070	0.0	0.0	100.0	0.0	100.0
ENRON CORP	8,652,297	520,447	0.0	0.0	100.0	0.0	100.0
ENSERCH CORP	48,476,079	1,383,155	0.0	0.0	100.0	0.0	100.0
FORD MOTOR CO	277,091,908	31,870,063	0.0	0.0	100.0	0.0	100.0
GENERAL MOTORS	305,136,409	31,134,358	0.2	0.3	99.8	0.0	99.8
GULF & WESTERN INC	5,797,100	540,297	0.0	0.0	100.0	0.0	100.0
HALLIBURTON	108,713,557	4,752,445	0.0	0.0	100.0	0.0	100.0
INSPIRATION RES	43,067,335	422,850	1.5	1.5	98.5	0.0	98.5
INTL BUSINESS MACH	509,982,668	117,596,905	0.1	0.1	99.9	0.0	99.9
IU INTERNATIONAL	30,203,130	702,123	0.5	0.6	99.4	0.0	99.4
KERR MCGEE	50,210,282	2,473,209	0.0	0.0	100.0	0.0	100.0
LAFARGE CORP	9,882,635	163,987	7.6	10.1	89.9	0.0	89.9
LOUISIANA LAND	30,665,885	1,435,088	0.0	0.0	100.0	0.0	100.0
MCDONALDS CORP	153,175,332	12,026,002	0.0	0.0	100.0	0.0	100.0
MOBIL CORP	251,484,180	15,173,583	0.0	0.0	100.0	0.0	100.0
OCCIDENTAL PETE	216,614,190	9,263,389	0.0	0.0	100.0	0.0	100.0
PANHANDLE EASTERN	61,276,689	2,341,800	0.0	0.0	100.0	0.0	100.0
PENNZOIL CO	46,626,879	4,635,883	0.0	0.0	100.0	0.0	100.0
PHH GROUP	8,607,013	414,076	0.0	0.0	100.0	0.0	100.0
PHILLIPS PETROLEUM	265,153,706	5,133,588	0.0	0.0	100.0	0.0	100.0
QUAKER OATS	56,423,969	3,596,211	0.0	0.0	100.0	0.0	100.0
ROCKWELL INTL	101,359,964	3,911,370	0.0	0.0	100.0	0.0	100.0
SONY CORP AMR	28,475,164	1,041,076	0.1	0.1	99.9	0.0	99.9
ST JOE GOLD CORP	9,457,158	195,929	1.9	1.9	0.0	98.1	98.1
STAN WEST J	17,635,551	94,138	4.1	4.1	0.0	0.0	95.9
TENNECO INC	159,196,648	10,198,245	0.0	0.0	100.0	0.0	100.0
TEXAS EASTERN CORP	45,092,982	1,981,495	0.0	0.0	100.0	0.0	100.0
TRICENTROL AMR	6,171,864	32,517	0.3	0.3	99.7	0.0	99.7
TRITON ENERGY	12,151,583	295,662	0.8	0.8	99.2	0.0	99.2
UTILICORP UNITED	2,[illegible]00,778	53,622	0.2	0.2	99.8	0.0	99.[illegible]
TOTAL U.S -BASED INTLST	4,603,984,828	364,025,733	0.1	0.1	99.8	0.1	99.9
TOTAL U.S. & CDN BASED	8,659,111,332	453,600,625	8.8	10.5	86.1	1.7	89.5

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[a] Totals reflect trading on all exchanges in each country.

TABLE 3
SUMMARY OF VOLUME AND VALUE OF CANADIAN-BASED AND U.S.-BASED INTERLISTED SECURITIES FOR THE YEAR ENDED DECEMBER 31,1987

- VALUE OF TRADING -
($000)

EXCHANGE	CDN-BASED INTLST	U S -BASED INTLST	GRAND TOTAL
TORONTO	39,256,630	455,270	39,711,901
MONTREAL	7,451,51[illegible]450	51,450	7,502,701
VANCOUVER	213,549	00	213,949
OTHER CDN	05	00	05
SUB TOTAL CDN EXCHANGES	46,921,837	506,720	47,428,558
NEW YORK	27,134,410	363,228,669	390,363,079
AMERICAN	7,730,895	197,113	7,928,008
NASCAQ	7,775,713	93,229	7,868,942
OTHER U.S.	12,034,00	.00	12,034
SUB TOTAL U.S. EXCHANGES	42,653,053	363,519,012	406,172,066
TOTAL ALL EXCHANGES	89,574,891	364,025,733	453,600,625

- VOLUME OF TRADING -

EXCHANGE	CDN-BASED INTLST	U.S.-BASED INTLST	GRAND TOTAL
TORONTO	1,891,284,042	11,973,166	1,903,257,208
MONTREAL	268,212,175	740,447	268,952,622
VANCOUVER	33,251,864	00	33,251,864
OTHER CDN	1,000	00	1,000
SUB TOTAL CDN EXCHANGES	2,192,749,081	12,713,613	2,205,462,694
NEW YORK	969,990,532	4,563,839,519	5,533,830,049
AMERICAN	368,348,734	9,610,498	377,959,232
NASDAQ	520,465,657	17,821,200	538,286,857
OTHER U.S.	3,572,500	00	3,572,500
SUB TOTAL U.S. EXCHANGES	1,862,377,423	4,591,271,215	6,453,648,638
TOTAL ALL EXCHANGES	4,055,126,504	4,603,984,828	8,659,111,332

TABLE 4
DIFFERENCE OF MEANS TESTS, MEANS, AND VARIANCES FOR LOGIT REGRESSION COEFFICIENTS ACROSS DAYS OF THE WEEK USING CANADIAN DATA 1979 - 1987 AND U.S. DATA 1984 - 1987[a]

Model: $\Omega_{it} = \delta_1 D_{1it} + \delta_2 D_{2it} + \delta_3 D_{3it} + \delta_4 D_{4it} + \delta_5 D_{5it} + e_{it}$

Panel A: T Statistics for Difference of Means Tests Across Days of the Week

Canadian Data

	Mon	Tue	Wed	Thu
Tue	-0.2417			
Wed	-0.8999	-0.6807		
Thu	-0.5052	-0.2732	0.4047	
Fri	-2.4832*	-2.3240*	-1.6468	-2.0420*

U.S. Data

	Mon	Tue	Wed	Thu
Tue	0.0721			
Wed	-1.4143	-1.4882		
Thu	-0.8728	-0.9478	0.5730	
Fri	-1.5827	-1.6603	-0.1080	-0.7083

Panel B: Means and Variances of Regression Coefficients Across Days of the Week

Canadian Data

	Mon	Tue	Wed	Thu	Fri
Mean	-0.3333	-0.3279	-0.3134	-0.3220	-0.2798
Variance	0.0291	0.0252	0.0239	0.0251	0.0210

U.S. Data

	Mon	Tue	Wed	Thu	Fri
Mean	0.0724	0.0666	0.1882	0.1415	0.1969
Variance	0.1524	0.1507	0.1695	0.1489	0.1449

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[a] The model is run monthly giving (12 x 9) 108 sets of regression coefficients with the Canadian data and (12 x 4) 48 with the U.S. data. Means and variances of these coefficients are used to calculate the difference of means tests. Variables: Ω_{it} = 0 if closing trade on day t for stock i is below the mean of the preceding quote and 1 above the mean. The dummy variables are for day of the week, D_{1it} = 1 if day t is a Monday and zero otherwise, Ω_{2it} = 1 if day t is a Tuesday and zero otherwise, etc.

* Significant at the 0.05 level.

TABLE 5
DIFFERENCE OF MEANS TESTS, MEANS, AND VARIANCES FOR LOGIT REGRESSION COEFFICIENTS ACROSS PRICE PORTFOLIO QUINTILES USING CANADIAN DATA 1979 - 1987[a]

Model: $\Omega_{it} = \delta_1 d_{1it} + \delta_2 d_{2it} + \delta_3 d_{3it} + \delta_4 d_{4it} + \delta_5 d_{5it} + e_{it}$

Panel A: t Statistics for Difference of Means Tests Across Price Portfolios

Port 2	-2.8851**			
Port 3	-2.9907**	-0.2528		
Port 4	-5.7422**	-3.3779**	-2.9316**	
Port 5	-7.4473**	-5.4115**	-4.6300**	-1.9953*
	Port 1	Port 2	Port 3	Port 4

Panel B: Means and variances of Regression Coefficients Across Price Portfolios

	Port 1	Port 2	Port 3	Port 4	Port 5
Mean	-0.4146	-0.3397	-0.3339	-0.2682	-0.2283
Variance	0.0474	0.0255	0.0314	0.0229	0.0202

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[a] The model is run monthly giving (12 x 9) 108 sets of regression coefficients. Means and varainces of these coefficients are used to calculate the difference of means tests. Variables: $\Omega_{it} = 0$ if a transaction is below the mean of the preceding quote and 1 above the mean. The dummy variables are for price portfolio, $d_{1it} = 1$ if stock i is in lowest price portfolio and zero otherwise, $d_{2it} = 1$ if stock i is in price portfolio 2 and zero otherwise, etc.

* Significant at 0.05; ** significant at 0.01.

TABLE 6

DIFFERENCE OF MEANS TESTS, MEANS, AND VARIANCES FOR LOGIT REGRESSION COEFFICIENTS ACROSS TIMES OF THE DAY, ALL DAYS COMBINED, USING CANADIAN DATA 1979 - 1987 AND U.S. DATA 1984 - 1987[a]

Model: $\Omega_{nd} = \delta_1 D_{1nd} + \delta_2 D_{2nd} + \delta_3 D_{3nd} + \delta_4 D_{4nd} + \delta_5 D_{5nd} + \delta_6 D_{6nd} + \delta_7 D_{7nd} + e_{id}$

Panel A: T Statistics for Difference of Means Tests Across Times of the Day

Canadian Data

11:00	-4.7867**					
12:00	-4.8853**	0.0100				
1:00	-3.0325**	1.2587	1.2718			
2:00	-3.2487**	1.0906	1.1011	-0.1661		
3:00	-4.0325**	0.9158	0.9267	-0.4722	-0.2910	
4:00	-11.3099**	-5.5547**	-5.7268**	-6.3025**	-6.1791**	-6.9008**
	Open	11:00	12:00	1:00	2:00	3:00

U.S. Data

11:00	3.1314**					
12:00	2.4002*	0.8967				
1:00	1.4164	-1.5357	-0.7691			
2:00	3.5956**	0.5253	1.4299	2.0039*		
3:00	2.2523*	-0.4750	0.2743	0.9003	-0.9255	
4:00	-3.6638**	-7.0636**	-6.5063**	-4.9569**	-7.4778**	-5.5486**
	Open	11:00	12:00	1:00	2:00	3:00

Panel B: Means and Variances of LOGIT Regression Coefficients

Canadian Data	Open	11:00	12:00	1:00	2:00	3:00	4:00
Mean	-0.1468	-0.0588	-0.0590	-0.0850	-0.0813	-0.0754	0.0322
Variance	0.0096	0.0107	0.0098	0.0153	0.0148	0.0092	0.00[illegible]4
U.S. Data							
Mean	0.0845	-0.0236	0.0055	0.0323	-0.0417	-0.0049	0.2052
Variance	0.0368	0.0346	0.0282	0.0447	0.0371	0.0577	0.0283

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[a] The model is run triannually for each day of the week giving (3 periods per year x 5 days per week x 9 years) 135 sets of regression coefficients in the Canadian sample and (3 x 5 x 4) 60 in the U.S. sample. Means and variances of these coefficients are used to calculate the difference of means tests. Variables: $\Omega_{nd} = 0$ if transaction n on day d is below the mean of the preceding quote and 1 above the mean. The dummy variables are for time of the day, $D_{1nd} = 1$ if transaction n on day d occurs in the opening three minutes and zero otherwise, $D_{2nd} = 1$ if transaction n on day d occurs in the 11.00 to 11:03 time period and zero otherwise, etc.

*Significant at 0.05; ** significant at 0.01.

TABLE 7
T STATISTICS FOR DIFFERENCE OF MEANS TESTS FOR LOGIT REGRESSION COEFFICIENTS ACROSS DAYS OF THE WEEK, FOR SEVEN TIME PERIODS DURING THE DAY USING CANADIAN DATA 1979 - 1987 AND U.S. DATA 1984 - 1987[a]

Model: $\Omega_{nt} = \delta_1 D_{1nt} + \delta_2 D_{2nt} + \delta_3 D_{3nt} + \delta_4 D_{4nt} + \delta_5 D_{5nt} + e_{nt}$

Panel A: Canadian Data

			Open	11:00	12:00	1:00	2:00	3:00	4:00
MON	vs	TUE	3.4141**	0.8842	0.5469	0.4032	-0.2823	0.0022	-0.1301
MON	vs	WED	1.9944*	-1.0203	-0.7843	-0.1618	-1.7039	-0.6875	-0.2738
MON	vs	THU	2.6874**	-1.1662	-1.0605	-1.1472	-1.6498	-0.1514	-1.3731
MON	vs	FRI	2.4945**	-0.8407	-2.1037*	-2.9706**	-1.0464	-1.4384	-2.5781*
TUE	vs	WED	-1.5616	-1.9262	-1.3316	-0.5761	-1.4510	-0.7381	-0.1330
TUE	vs	THU	-0.8988	-2.1172*	-1.6271	-1.5386	-1.3977	-0.1655	-1.1970
TUE	vs	FRI	-0.8765	-1.8297	-2.6538**	-3.3114**	-0.7874	-1.5509	-2.3514*
WED	vs	THU	0.7075	-0.1036	-0.2461	-1.0007	0.0393	0.5925	-1.1197
WED	vs	FRI	-0.6279	0.2677	-1.3157	-2.8725**	0.6112	-0.7566	-2.3416*
THU	vs	FRI	-0.0337	0.3939	-1.1271	-1.9302	0.5677	-1.4173	-1.1796

Panel B: U.S. Data

			Open	11:00	12:00	1:00	2:00	3:00	4:00
MON	vs	TUE	-0.9376	-1.0602	-1.6126	1.2846	0.4975	-0.9838	0.2390
MON	vs	WED	-0.5358	-1.2522	-1.6880	1.3904	-0.0261	1.8707	0.5133
MON	vs	THU	-1.4524	-1.9666	-0.5039	0.1444	-1.1994	-0.3834	-0.2068
MON	vs	FRI	-2.0680*	-1.4006	-1.6689	1.9264	0.6351	0.3265	-0.1033
TUE	vs	WED	0.4549	-0.2924	-0.2450	0.1721	-0.5448	1.8916	0.2860
TUE	vs	THU	-0.7193	-1.2064	1.1996	0.0057	-1.6023	0.5396	-0.4296
TUE	vs	FRI	-1.4246	-0.5079	-0.3632	0.6589	0.1678	1.3554	-0.3371
WED	vs	THU	-1.0888	-0.9021	1.3057	-0.1482	-1.2324	-1.2154	-0.6781
WED	vs	FRI	-1.7946	-0.2182	-0.1370	0.4552	0.6820	-0.5695	-0.6012
THU	vs	FRI	-0.5470	0.6707	-1.3092	0.5776	1.6562	0.7048	0.1062

---

[a] Table 8 contains a decription of the model. The model is run 756 times (12 months x 7 time periods x 9 years) for the Canadian data and 336 times (12 months x 7 time periods x 9 years) for the U.S. data. Means and variances of the regression coefficients are calculated on the 108 (48) monthly Canadian (U.S.) observations for each of the 7 time periods. Difference of means tests are computed for each day of the week within each time period based on the means an variances.

* Significant at 0.05, ** significant at 0.01.

TABLE 8
MEANS AND VARIANCES OF LOGIT REGRESSION COEFFICIENTS ACROSS DAYS OF THE WEEK, FOR SEVEN TIME PERIODS DURING THE DAY USING CANADIAN DATA 1979 - 1987 AND U.S. DATA 1984 - 1987[a]

Model: $\Omega_{nt} = \delta_1 D_{1nt} + \delta_2 D_{2nt} + \delta_3 D_{3nt} + \delta_4 D_{4nt} + \delta_5 D_{5nt} + e_{nt}$

Canadian Data		Mon	Tue	Wed	Thu	Fri
Open	Mean	-0.0738	-0.1859	-0.1388	-0.1591	-0.1580
	Variance	0.0542	0.0531	0.0452	0.0433	0.0561
11:00	Mean	-0.0948	-0.1265	-0.0569	-0.0532	-0.0861
	Variance	0.0733	0.0648	0.0760	0.0646	0.0526
12:00	Mean	-0.1075	-0.1281	-0.0791	-0.0708	-0.0347
	Variance	0.0743	0.0786	0.0677	0.0554	0.0550
1:00	Mean	-0.1336	-0.1501	-0.1270	-0.0899	-0.0198
	Variance	0.0861	0.0949	0.0782	0.0702	0.0722
2:00	Mean	-0.1398	-0.1275	-0.0685	-0.0700	-0.0937
	Variance	0.1082	0.0976	0.0811	0.0851	0.1021
3:00	Mean	-0.1176	-0.1176	-0.0900	-0.1117	-0.0620
	Variance	0.0938	0.0717	0.0801	0.0657	0.0671
Close	Mean	-0.0184	-0.0140	-0.0097	0.0248	0.0589
	Variance	0.0565	0.0634	0.0521	0.0500	0.0405

U.S. Data		Mon	Tue	Wed	Thu	Fri
Open	Mean	-0.0030	0.0760	0.0437	0.1323	0.1766
	Variance	0.2321	0.1092	0.1322	0.1846	0.1300
11:00	Mean	-0.1099	-0.0473	-0.0319	0.0250	-0.0190
	Variance	0.1104	0.0569	0.0757	0.1154	0.0915
12:00	Mean	-0.0906	0.0094	0.0226	-0.0564	0.0316
	Variance	0.1311	0.0536	0.0847	0.0907	0.1262
1:00	Mean	0.0952	0.0127	0.0012	0.0123	-0.0292
	Variance	0.1023	0.0956	0.1167	0.1495	0.0977
2:00	Mean	-0.0421	-0.0767	-0.0405	0.0400	-0.0900
	Variance	0.1013	0.1311	0.0811	0.1236	0.1724
3:00	Mean	-0.1173	0.0639	-0.0805	0.0203	-0.0369
	Variance	0.1517	0.1315	0.1481	0.1819	0.1336
Close	Mean	0.2164	0.2037	0.1889	0.2288	0.2222
	Variance	0.0721	0.0630	0.0653	0.1007	0.0822

---

[a] The model is run monthly for each time period as described in Table 7. Variables: Ω_{nt} = 0 if a transaction is below the mean of the preceding quote and 1 above the mean. The dummy variables are for day of the week, D_{1nt} = 1 if transaction n, in time period t, is on a Monday and zero otherwise; D_{2nt} = 1 if transaction n, in time period t, is on a Tuesday, etc. Difference of means tests, computed for each day of the week within each time period, are shown in Table 7.

TABLE 9
SUR REGRESSION COEFFICIENTS (T STATS) FOR CANADIAN DATA BY TIME OF DAY AND PRICE STRATIFIED QUINTILES FROM 1979 - 1987[a]

Model: $\Gamma_{pt} = \Sigma_{j=1}^{7} \delta_j D_{jt} + e_{pt}$

	Open	11:00	12:00	1:00	2:00	3:00	Close
p=1	6.148E-02 (49.49)	5.641E-02 (44.81)	5.518E-02 (43.83)	5.580E-02 (44.32)	5.250E-02 (41.71)	5.276E-02 (41.91)	5.340E-02 (42.90)
p=2	3.450E-02 (89.44)	3.098E-02 (80.32)	2.956E-02 (76.64)	2.922E-02 (75.76)	2.835E-02 (73.52)	2.956E-02 (76.65)	2.984E-02 (77.37)
p=3	2.648E-02 (96.53)	2.469E-02 (89.99)	2.299E-02 (83.80)	2.321E-02 (84.58)	2.285E-02 (83.28)	2.313E-02 (84.30)	2.386E-02 (86.98)
p=4	1.683E-02 (75.72)	1.488E-02 (66.91)	1.476E-02 (66.37)	1.394E-02 (62.69)	1.423E-02 (64.02)	1.439E-02 (64.72)	1.492E-02 (67.12)
p=5	0.982E-02 (108.72)	0.854E-02 (94.54)	0.836E-02 (92.63)	0.823E-02 (91.18)	0.812E-02 (89.92)	0.822E-02 (91.05)	0.862E-02 (95.47)

---

[a] P=1 to p=5 represent the five price stratified portfolios. Each equation has 3,780 observations (7 time periods/day, 5 days/week, 108 months). Variables: Γ_{pt} = average proportional spread in time period t and portfolio p. Proportional spread = (ask-bid)/((ask+bid)/2). The dummies are for time of the day, D_{1t} = 1 if the observation on portfolio p is at the open and zero otherwise, D_{2t} = 1 if the observation on portfolio p is during 11:00 to 11:03 and zero otherwise, etc.

TABLE 10
SUR REGRESSION COEFFICIENTS (T STATS) FOR CANADIAN DATA BY TIME OF DAY, VOLUME, AND PRICE STRATIFIED QUINTILES FROM 1979 - 1987[a]

Model: $\Gamma_{pt} = \Sigma_{j=1}^{7} \delta_j D_{jt} + \delta_8 \ln(\bar{V}_{pt}) + e_{pt}$

	Open	11:00	12:00	1:00	2:00	3:00	Close	ln(V)
p=1	2.564E-02 (3.82)	2.371E-02 (3.85)	2.268E-02 (3.71)	2.491E-02 (4.28)	2.136E-02 (3.64)	2.025E-02 (3.47)	1.937E-02 (2.98)	3.063E-03 (5.43)
p=2	3.277E-02 (14.44)	2.944E-02 (14.50)	2.803E-02 (13.83)	2.777E-02 (14.48)	2.689E-02 (13.84)	2.806E-02 (14.15)	2.818E-02 (12.89)	1.467E-04 (0.77)
p=3	2.570E-02 (19.00)	2.399E-02 (19.75)	2.229E-02 (18.40)	2.255E-02 (19.91)	2.219E-02 (19.51)	2.245E-02 (19.12)	2.309E-02 (17.43)	6.840E-05 (0.59)
p=4	1.953E-02 (21.81)	1.733E-02 (21.18)	1.719E-02 (21.15)	1.618E-02 (21.51)	1.651E-02 (21.65)	1.676E-02 (21.11)	1.759E-02 (19.84)	-2.286E-04 (-3.11)
p=5	1.172E-02 (23.78)	1.028E-02 (22.72)	1.010E-02 (22.42)	0.983E-02 (23.62)	0.973E-02 (23.16)	0.992E-02 (22.53)	1.052E-02 (21.40)	-1.584E-04 (-3.93)

---

[a] Excluding $\ln(\bar{V}_{pt})$, the model is described in Table 9. $\ln(\bar{V}_{pt})$ = the log of the arithimetic average of volume traded averaged within each time period and portfolio. For example, for every trade occurring in time period t, in the month m, on stocks assigned to price portfolio p, the volume of the transaction is recorded and the arithimetic average of all these volumes is calculated. Then the log of the average is used as the observation on the volume variable for portfolio p, at time t, in month m.

TABLE 11
SUR REGRESSION COEFFICIENTS (T STATS) FOR CANADIAN DATA BY TIME OF DAY, VARIANCE, VOLUME, AND PRICE STRATIFIED QUINTILES FROM 1979 - 1987[a]

$$\text{Model: } r_{pt} = \Sigma_{j=1}^{7} \delta_j D_{jt} + \delta_8 \ln(\bar{V}_{pt}) + \delta_9 \overline{\sigma^2}_{p\tau} + e_{pt}$$

	Open	11:00	12:00	1:00	2:00	3:00	Close	$\ln(\bar{V})$	$\overline{\sigma^2}$
p=1	1.81E-02 (2.72)	1.73E-02 (2.83)	1.63E-02 (2.69)	1.91E-02 (2.32)	1.55E-02 (2.66)	1.47E-02 (2.47)	1.23E-02 (1.90)	4.15E-03 (7.31)	-3.26E-01 (-9.40)
p=2	3.27E-02 (14.32)	2.94E-02 (14.37)	2.80E-02 (13.70)	2.78E-02 (14.34)	2.69E-02 (13.70)	2.81E-02 (14.01)	2.82E-02 (12.73)	1.60E-04 (0.84)	-2.73E-03 (-0.77)
p=3	2.54E-02 (18.66)	2.37E-02 (19.34)	2.20E-02 (18.07)	2.23E-02 (19.45)	2.19E-02 (19.06)	2.22E-02 (18.69)	2.28E-02 (17.09)	6.98E-05 (0.60)	1.12E-03 (1.23)
p=4	1.93E-02 (21.34)	1.71E-02 (20.63)	1.70E-02 (20.60)	1.60E-02 (20.86)	1.63E-02 (21.02)	1.65E-02 (20.53)	1.74E-02 (19.39)	-2.30E-04 (-3.13)	4.51E-04 (1.19)
p=5	1.09E-02 (22.07)	0.94E-02 (20.76)	0.92E-02 (20.45)	0.90E-02 (21.38)	0.89E-02 (20.96)	0.91E-02 (20.49)	0.97E-02 (19.70)	-1.75E-04 (-4.40)	9.05E-04 (9.47)

---

[a] Excluding $\overline{\sigma^2}_{p\tau}$, the model is described in Tables 9 and 10. $\overline{\sigma^2}_{p\tau}$ = the arithimetic average of monthly mean of the bid-ask spread variances averaged within each portfolio. They are assumed stable within each month. For example, the mean of every quote for stock i in month τ is calculated. The variance of these means is added to the variances of all other stocks assigned to portfolio p, in month τ. The arithimetic average of these varainces is used as the variance observation for all seven time periods for portfolio p in month τ.

TABLE 12
F TESTS FOR EQUALITY OF SUR REGRESSION TIME DUMMY COEFFICIENTS[a]

Model: $r_{pt} = \Sigma_{j=1}^{7} \delta_j D_j + \delta_8 \ln(\bar{V}_{pt}) + \delta_9 \overline{\sigma^2}_{pt} + e_{pt}$

p = 1

11:00	0.354					
12:00	1.180	0.579				
1:00	0.308	1.418	4.730*			
2:00	2.057	1.211	0.299	8.434**		
3:00	4.082*	2.549	1.010	8.384**	0.379	
Close	20.997**	10.388**	6.037*	15.419**	3.829	3.273
	Open	11:00	12:00	1:00	2:00	3:00

p = 2

11:00	47.448**					
12:00	73.707**	11.659**				
1:00	62.563**	10.848**	0.335			
2:00	91.016**	23.672**	5.178*	4.567*		
3:00	67.276**	7.034**	0.005	0.334	7.995**	
Close	117.703**	6.099*	0.064	0.636	5.346*	0.045
	Open	11:00	12:00	1:00	2:00	3:00

p = 3

11:00	28.105**					
12:00	82.646**	34.415**				
1:00	53.838**	16.292**	0.759			
2:00	67.739**	23.229**	0.077	1.548		
3:00	69.010**	17.660**	0.184	0.089	0.767	
Close	80.412**	6.124*	4.349*	1.670	5.127*	3.804
	Open	11:00	12:00	1:00	2:00	3:00

p = 4

11:00	145.043**					
12:00	110.115**	0.697				
1:00	156.596**	28.186**	33.740**			
2:00	133.144**	12.796**	10.485**	4.029*		
3:00	143.542**	6.352*	3.677	7.773*	2.481	
Close	140.879**	[illegible]	2.882	28.973**	20.063**	19.239**
	Open	11:00	12:00	1:00	2:00	3:00

p = 5

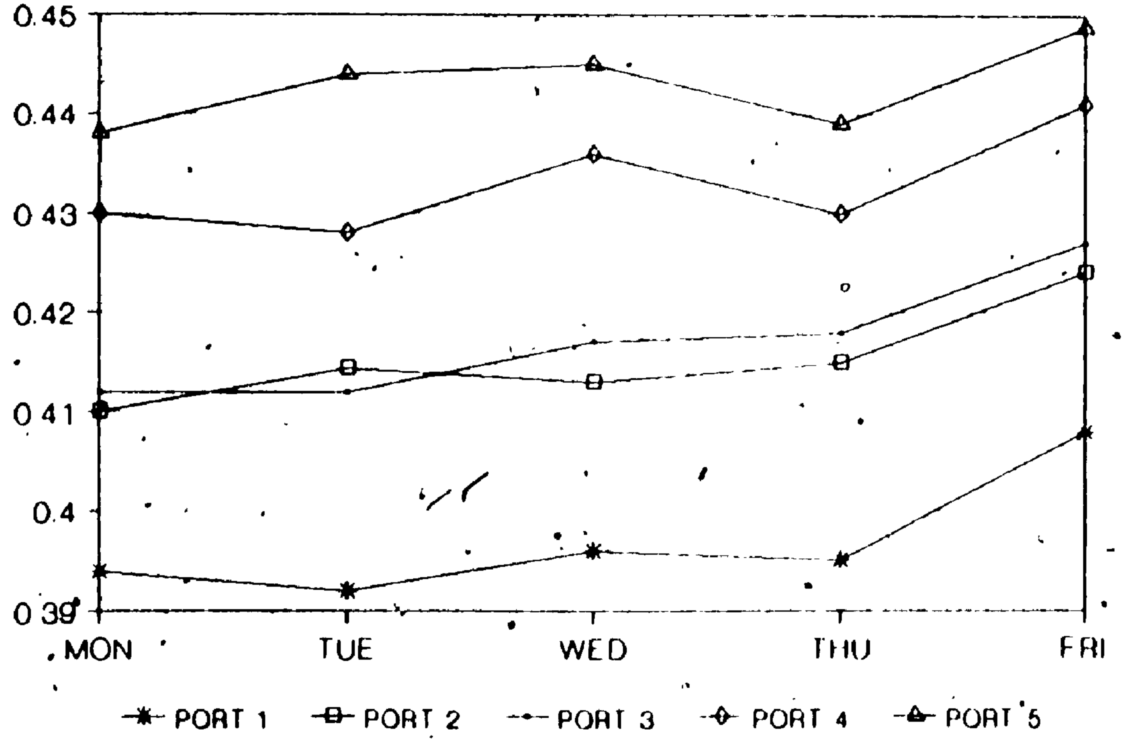
11:00	268.486**					
12:00	234.938**	5.278*				
1:00	216.684**	19.718**	10.737**			
2:00	247.873**	25.983**	13.666**	1.485		
3:00	268.594**	12.281**	3.210	0.861	5.430*	
Close	230.337**	5.825*	14.933**	30.769**	45.075**	43.802
	Open	11:00	12:00	1:00	2:00	3:00

---

[a] Model description is in Tables 9, 10, and 11. P = 1 through p = 5 represent price portfolio quintiles 1 through 5. All the F tests have 1 and 3267 degrees of freedom.

* Significant at 0.05; ** significant at 0.01.

FIGURE 1
PROBABILITY OF THE LAST TRADE OF THE DAY OCCURRING
AT THE ASK ACROSS FIVE PRICE STRATIFIED PORTFOLIOS USING CANADIAN DATA 1979 - 1987[a]



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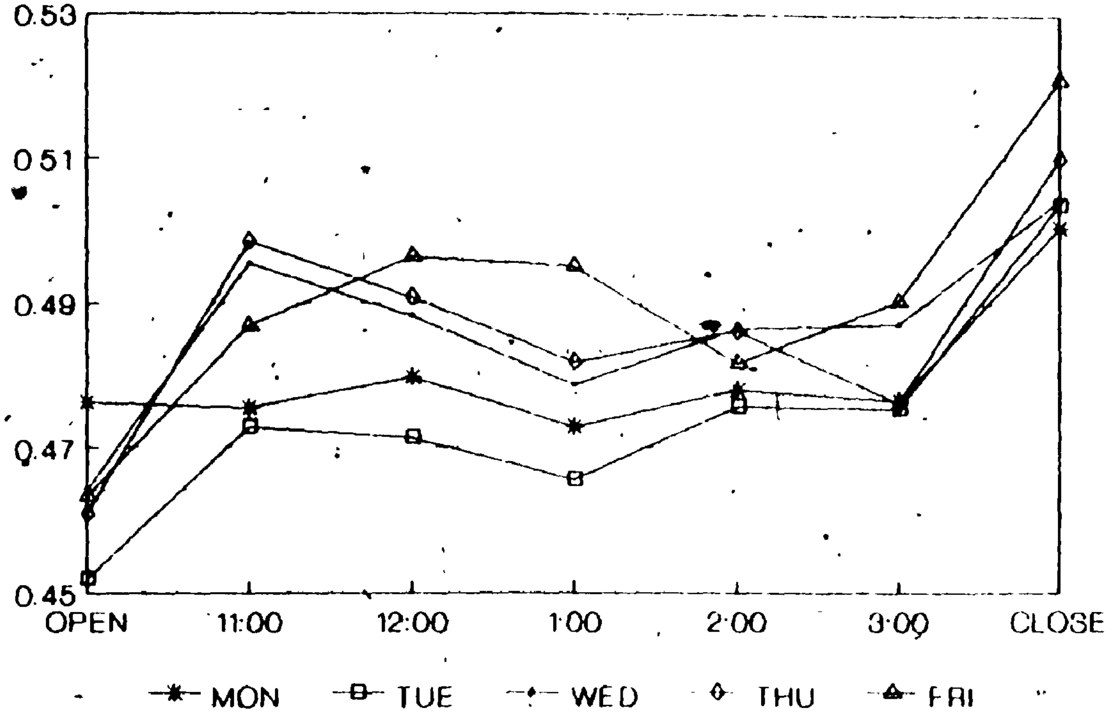
[a] The model: $\Omega_{it} = \delta_1 D_{1it} + \delta_2 D_{2it} + \delta_3 D_{3it} + \delta_4 D_{4it} + \delta_5 D_{5it} + e_{it}$, is run monthly giving (12 x 9) 108 sets of regression coefficients. Means of the dummy coefficients are calculated and converted to probabilities using: $\exp(\bar{x}) / (1 + \exp(\bar{x}))$. Variables: Ω_{it} = 0 if transaction on stock i on day t is below the mean of the preceding quote and 1 above the mean. The dummy variables are for price portfolio, D_{1it} = 1 if stock i is assigned to the lowest price portfolio and zero otherwise, D_{2it} = 1 if stock i is assigned to price portfolio 2 and zero otherwise, etc.

FIGURE 2

PROBABILITY OF A TRADE OCCURRING AT THE ASK ACROSS TIMES OF THE DAY, FOR DAYS OF THE WEEK USING CANADIAN DATA 1979 - 1987[a]



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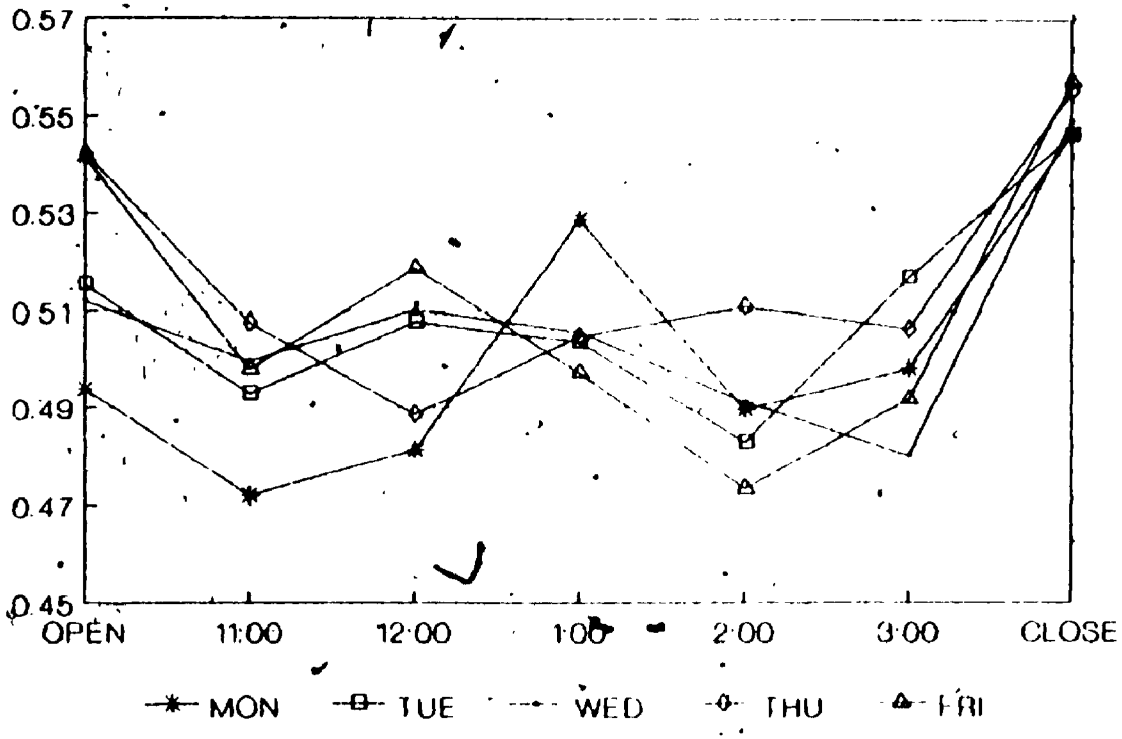
[a] The model: $\Omega_{nd} = \delta_1 D_{1nd} + \delta_2 D_{2nd} + \delta_3 D_{3nd} + \delta_4 D_{4nd} + \delta_5 D_{5nd} + \delta_6 D_{6nd} + \delta_7 D_{7nd} + e_{nd}$, is explained in Table 6. Means of the dummy coefficients are calculated and converted to probabilities using: $\exp(\bar{x}) / (1 + \exp(\bar{x}))$.

FIGURE 3
PROBABILITY OF A TRADE OCCURRING AT THE ASK ACROSS TIMES OF THE DAY, FOR DAYS OF THE WEEK USING U.S. DATA 1984 - 1987[a]



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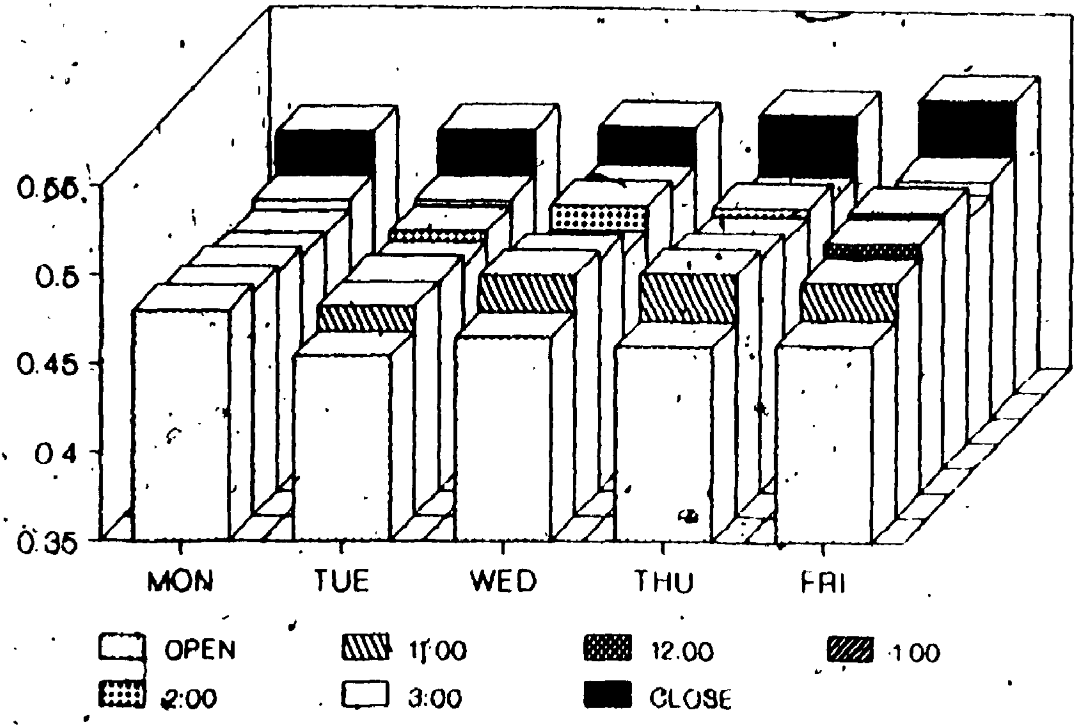
[a] The model: $\Omega_{nd} = \delta_1 D_{1nd} + \delta_2 D_{2nd} + \delta_3 D_{3nd} + \delta_4 D_{4nd} + \delta_5 D_{5nd} + \delta_6 D_{6nd} + \delta_7 D_{7nd} + e_{nd}$, is explained in Table 6. Means of the dummy coefficients are calculated and converted to probabilities using: $\exp(\bar{x}) / (1 + \exp(\bar{x}))$.

FIGURE 4

PROBABILITY OF A TRADE OCCURRING AT THE ASK ACROSS DAYS OF THE WEEK, FOR SEVEN TIME PERIODS DURING THE DAY USING CANADIAN DATA 1979 - 1987[a]



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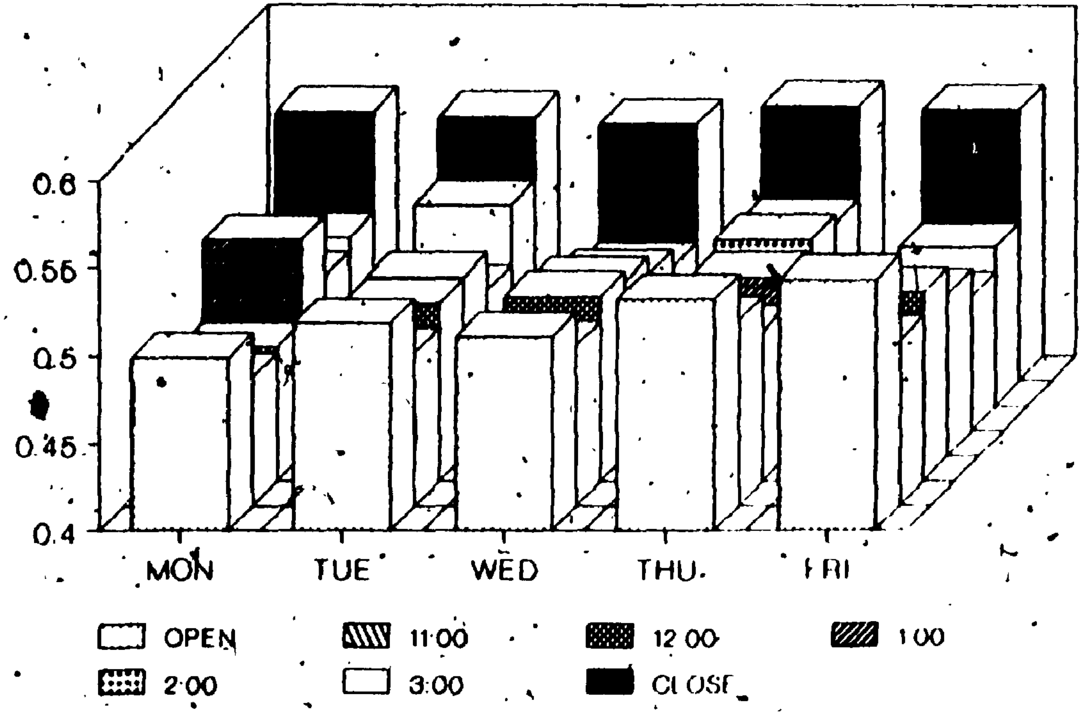
[a] The model: $\Omega_{nt} = \delta_1 D_{1nt} + \delta_2 D_{2nt} + \delta_3 D_{3nt} + \delta_4 D_{4nt} + \delta_5 D_{5nt} + e_{nt}$, is explained in Tables 7 and 8. Means of the dummy coefficients are calculated and converted to probabilities using: $\exp(\bar{x}) / (1 + \exp(\bar{x}))$.

FIGURE 5

PROBABILITY OF A TRADE OCCURRING AT THE ASK ACROSS DAYS OF THE WEEK, FOR SEVEN TIME PERIODS DURING THE DAY USING U.S. DATA 1984 - 1987[a]



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[a] The model: $\Omega_{nt} = \delta_1 D_{1nt} + \delta_2 D_{2nt} + \delta_3 D_{3nt} + \delta_4 D_{4nt} + \delta_5 D_{5nt} + e_{nt}$ is explained in Tables 7 and 8. Means of the dummy coefficients are calculated and converted to probabilities using: $\exp(\bar{x}) / (1 + \exp(\bar{x}))$.

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