THE INTRADAY PRICING BEHAVIOR OF INTERNATIONAL DUALLY LISTED SECURITIES

Darius P. Miller
Matthew R. Morey

Abstract: International capital asset theory assumes that international dually listed securities should sell at the same price in the absence of transaction costs and restrictions to capital flows. This note presents evidence that price differences between a British security and its American Depository Receipt are small when using contemporaneous intraday data. In addition, we find that during the overlap period between the London and New York exchanges, the mean price differences are higher in the first and last half-hours of the overlap. This result is consistent with the volatility of stock returns being higher in at the beginning and ending of the trading day. Finally, we find evidence that supports the practice of using daily non-contemporaneous data as a proxy for contemporaneous intraday data.

JEL Classification: F3
Key Words: American Depositary Receipts, Arbritrage, Intraday

I. INTRODUCTION

Although dually listed securities such as American Depository Receipts (ADRs) have become one of the most important methods of facilitating cross-border capital flows, little is known about the behavior of one security traded in many markets. International asset pricing models (IAPMs) implicitly assume that perfect cross border arbitrage will require the securities be sold at the same price in different markets.[1]

[1]Black (1974), Solnik (1974), Grauer et al. (1976), Alder and Dumas (1975), Stulz (1981a, 1981b), and Errunza and Losq (1985a, 1989).

Darius P. Miller is affiliated with the University of California, Irvine, CA 92717. Matthew R. Morey is affiliated with Fordham University, Bronx, NY 10458. *The authors thank Analytic Investment Company, Irvine, California for help with the data. They also thank Ike Mathur (the editor), and an anonymous referee for valuable comments that improved the manuscript. Finally, they thank Mark Levy for his research assistance.*

However, empirical evidence such as that of Bailey and Jagtiani (1994) and Hietala (1989) show that various barriers to capital flows can affect the behavior of dual listed securities. Errunza et. al (1993) present a model of ADR pricing in a microstructure setting. In their model, the price of ADRs straddle the price of the underlying security, preventing cross-border arbitrage opportunities. This note presents evidence on how effective cross-border arbitrage is at equating the prices of a dual listed security in markets using contemporaneous intraday data. The use of intraday data allows the tests to be conducted when both markets are open, unlike Maldonado and Saunders (1983), Kato et al. (1991), Wahab et al. (1992) and Park and Tavakkol (1994) who use daily non-overlapping data. Our findings indicate that the market is efficient with respect to arbitrage opportunities. This finding is consistent with the assumptions of the various IAPM's and the model of Errunza et. al (1993).

We also investigate the intraday price difference pattern between ADRs and the underlying securities. Microstructure models analyzing volatility patterns such as Admati and Pfleiderer (1988) and Foster and Viswanathan (1990) predict an increase in volatility when liquidity and informed traders meet to trade in intervals such as just when the market opens or just before it closes. Empirical findings confirm that stock return volatility and bid-ask spreads follows this U shape (e.g., Wood et al. 1985, Harris 1986, Jain and Joh 1988, Kleidon and Werner 1995 and Chan et. al 1995). If there is a link between the price volatility, bid-ask spreads and arbitrage, we should expect to see a similar pattern in the price differences. We find this U shape in the price difference during the periods that the two markets overlap, suggesting that prices between markets are the most different at the beginning and ending of the overlap period.

Finally, we compare our intraday price difference results to those obtained using daily data. In studies of international finance, the use of daily data is often used as a proxy for contemporaneous data. For example, when measuring the premiums in closed-end equity funds, lack of contemporaneous data precludes measuring net-asset-value and market value in the two markets simultaneously. We find evidence that supports the use of daily data as a proxy for contemporaneous intraday data.

The note is organized as follows: Section 2 provides a very brief treatment of how arbitrage can take place in American Depository Receipts; Section 3, describes the data used in the note; Section 4 describes the methodology and empirical results while section 5 concludes the note.

II. ARBITRAGE IN INTERNATIONAL DUALLY LISTED SECURITIES

An ADR is a negotiable certificate which represents ownership of shares of a company registered in a country other than the United States. ADRs are traded on U.S. exchanges (or in the OTC 'pink sheet' market) and are quoted in U.S. dollars. The holder of an ADR has the right to redeem the receipt for the underlying share. Therefore the ADR and the underlying share are essentially perfect substitutes after adjusting for transactions costs. Transactions costs include bid-ask spreads and fees

paid to the depositary bank for ADR creation and cancellation. As a result, when an ADR is trading at a discount to the underlying share, a trader can make arbitrage profits by buying the ADR, converting it into the underlying shares, and then selling them in the underlying market. If the ADR is selling at a premium, a trader can buy the underlying shares and then request the custodian bank to issue ADRs based on the underlying shares until the price difference is eliminated. In absence of transactions costs and restrictions to capital flows, perfect cross-market arbitrage should equate the price of the two securities.

III. THE DATA

In this paper we examine the ADR arbitrage possibilities for the Glaxo-Wellcome PLC, a large British pharmaceutical corporation. The data was manually entered from the Bloomberg data system. The decision to use Glaxo-Wellcome PLC was based upon the fact that both the underlying issue in London and the ADR in New York are both heavily traded and therefore the number of listed intraday trades available on the London and New York exchanges was large.[2] To see whether arbitrage profits were available we examine the contemporaneous prices in both the New York and London markets over the overlap period of the two markets (9:30am - 11:30am New York time or 2:30pm - 4:30pm London time) during the period of March 27, 1995 to May 31, 1995. To construct each contemporaneous data point, we first found a traded price in the overlap period for the ADR. Then we found an underlying London market traded price and a U.S. Dollar/British Pound traded price at the same minute as the ADR price. Each underlying price was then adjusted into the correct denomination and then transformed into its U.S. Dollar value by the contemporaneous U.S. Dollar/British Pound exchange rate.[3] In terms of total observations, we found 2235 total observations where the U.S. price corresponded with the London market price and the U.S. Dollar/British Pound exchange rate price.

VI. METHODOLOGY AND EMPIRICAL RESULTS

A. Arbitrage relationships

Our first objective is to examine the arbitrage relationship between the London Glaxo-Wellcome price and the Glaxo-Wellcome ADR price. To tests this we examine the difference between the two prices after adjusting for exchange rate changes. Formally, we investigate if

$$(P^{f})(\$/BP) = P^{US} \quad (1)$$

[2]Lack of data on the less liquid ADRs and the fact that the data was manually entered precluded a larger cross section. Glaxo-Wellcome is one of the most heavily traded of all dual listed securities.

[3]As with many American Depository Receipts, each Glaxo-Wellcome ADR represents a number of shares in the London Market. For the Glaxo-Wellcome ADR, each ADR represented 2 shares in the London Market.

where P^f = underlying (London) price of Glaxo-Wellcome, adjusted for the number of ADRs per share
$/BP = the U.S. Dollar/British Pound exchange rate,
P^{US} = the ADR price of Glaxo-Wellcome.

The results indicate that there is very little opportunity for arbitrage using the ADR market. In figure 1 the differences between the exchange rate adjusted underlying price and the ADR price are shown. In almost all instances, the difference is less than 2 ticks or 25 cents. Arbitrage between the underlying and ADR market would represent at three transactions: one, buying the issue, two, creating or cancelling the ADR, and three, selling the issue. Since both the buy and sell transactions would each have at least the cost of one tick, and because the cost of creating or cancelling an ADR is about 4 to 5 cents[4], it is doubtful whether any profitable arbitrage could take place. This finding is consistent with assumptions of the IAPMs, as well as the model of Errunza et. al (1993) where the price of the ADR straddles the Bid/Ask spread of the underlying security.

Figure 1 also illustrates that the difference between the underlying and the ADR is biased in the direction of the underlying share. That is, the London market is generally priced slightly higher than the ADR. If the bid/ask price of the ADR straddles the underlying price as in the model of Errunza et. al (1993), the bias can result from a majority of the trades being transacted on the bid side. Further, it maybe that the bias is caused by the tick difference between markets. In the London market, prices are quoted in pence, whereas in the U.S. they are quoted in 12.5 cent blocks. Consequently, a very slight movement in the price will change the London price and not the U.S. price. Glaxo-Wellcome had an slight upward drift in its value over the sample period (on March 27, 1995 the opening value of the ADR was quoted at $22.625 while on May 31, 1995 the closing value was equal to $23.00). Due to the sensitive tick measurement in the London market, the London price may have moved up more often than in the U.S. market. As a result, when looking at the difference, there will be an upward bias. This tick difference issue can be clearly seen in figure 2.

The mean difference for the overlap period is shown in table 1. The overall results show that the prices differences are well within the transactions costs of arbitrage: the mean of the absolute value of difference is $0.0991 while the overall average difference is 8.16 cents.

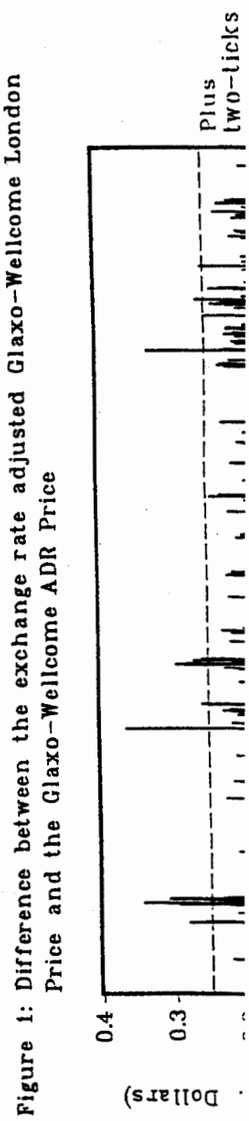

Figure 1: Difference between the exchange rate adjusted Glaxo-Wellcome London Price and the Glaxo-Wellcome ADR Price

[4]According to Citibank the cost of creating an ADR is 4 cents per share whereas the cost of cancelling an ADR is 5 cents per share. These costs can vary slightly depending upon the liquidity of the ADR. More specifically, the costs of creating or cancelling a Glaxo-Wellcome ADR are evidently between 4 and 5 cents per share. We thank Mike Chafkin, Vice President, Citibank, New York, NY, for this information.

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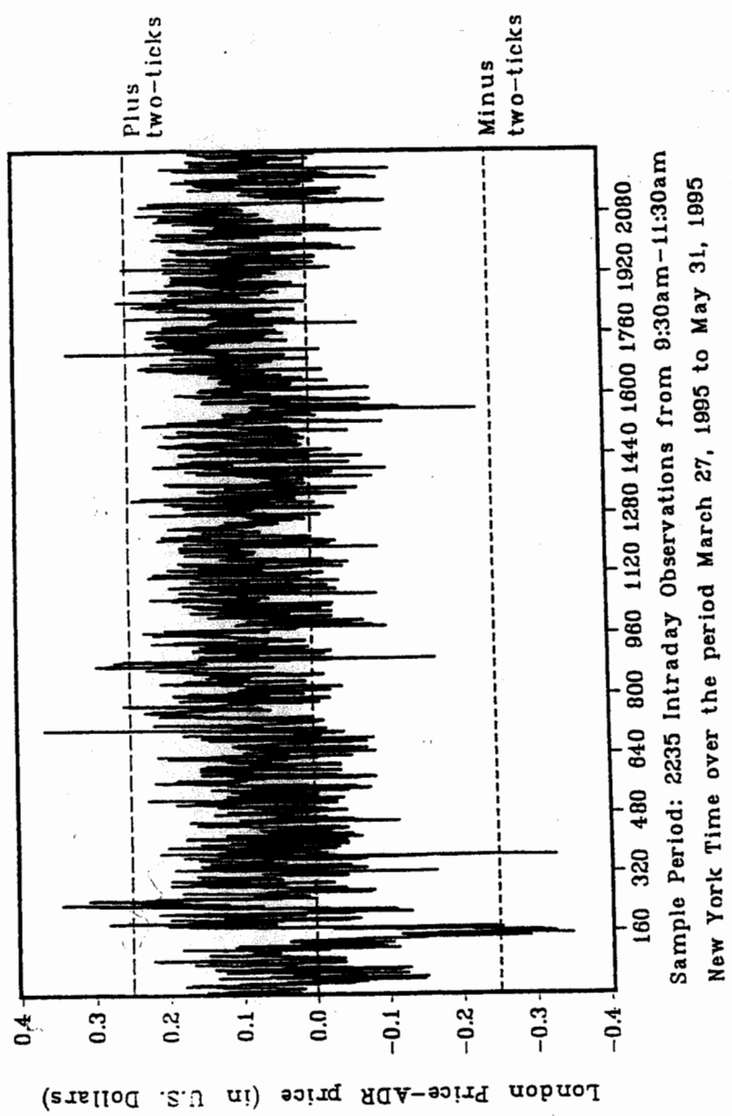

Figure 1: Difference between the exchange rate adjusted Glaxo-Wellcome London Price and the Glaxo-Wellcome ADR Price

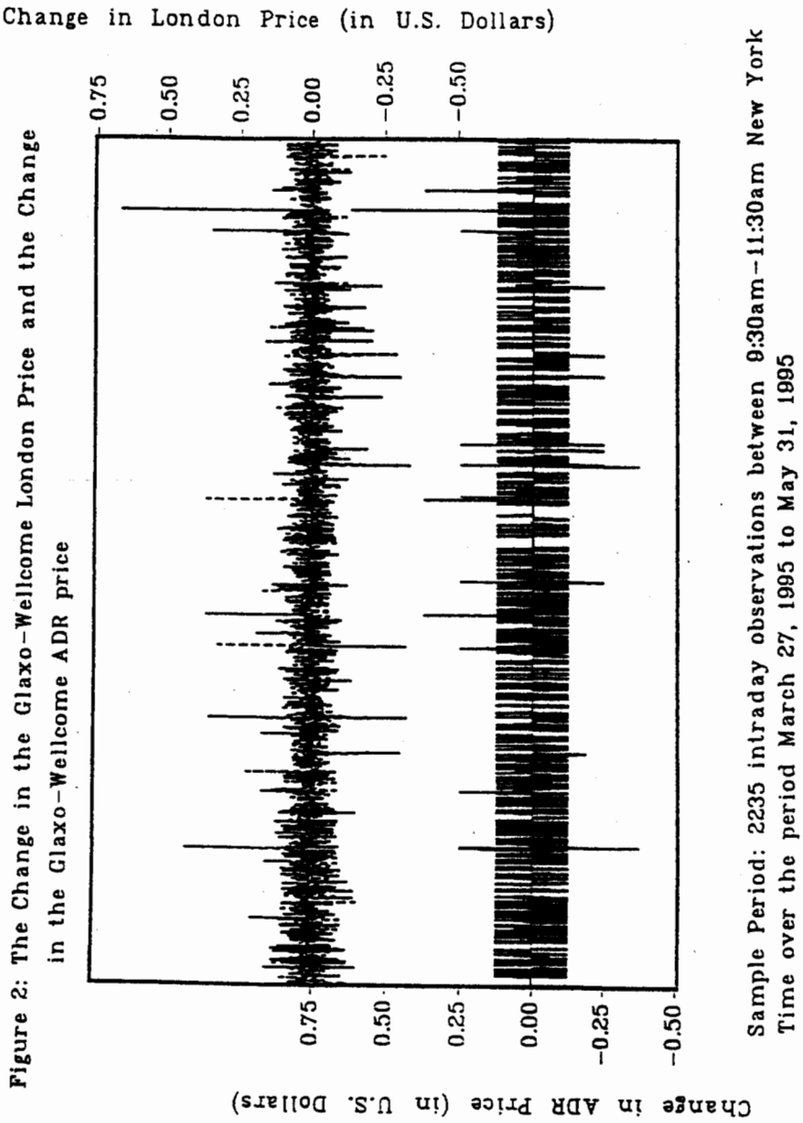

Figure 2: The Change in the Glaxo-Wellcome London Price and the Change in the Glaxo-Wellcome ADR price

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Table I. Sample Period Stat

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	ABS
Time (a.m.)	ABS
9:30-10:00	0.10
10:00-10:30	0.09
10:30-11:00	0.10
11:00-11:30	0.10
9:30-11:30	0.09

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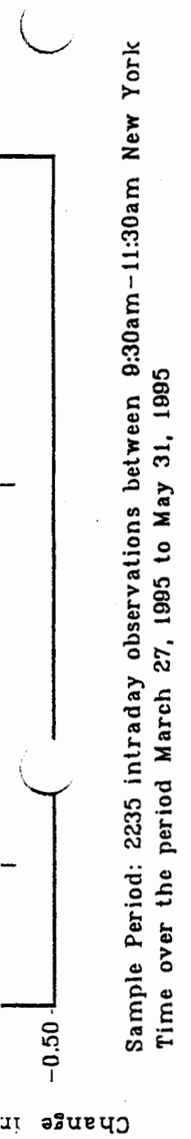

B. Intraday Price Patterns

Foster and Viswanathan (1990) predict an increase in volatility when liquidity and informed traders meet to trade in intervals such as when markets opens or just before they close. Empirically, the U-shape in volatility of U.S. stock returns has been documented by Wood et al. (1985), Harris (1986) and Jain and Joh (1988). Chang, Jain and Locke (1995) document a U-shape in the volatility of the S&P futures market when both the underlying and derivative asset are traded. Recent work by Kleidon and Werner (1995) and Chan et. al (1995) document the U-shape for return volatility in the United Kingdom. Intraday arbitrage between the U.K. and the U.S. requires participation in each market during the two hour period that the markets overlap. At the beginning of the overlap (9:30 EST), the U.S. market is opening. At the end of the overlap (11:30 EST), the British market is closing. Therefore, the arbitrageur faces higher volatility in the beginning and the ending of the overlap period. In effect, the arbitrageur encounters a U-shaped return volatility pattern.

Kleidon and Werner (1995) also document a U-shape pattern in the bid-ask spread for U.K. cross-listed firms in the United Kingdom. They find that cross-listed firms traded in the U.S. display their largest bid-ask spreads at the U.S. market opening. Therefore, as with return volatility, the arbitrageur faces a U-shape in the bid-ask spread during the overlap period. If the volatility patterns, bid-ask spreads and arbitrage are related, we expect to observe a similar pattern in the price differences. As volatility increases, the price differences between dually listed securities may increase as the high volatility makes arbitrage less certain. Larger bid-ask spreads may increase trading costs, causing increased price differences during these periods.

Table I. Sample Period Statistics for Cross-Market Differences (March 27-May 31,1995)

For each day in the sample period, statistics were calculated when a trade occurred in the U.S., London, and exchange market at the same minute. The first variable is the absolute value of the difference in the U.S. and London prices, where P_{Lt} is the London price at minute t, $Z_{US/Lt}$ is the dollar/pound exchange rate, and P_{US} is the trading price of the ADR in dollars. The second variable is the difference only.

$ABS = \cdot P_{Lt} Z_{US/Lt} - P_{US} \cdot$; $DIFF = P_{Lt} Z_{US/Lt} - P_{US}$

Time (a.m.)	ABS	Std Error	DIFF	Std Error	N
9:30-10:00	0.1031	0.0028	0.088	0.0037	508
10:00-10:30	0.091	0.0025	0.0767	0.0032	609
10:30-11:00	0.1011	0.0027	0.0781	0.0038	600
11:00-11:30	0.1023	0.0029	0.0851	0.0039	518
9:30-11:30	0.0991	0.0014	0.0816	0.0018	2235

Table 1 presents the differences for each half-hour of the overlap period. We find that the differences appear greater in the first and last of the four half hour increments (9:30am -10:00am and 11:00am -11:30am New York Time). Table II reports differences of means tests for each half hour time period. If there exist a U shape pattern in the differences, we should find a decrease in the middle of the overlap period relative to the beginning and the end. Therefore, we should find significantly different results when we examine the first to second and second to fourth periods or

when we examine the first to third and third to fourth periods. We should also expect that the first and fourth periods, and second and third periods should not be significantly different. We find that we can reject the null hypothesis of equality of means at the 5 percent significance level for the first to the second time period as well as the second to fourth using the Mann-Whitney non-parametric test. We could not reject, however, the first to the third time period nor the third to the fourth period.[5] Consistent with our U-shape hypothesis for the differences, we could not find that the first to the fourth periods nor the second to third periods were significantly different. Consequently, it seems that the familiar U-shape found in volatility studies also appears in the price differences of dual listed securities during the period of overlap between the two markets. This finding suggests that the difference between the two markets is higher in two situations: 1)when one market is open and another just begins to trade (from 9:30am -10:00am New York time, the London market is open and the New York begins to trade), 2) when both markets are open and one of the markets is about to close (from 11:00am -11:30am New York time, the London market is about to close and the New York is in the middle of the trading day). These results are consistent with the microstructure models of Admati and Pfleiderer (1988) and Foster and Viswanathan (1990).

Table II. Comparison of Cross-Market Differences Across Time Periods

The sample period is segmented according to four half-hour intervals for the two hour overlap between the U.S. and London Market. The variables ΔABS and ΔDIFF represent the differences in means between the time intervals. A Mann-Whitney nonparametric test is used to test the null hypothesis that the means are equal.

Time interval(s)	ΔABS	ΔDIFF
First - Second	0.0121*	0.0113*
Second - Third	-0.0101	-0.0014
Third - Fourth	-0.0012	-0.0070
First - Fourth	0.0008	0.0029
First - Third	0.0020	0.0099
Second - Forth	-0.0113*	-0.0854*

* Denotes Significance at the 5% Level

C. Contemporaneous vs. Non-Contemporaneous Data

The lack of empirical evidence from international markets using contemporaneous data can be attributed to a lack of intraday data. In many of these studies, daily data is assumed to proxy for the use of contemporaneous intraday data. For example, Hardouvelis et al. (1993) and Bonser-Neal et al (1990) examine the

[5]Although the distribution assumptions for the parametric test of difference in means are violated by the ABS variable, we can also reject the difference between the first and third half hour period for variable DIFF using the standard parametric test.

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Table III. Comparison of Means

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Daily Diff	0.(
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*Denotes significance at the 5%

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discount in country equity funds. When examining the discount/premium, market value is calculated in one market, while net-asset-value is calculated in the underlying foreign market, using non-contemporaneous daily data.

In examining arbitrage opportunities in the ADR market previous work by Maldonado and Saunders (1983) Kato et al. (1991), Wahab et al. (1992) and Park and Tavakkol (1994) have used non-contemporaneous daily data. Using our data set we compared the use of contemporaneous intraday data with non-contemporaneous daily data. Taking the daily closing prices in the London and New York markets for the period March 27, 1995, to May 31, 1995, yielded a total of 44 daily observations. Table III shows a comparison of means, both absolute(ABS) and relative values(DIFF), using intraday versus daily data. For the variable ABS (DIFF), the use of contemporaneous rather than non-contemporaneous data gives a 0.12 (3.07) cent difference. For the variable ABS, we cannot reject the null hypothesis that the means are equal whereas for the variable DIFF we can reject. Since arbitrage opportunity would exist when the ADR price is higher or lower than its underlying share, ABS is the correct variable to examine for arbitrage opportunities.[6] It appears from this sample that the economic conclusions regarding arbitrage opportunities are the same whether contemporaneous intraday data or non-contemporaneous daily data are used. This finding supports the common practice of using daily data as a proxy for contemporaneous intraday data.

Table III. Comparison of Means using Intraday vs. Daily Data

The variable ABS and Diff is the same as in Table I. The variable Daily Difference is computed using the non-contemporaneous closing trade on each day of the sample period.

Panel A. ABS

Variable	Mean	Minimum	Maximum	N
ABS	0.0991	0	0.3652	2235
Daily ABS	0.1003	0.0038	0.5137	44
Difference	-0.0012			

Panel B. Diff

Variable	Mean	Minimum	Maximum	N
Diff	0.0816	-0.3495	0.3652	2235
Daily Diff	0.0509	-0.2103	0.5137	44
Difference	0.0307*			

*Denotes significance at the 5% level, using the Mann-Whitney nonparametric test

V. CONCLUSION

International capital asset theory predicts that international dually listed securities should sell at the same price in the absence of transaction costs and restrictions to capital flows. This note has presented evidence that price differences are

[6]We thank an anomoyouns refreee for this point.

small when using contemporaneous intraday data. In addition, we find that during the overlap period, the mean price differences are higher in the first and last half-hours of the overlap. This result is consistent with the volatility of stock returns and bid-ask spreads being higher at the beginning and ending of the overlap period. Finally, we find evidence that supports the practice of using daily non-contemporaneous data as a proxy for contemporaneous intraday data.

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