Liquidity Commonality and Spillover in the US and Japanese Markets: An Intraday Analysis using the Exchange-Traded Funds

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Abstract

This article examines the intraday returns and liquidity patterns of the *Standard & Poor's Depositary Receipts* (SPY) and the *iShares Morgan Stanley Capital International Inc. (MSCI) Japan Index Fund* (EWJ). These exchange traded funds seemingly have very different holdings namely, US stocks and Japanese stocks. We make several observations that suggest some commonality in returns and liquidity of these apparently different assets. First, there are intraday, daily and monthly patterns in measures of liquidity for both funds. Second, the measures of liquidity are correlated across these two assets. Third, there is evidence of intraday spillover in mean, volatility and depth from the SPY to the EWJ but daily spillover is not observed. Our study extends two evolving strands of the literature: one strand that deals with the integration of world markets in terms of returns behavior; and the other strand suggests that liquidity may have a systematic, or market wide, component. Evidence documenting in this paper on the integration between the US and Japanese markets is more direct because contemporaneous trading prices for US (SPY) and Japanese (EWJ) indices are employed.

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1. Introduction

Liquidity and returns are two desirable characteristics of economic assets. These two attributes, in turn, have some influences on each other. Liquidity is partly affected by the nature of the asset (Glosten and Milgrom, 1985) and returns are, in part, affected by liquidity (Amihud and Mendelson, 1986). Liquidity may also be affected by dealers' inventory cost related to suboptimal diversification (Amihud and Mendelson, 1980; Grossman and Miller, 1988).

Until recently, the literature on liquidity of economic assets primarily focused on the cross-sectional aspects of liquidity of individual assets. The seminal work of Chordia, Roll and Subrahmanyam (2000) suggests that there are market wide co-movements in measures of liquidity. In a subsequent paper, they also documented day-of-the week patterns in market liquidity (Chordia, Roll and Subrahmanyam, 2001). The study of liquidity has also been extended to cross-market analysis of liquidities of different markets. As shown in Chordia, Sarkar and Subrahmanyam (2005), liquidities in stock and bond markets are driven by common factors.

Motivated by these studies, we examine the returns and liquidities of the *Standard & Poor's Depositary Receipts* (SPY) and the *iShares Morgan Stanley Capital International Inc. (MSCI) Japan Index Fund* (EWJ). Our motivation comes from the observation that these two assets, though they represent stocks in different markets, are traded in the same market place. And, since the two assets are traded in the same market, intuitively it is logical to perceive that returns of the two assets are related, as their prices respond to the same set of information. Furthermore, if the returns behaviors of US stocks and Japanese stocks are related, then there is an additional reason to expect a relationship between the liquidities of these assets. Liquidity of these two traded bundles of US stocks and Japanese stocks could then be driven by common factors.

Indeed, there is a considerable amount of evidence suggesting that the US and Japanese stock markets are affected by the same set of information; hence the two markets are integrated and their returns may be driven by common factors. Early works in the 1990s already provide evidence that the two markets are inter-related. For example, Campbell and Hamao (1992) conclude that the US and Japanese markets are integrated. Chan, Karolyi and Stulz (1992) find that the risk premium of US assets is significantly affected by foreign assets. In terms of information transmission, Lee (1995) provides evidence suggesting that US market contains information for predicting the Japanese market, but movements in the Japanese markets do not contribute to changes in US market. Craig, Dravid and Richardson (1995) find that Japanese

Nikkei index based futures traded in the US contain complete information about overnight returns in the Japanese market. Hamao, Masulis and Ng (1990) document volatility spillover from US market to Japan. Apart from integration between the US and Japanese markets, global market integration is also examined. Further evidence of global market integration is provided by Olienyk, Schwebach and Zumwalt (1999) and Pennathur, Delcoure and Anderson (2002). Both document that Non-US assets stocks behave similar to US stocks and do not provide significant additional diversification.

We extend these two strands of literature, namely, commonality of liquidity in the US market and integration of the US and Japanese markets. To achieve our goal, we employ intraday data to examine the liquidity and returns behavior of SPY and EWJ. These exchange traded funds (ETF) are traded actively and they have average daily trading volume of 40.6 million shares and 4.1 million shares respectively.

We contribute to the literature by providing further evidence of market integration between the US and Japanese market when the related assets are traded in the same market place, hence eliminating the problems of stale quotes and non-synchronous data. In Lin, Engle and Ito (1994), when close-to-open data in the US and open-to-close data in Japan are used, they find that the US market efficiently adjusts to information about the Japanese market. Hamao, Masulis and Ng (1990) also document similar results. Their findings also show that open-to-close returns exhibit some evidence of inefficiency of adjustment to foreign information. They suggest that this may be driven by stale quotes and non-synchronous data.

Our study extends these findings and overcomes the potential data problem. This is done by providing more direct evidence on market integration by using contemporaneous intraday trading prices for US (SPY) and Japanese (EWJ) indices. This point is further explained in Section 2 on the data environment. In particular, we find evidence of commonality in US and Japanese indices using intraday data as well as daily data. Intraday data shows spillover effects which may be an evidence of delayed correction or alternatively an indication of contagion. To resolve this issue, we examine daily close-to-close data and find no evidence of inefficiency.

We make several observations which suggest some commonality in the returns as well as liquidity of US assets (SPY) and Japanese assets (EWJ). First, there are intraday, daily and monthly patterns in measures of liquidity for both SPY and EWJ. Second, the measures of liquidity are correlated across these two assets. Third, there is evidence of spillover in mean, volatility and depth from SPY to EWJ. Fourth, close-to-close daily returns of SPY and EWJ are significantly correlated and there is no evidence of causality from one market to the other.

Our results about convergence to efficiency are similar in spirit to Chordia, Roll and Subrahmanyam (2005). They find that sophisticated investors react within sixty minutes to order imbalances and remove serial dependence over a daily horizon. The significant spillover results are also consistent with Bodurtha, Kim, and Lee (1995) that in the U.S. market, the prices of closed-end country funds are strongly affected by U.S. market movement.

This article proceeds as follows. Section 2 describes the data and definitions of variables used in the study. Section 3 describes the process of adjustments to the time series to filter out trends and seasonality. Section 4 discusses results of Granger causality analysis and provides evidence from daily data. Conclusion is contained in Section 5.

2. Data Environment

Using SPY and EWJ data provides a special opportunity to directly study the commonality of returns behavior across US and Japan. Earlier studies examining the commonality of US and Japanese markets were less direct because they were limited by the availability of data. Prior to the introduction of EWJ, the Japanese index and the US index would trade in the respective national markets during non-overlapping trading hours. This created several problems including issues related to fluctuating foreign exchange rates and non-synchronous trading. As described by Olienyk, Schwebach and Zumwalt (1999), the exchange traded funds such as SPY and EWJ help to address these issues effectively for two reasons. First, they are both traded contemporaneously in the US market. Second, the possibility of arbitrage through creation and redemption units guarantees that there are no premiums or discounts in traded prices relative to underlying net asset values.

Intraday data for the SPY and EWJ are collected from the TAQ (Trades and Automated Quotations) database of the New York Stock Exchange. The sample period spans from January 2, 2002 through December 31, 2004, covering two years of transaction data. To avoid the well known bias induced by auto-quotes, best bid or offer (BBO) quotes are used in the analysis. We only use the data obtained from the primary/listing exchange, the American Stock Exchange.

We use normal trading hours, 9:30 am to 4:00 pm EST. Apart from using BBO quotes, additional data filters are employed. In this window intraday returns are utilized in the sense that the first trade and overnight returns are not included. Besides, spreads greater than one dollar are excluded since these observations are likely to be key-punching errors. From the intraday data, we construct return series of fifteen minute interval.

We define the following variables for the SPY:

SPDS: Average of the quoted spread over a 15 minute interval for SPY;

PSPDS: Average of the percentage spread over a 15 minute interval for SPY;

DEPS: Average depth in dollars, measured as share depth multiplied by the ask/bid prices, with average taken over 15 minute intervals;

OIBS: Order imbalance, measured over 15 minute intervals as the ratio of the dollar value of shares bought net of dollar value of shares sold as a fraction of the total dollar value of trades[1];

RETS: Returns are measured over 15-minute intervals using the mid-quotes; and

VOLS: The absolute value of RETS is used as a proxy for volatility.

Using similar process as above, we define SPDJ, PSPDJ, DEPJ, OBIJ, RETJ and VOLJ for EWJ as measures of average spread, average percentage spread, average depth, average value of order imbalance, returns and volatility respectively. The sample is consisted of 19,176 observations.

Summary statistics on these measures of liquidity are presented in Table 1.

[Insert Table 1 About Here]

First we take a look at the percentage spread. Percentage spread of EWJ is 0.31% while SPY has a percentage spread of 0.06%. The median values of percentage spread for EWJ and SPY are 0.26% and 0.06% respectively. For each of the funds, the means and the medians are

[1] The well known Lee and Ready (1991) method with contemporaneous quotes was used to estimate the sign of the trades. In our large sample, this method of estimation is reliable as shown by Lee and Radhakrishna (2000), and Odders-White (2000).

not too far apart indicating that the distributions are not skewed. The percentage spread of EWJ is approximately five times in size as compared to SPY.

The order imbalance shows similar behavior. Mean absolute values of order imbalance shown in Table 1 are 0.64% for EWJ and 0.27% for SPY. The corresponding median values are 0.72% and 0.24% respectively. The distributions of absolute order imbalance are not skewed. The median order imbalance for EWJ is approximately three times the magnitude for SPY. In terms of depth, the median depth of SPY, $ 460,000, is approximately 1.6 times the size of the median depth, $ 280,000, for EWJ. The mean depth for SPY ($ 2.6 million) is seven times deeper than the mean depth for EWJ ($ 380,000).

Overall the measures of liquidity (percentage spread, order imbalance and depth) are three to seven times larger for SPY than for EWJ. This is consistent with the observation that SPY is more heavily traded than EWJ – the average daily trading volume of forty million shares for SPY and four million shares for EWJ during the sample period.

3. Adjusted Returns, Volatility and Liquidity

Our goal is to examine the relationship between liquidity of the SPY and EWJ. To ascertain that movements in liquidity are not caused by seasonality factors, all the time-series data on returns, volatility and liquidity for both SPY and EWJ are adjusted using several adjustment variables. We closely follow the adjustment methodology used in and Gallant, Rossi and Tauchen (1992) and Chordia, Sarkar and Subrahmanyam (2005). The series (returns, volatility and liquidity) are regressed on a set of adjustment variables using the following regression:

$$w = \chi^{'} \beta + \mu \, , \qquad (1)$$

where *w* is the series to be adjusted, x contains the adjustment variables.

The following adjustment variables are used:

1. Six time-of-the-day dummies for 9:30-9:59 and hourly thereafter till 14:59.
2. Four day-of-the-week dummies for Monday through Thursday.
3. Eleven monthly dummies for February through December.
4. A dummy for holidays to account for the effect on trading activity around holidays. Dummy is set to 1 before and after a holiday unless the holiday falls on a Friday or Monday. Holidays on Friday have a dummy set to 1 on Thursday. Holidays on Monday have a dummy set to 1 on Tuesday.
5. A time trend and a square of time trend. This removes any long term trends that we are not presently interested in.

A time series of returns, volatility, percentage spreads and depth are each regressed on the adjustment variables for SPY and for EWJ. The regression results are shown in Table 2.

[Insert Table 2 About Here]

Panel A of Table 2 shows the coefficients for spreads and depth. For SPY and for EWJ, the percentage spreads are the highest in the opening half hour. The spreads steadily decline during the trading day and are at the lowest level in the final trading hour of the day. This hour-of-the day regularity is observed at a 1% level of statistical significance for SPY and EWJ. For both assets, the percentage spreads are higher on Fridays than on weekdays at a 1% level of significance. Spreads for SPY are the lowest in January than the rest of the year. For EWJ the spreads are the lowest in March through June. The percentage spreads have a declining trend for EWJ and SPY over the sample period. Around holidays the spreads show a tendency to decline. This is counter-intuitive but the depth also decreases and may be, on balance, the liquidity decreases.

The depth is the highest in the opening hour for both SPY and EWJ. The depth for both SPY and EWJ is the lowest on Fridays and holidays. For SPY, the depth is higher in January and February than the rest of the year. The depth for EWJ is the higher in October to January and is lower in February to September. Over the sample period, SPY shows a declining trend for depth while EWJ shows increasing trend for depth.

Overall speaking, there is a strong evidence of seasonality in patterns of liquidity for SPY and EWJ. Liquidity is the highest during the beginning of the week than on Fridays. This finding is consistent with Chordia, Sarkar and Subrahmanyam (2005), who find a similar pattern in their study of the liquidities for stocks and bonds. Spreads are the lowest during the closing hour of the day while the depth is the highest in the opening hour for both funds.

Next we turn to the analysis of returns and volatility. Results for returns and volatility patterns are shown in Panel B of Table 2. The returns for SPY and EWJ do not show any seasonality by hour, day, month or holidays nor is there any trend over time. Volatility of both funds shows a familiar U shaped pattern through the day at 1% level of significance. Volatility is the highest in the opening half hour, and then it falls through the day before it rises in the last two hours of the day. Both funds have the lowest volatility in January, at 1% level, relative to the rest of the year. Volatility is lower on days around holidays relative to regular trading days. Over the sample period, the volatility has a declining trend for both funds.

In summary, volatility and liquidity show common seasonal patterns for SPY and EWJ.

As common seasonal patterns exist for volatility and liquidity of the SPY and EWJ, it will be interesting to examine the relationship among returns, volatility and liquidity of the two assets. In Table 3, the correlation matrix of returns, volatility and liquidity for SPY and EWJ is shown.

[Insert Table 3 About Here]

All measures have a significant positive across-fund-correlation with respective measures at the 1% level. For example, spreads for SPY (PSPDS) have a positive correlation of 26% with spreads of EWJ (PSPDJ). This level of positive correlation is comparable to that (31% correlation) documented in Chordia, Sarkar and Subramanyam (2005) for stock and bonds. Returns and volatility of the two funds are also positively correlated. The respective correlation between returns of SPY (RETS) and returns of the EWJ (RETJ) is 28%, and the correlation between volatility of the two funds, VOLS (volatility of SPY) and VOLJ (volatility of EWJ) is 16%. The order imbalance and depths each have a correlation of approximately 12% across the two funds.

Volatility in either fund shows a strong correlation with spreads in both funds. Both across-fund-correlations between volatility and spreads are approximately 13% each (14% for VOLJ and PSPDS, and 12% for VOLS and PSPDJ). Volatility in SPY (VOLS) has a correlation of 40% with spreads (PSPDS) while for EWJ the similar correlation (VOLJ and PSPDJ) is 17%. Volatility of SPY has a correlation of -5% with the depth of SPY (VOLS and DEPS), while that of EWJ is -9% (VOLJ and DEPJ). This indicates that the greater the depth of an asset, return of the asset will be less volatile.

The findings in Table 3 suggest that volatility of each asset seems to be strongly contemporaneously related to its own liquidity, as well as liquidity of the other fund. This result is similar to the finding documented in Chordia, Sarkar, and Subrahmanyam (2005) under the context of stocks and bonds. To summarize conclusions reached from evidenced documented in Tables 2 and 3, returns, volatility and liquidity of SPY and EWJ are driven by a common factor and volatility seems to play a role in driving liquidity of both the funds.

4. Granger Causality and Contemporaneous Correlations

Arrival of new information, consumption needs and rebalancing motives may lead to unanticipated shocks to liquidity as well as to returns and volatility. Commonality of factors driving returns behavior and liquidity across SPY and EWJ was explored with estimates of innovations using Vector Autoregression (VAR) with liquidity, returns and volatility of the following form:

$$\boldsymbol{Y} = \boldsymbol{A} + \boldsymbol{B}\,\boldsymbol{Y} + \varepsilon, \qquad (2)$$

in which $\boldsymbol{Y}$ is the vector containing the endogenous variables, $\boldsymbol{A}$ is the vector of constant terms and $\boldsymbol{B}$ is the matrix capturing lag coefficients of the endogenous variables, and error terms are contained in ε.

The VAR was estimated on OIBJ, OIBS, VOLJ, VOLS, RETJ, RETS, DEPJ, DEPS, PSPDJ, PSPDS as endogenous variables with 19,176 observations, two lags and a constant term. Correlations of the VAR innovations are shown in Panel A of Table 4.

[Insert Table 4 About Here]

Generally speaking, for both SPY and EWJ, the innovations to spreads are correlated negatively with returns, negatively with imbalances, positively with volatility and positively with depth. Across the two assets, positive correlations of 29% are observed between innovations to returns in EWJ and SPY (RETS and RETJ). Similarly, positive correlation of 13% of innovations to volatilities between the two markets (VOLS and VOLJ) is observed. For spreads and imbalances, the cross-market correlations of innovations is 6% and 8%, respectively. Evidence here suggests the existence of common influence in contemporaneous behavior of returns and liquidity of the EWJ and SPY, hence the US and Japanese assets are affected by common factors.

To formally test for causal effects among the liquidity variables, we employ pair-wise Granger causality tests using White's (1980) correction for heteroskedasticity in the estimation. Results of the Granger causality tests are presented in Panel B of Table 4. The cells in Panel B of the Table show the F-statistics for the null hypothesis that the column variable does not cause the row variable. For example, the cell in the first column second row reads a value of 1.62, which is the F-statistic for testing the null hypothesis that OIBJ does not Granger-cause OIBS.

For each fund, volatility causes spreads and returns cause order imbalance. Across the funds there is no evidence of causality for spreads or imbalances. There is strong evidence of spillover for returns, volatility and depth from SPY to EWJ with F-statistics of 48.62, 5.05 and 4.81 respectively, and all the statistics are significant at the 1% level. The reverse spillovers from EWJ to SPY for mean, volatility and depth, however, are not significant.

This observation is intuitively appealing. Since the SPY and the EWJ are traded at the same market, they should be affected by the same market wide information, which is specific to the US market in this case. The finding of spillovers for returns, volatility and depth from SPY to EWJ is consistent with this hypothesis. However, since the EWJ's underlying assets are Japanese stocks, the EWJ should also reacts to information specific to the Japanese market. As the Japanese market is closed when the EWJ is being traded, impacts from the US market wide information dominate the price behaviors of the EWJ. As a result, the returns, volatility and depth of EWJ do not Granger-cause those of the SPY.

Panel C of Table 4 provides information about the direction of the Granger causality in addition to the statistical significance. Similar to the presentation in Panel C of the same table, we present the sum of coefficients and test if sum of the coefficients equals to zero or not. As seen from the significances of the sum of coefficients in this Panel, changes in returns, volatility and depth of SPY are followed in the same direction by corresponding changes in EWJ. But the reverse is not necessarily true. For changes in returns and volatility of the EWJ, the impact on the corresponding changes in return and volatility of the SPY are not significant. This is consistent with the findings in Table B. However, when we consider causality of depth of EWJ on the depth of SPY, the test statistic is marginally significant at 5% with a sum of the coefficients equal to 0.006. We would consider this as a finding of no causality of EWJ depth to SPY depth, given the low economic significance of the sum of coefficients and the low significance level for a sample size of 19,176 observations.[2]

Overall, there is evidence of commonality between returns, volatility and liquidity of SPY and EWJ. Furthermore, returns, volatility and depth of SPY lead the innovations in returns,

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[2] According to Lindley (1957), lower significance levels should be required for large samples, otherwise spurious significance results may be obtained due to large sample. In the literature, this is known as the Lindley's paradox.

volatility and depth of EWJ. The results here are also consistent with Bodurtha, Kim, and Lee (1995) that in the U.S. market, the prices of closed-end country funds are strongly affected by U.S. market movement. Stock price movements are affected by their trading location, suggesting that country-specific investment influences the stock prices (See, Froot and Dabora, 1999; Chan, Hameed, and Lau, 2003).

Our finding of commonality and spillover across SPY to EWJ is consistent with inefficiency such as contagion or alternatively indicates efficient transmission of information with some small delay. Indeed, Chordia, Roll and Subrahmanyam (2005) find convergence to efficient prices with sixty minutes of order imbalance. To shed more light on this issue, we examine daily close-to-close data for SPY and EWJ. We find that the daily returns are not serially auto-correlated. This suggests that each fund is priced efficiently. Furthermore, the cross-correlation across funds is significant with a coefficient of 0.57. This suggests that the intraday correlation across funds is not driven by temporary herding. Furthermore, there is no evidence of spillover across funds in either direction in daily data. This suggests that intraday spillover is not inefficiency but a process of adjustment that gets completed within a trading session.

5. Concluding Remarks

We examine the relationship between liquidity, returns and volatility of US assets and Japanese assets as proxied by SPY and EWJ. We make several important observations. First, there are common patterns in liquidity and volatility of SPY and EWJ. Second, measures of liquidity are correlated across SPY and EWJ. Third, mean, volatility and depth spill over from SPY to EWJ but not the other way around. And fourth, close-to-close daily returns show evidence of significant cross-correlation without any evidence of spillover effects and, furthermore, the funds are not serially auto-correlated.

Our study extends two evolving strands of literature. One strand deals with global market integration and the second one deals with commonality of liquidity across traded assets. Evidence in this paper corroborates more directly than prior evidence of commonality of returns in US and Japanese indices because contemporaneous trading data are employed. The significant results of spillovers from the SPY to EWJ also indicate that country-specific investment sentiment influences the stock prices.

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Table 1

Summary Statistics of Level of liquidity for SPY and EWJ

Liquidity estimates are based on averages over 15-minute intervals for SPY and EWJ. Sample period spans January 2, 2002-December 31, 2004. Sample size is 19176 observations.

Panel A: Bid-ask Spread and Order Imbalance				
	Mean	Median	Standard deviation	Coefficient of Variation
SPDJ	0.025	0.021	0.013	50.386
PSPDJ (%)	0.307	0.260	0.176	57.094
AOIBJ (%)	0.642	0.717	0.330	51.416
SPDS	0.060	0.057	0.024	40.448
PSPDS (%)	0.060	0.055	0.029	49.357
AOIBS (%)	0.274	0.242	0.191	69.754
Panel B: Market Depth (US$ millions)				
	Mean	Median	Standard Deviation	Coefficient of Variation
DEPJ	0.380	0.283	0.340	89.30
DEPS	2.602	0.464	5.114	196.54

SPDS is the average of the quoted spread over a 15 minute interval for SPY, PSPDS is the average of the percentage spread over a 15 minute interval for SPY; DEPS is the average depth in dollars for SPY is measured as share depth multiplied by the ask/bid prices. The average is taken over 15 minute intervals. OIBS is the order imbalance for SPY is measured over 15 minute intervals as a ratio of the dollar value of shares bought net of dollar value of shares sold as a fraction of the total dollar value of trades, while AOIBS is the absolute value of OIBS. Similarly, SPDJ is the average of the quoted spread for EWJ, PSPDJ is the average of the percentage spread for EWJ; DEPJ is the average depth in dollars for EWJ, OIBJ is the order imbalance for the EWJ and AOIBJ is the absolute value of OIBJ.

Table 2

Adjustment regression for EWJ and SPY

Panel A: Quoted Spread and Depth				
	PSPDJ	DEPJ	PSPDS	DEPS
Intercept	0.442**	-0.007	0.073**	14.86**
Hour of the day (EST)				
9:30 – 9:59	0.060**	0.051**	0.013**	0.681**
10:00 – 10:59	0.027**	0.043**	0.009**	0.303**
11:00 – 11:59	0.015**	0.022**	0.001	-0.196**
12:00 – 12:59	0.012**	0.011	-0.002*	-0.334**
13:00 – 13:59	0.009*	-0.004	-0.004*	-0.340**
14:00 – 14:59	0.007	0.020*	0.001	-0.097
Day of the week				
Monday	-0.011**	0.024**	-0.003**	0.042
Tuesday	-0.008*	0.014*	-0.002**	0.193**
Wednesday	-0.004	0.025**	-0.000	0.224**
Thursday	-0.013**	0.007	-0.000	0.070
Holiday	-0.022**	-0.054**	-0.005**	-0.128**
Month				
February	0.018**	-0.068**	0.007**	1.415**
March	-0.016**	-0.090**	0.005**	0.142
April	-0.020**	-0.042**	0.001	-0.515**
May	-0.027**	-0.081**	0.003**	-2.342**
June	-0.020**	-0.074**	0.009**	-1.304**
July	0.048**	-0.078**	0.029**	-1.214**
August	0.048**	-0.129**	0.018**	-1.744**
September	0.063**	-0.089**	0.013**	-1.998**
October	0.100**	0.018	0.020**	-1.828**
November	0.066**	0.006	0.013**	-2.202**
December	0.046**	-0.002	0.010**	-2.176**
Trend				
Time (by day)	-0.000**	0.002**	-0.000**	-0.061**
Square of Time	0.000	-0.000**	-0.000**	0.000**

*significant at the 5% level, **significant at the 1% level.

Table 2 (Continued)

Panel B: Returns and Volatility				
	RETJ	VOLJ	RETS	VOLS
Intercept	-0.006	0.137**	0.073	0.168**
Hour of the day				
9:30 – 9:59	-0.000	0.049**	-0.000	0.024**
10:00 – 10:59	-0.000	0.009**	-0.000	0.022**
11:00 – 11:59	-0.000	-0.012**	-0.000	-0.026**
12:00 – 12:59	-0.000	-0.027**	-0.000	-0.036**
13:00 – 13:59	-0.000	-0.031**	-0.000	-0.040**
14:00 – 14:59	-0.000	-0.023**	-0.000	-0.012**
Day of the week				
Monday	0.000	0.000	0.000	-0.005
Tuesday	0.000	0.003	-0.000	-0.001
Wednesday	0.000	0.004	0.000	0.001
Thursday	0.000	0.004	0.000	0.005
Holiday	0.004	-0.022**	0.008	-0.018**
Month				
February	-0.002	-0.002	0.001	0.018**
March	0.011	-0.002	0.009	0.022**
April	-0.001	-0.011*	-0.001	0.012**
May	0.010	-0.000	0.006	0.015**
June	0.003	0.006	0.003	0.028**
July	-0.003	0.027**	-0.002	0.084**
August	0.006	0.007	0.008	0.047**
September	0.001	0.017**	0.001	0.040**
October	0.007	0.017**	0.008	0.067**
November	0.005	0.003**	0.008	0.034**
December	0.007	-0.010*	0.006	0.024**
Trend				
Time (by day)	0.000	-0.000**	0.000	-0.000**
Square of Time	-0.000	0.000**	-0.000	0.000**

Note: The suffixes J and S refer to EWJ and SPY, respectively.

RET is return and VOL is volatility. RET is measured over 15 minute interval using mid-quotes. VOL is proxied by absolute value of RET. PSPD is percentage spread and DEP is depth as defined more fully in Table 1. The sample spans January 2, 2004-December 31, 2004 and consists of 19,176 observations.

*significant at the 5% level.
**significant at the 1% level.

Table 3

Correlations in EWJ and SPY market liquidity

	PSPDJ	OIBJ	DEPJ	VOLJ	RETJ	PSPDS	OIBS	DEPS	VOLS	RETS
PSPDJ	1.00									
OIBJ	-0.11**	1.00								
DEPJ	-0.05**	0.03**	1.00							
VOLJ	0.17**	-0.04**	-0.07**	1.00						
RETJ	-0.00	0.31**	-0.00	-0.01	1.00					
PSPDS	0.26**	-0.09**	-0.19**	0.14**	-0.01*	1.00				
OIBS	-0.02**	0.11**	0.01	-0.02*	0.18**	-0.02**	1.00			
DEPS	-0.02**	0.01	0.12**	0.03**	-0.01	-0.11**	-0.00	1.00		
VOLS	0.12**	-0.05**	-0.09**	0.16**	-0.01	0.40**	-0.00	-0.05**	1.00	
RETS	-0.00	0.11**	0.00	0.00	0.28**	-0.00	0.37**	-0.00**	0.20*	1.00

The suffixes J and S refer to EWJ and SPY, respectively.

The table presents correlations of liquidity, returns and volatility for SPY and EWJ. All variables are adjusted for seasonality and trend as described in Table 2. The variables are defined as follows: RET is return and VOL is volatility. RET is measured over 15 minute interval using mid-quotes. VOL is proxied by absolute value of RET. PSPD, OIB, DEP are percentage spread, order imbalance and depth as defined in more fully Table 1. The sample spans January 2, 2004-December 31, 2004 and consists of 19,176 observations.
*significant at the 5% level, **significant at the 1% level.

Table 4

Granger causality and contemporaneous correlations between VAR innovations

Panel A: Correlations between VAR innovations										
	OIBJ	OIBS	VOLJ	VOLS	RETJ	RETS	DEPJ	DEPS	PSPDJ	PSPDS
OIBJ	1.00									
OIBS	**0.08****	1.00								
VOLJ	-0.02**	-0.02*	1.00							
VOLS	-0.02**	-0.00	**0.13****	1.00						
RETJ	0.29**	016**	-0.01	-0.02**	1.00					
RETS	0.12**	0.37**	-0.01	0.01	**0.29****	1.00				
DEPJ	-0.02**	-0.00	-0.03*	-0.005	0.02*	0.01	1.00			
DEPS	-0.02*	-0.00**	0.04**	0.11**	-0.02**	-0.01	**0.00**	1.00		
PSPDJ	-0.04**	-0.01	0.12**	0.04**	0.01	-0.02*	0.17**	0.04**	1.00	
PSPDS	-0.03**	-0.04**	0.08**	0.23**	-0.04**	-0.07**	-0.01	0.31**	**0.06****	1.00

Table 4 continued

Panel B: Joint *F*-statistics from Granger causality tests with heteroskedasticity-constant covariance matrix. Null hypothesis: Column variable does not Granger-cause row variable										
	OIBJ	OIBS	VOLJ	VOLS	RETJ	RETS	DEPJ	DEPS	PSPDJ	PSPDS
OIBJ	*48.72***	**1.52**	1.05	2.05*	6.11**	23.25**	1.66	0.95	2.36**	0.62
OIBS	**1.62**	*18.52***	1.49	0.86	1.79	8.39**	1.25	1.00	1.49	0.64
VOLJ	0.68	0.78	*15.02***	**5.05****	0.75	1.15	2.70**	3.16**	1.92*	0.68
VOLS	0.66	1.37	**1.33**	*3.24***	0.61	1.00	1.18	2.33*	0.60	17.82**
RETJ	3.04**	1.31	0.91	0.90	*13.03***	**48.62****	1.92*	1.56	1.64	1.26
RETS	0.57	0.79	1.19	1.76*	**1.46**	*0.13*	1.64	0.75	0.92	1.21
DEPJ	1.72	0.95	1.23	1.03	3.74**	0.70	*106.2***	**4.81****	8.77**	1.61
DEPS	1.92*	1.15	0.32	1.32	0.57	1.04	**2.14***	*203.2***	0.49	4.66**
PSPDJ	2.12**	1.23	3.66**	1.92*	1.13	1.07	12.32**	1.09	*509.2***	**1.51**
PSPDS	1.49	0.93	1.02	4.30**	1.17	1.66	1.01	4.39**	**1.35**	*962.2***

Table 4 Continued

Panel C: Sum of lagged coefficients Null hypothesis: Column variable does not Granger-cause row variable										
	OIBJ	OIBS	VOLJ	VOLS	RETJ	RETS	DEPJ	DEPS	PSPDJ	PSPDS
OIBJ	*0.406***	**0.041**	-0.011	-0.058*	-0.053	0.267**	0.030**	0.004	-0.055**	-0.006
OIBS	**0.039***	*0.259***	0.029	-0.007	-0.064*	0.039	0.006	-0.004	-0.030*	0.017
VOLJ	-0.000	-0.043*	*0.265***	**0.141****	-0.043	0.021	-0.032**	0.038**	0.056**	0.019
VOLS	-0.023	-0.042*	**-0.006**	*0.177***	0.034	-0.026	-0.011	-0.025**	0.018	0.281**
RETJ	0.039	0.050*	-0.015	-0.019	*-0.297***	**0.566****	-0.022*	-0.001	-0.018	0.015
RETS	-0.001	-0.027	0.023	0.043	**-0.023**	*0.022*	-0.005	0.011	-0.015	0.056*
DEPJ	0.036*	-0.010	0.031*	-0.011	0.082**	-0.033	*0.767***	**0.024****	-0.069**	-0.025**
DEPS	-0.001	0.016	0.001	0.009	-0.006	-0.006	**0.006***	*0.965***	0.005	-0.023**
PSPDJ	-0.062**	-0.035*	0.043*	0.037	0.028	-0.023	-0.075**	0.008	*0.749***	**0.033***
PSPDS	-0.025*	0.010	-0.024*	0.073**	0.024	-0.064**	0.004	-0.019**	**0.019***	*0.911***

The suffixes J and S refer to EWJ and SPY, respectively.

The results from VAR with OIB, VOL, RET, DEP, PSPD for both SPY and EWJ are presented in this table. The estimation is done with two lags and a constant using 19,176 observations. Panel A presents correlations between innovations of VAR. Panel B presents F-statistics for pair-wise Granger causality tests. Panel C presents the sum of the lagged coefficients with the null hypothesis that the sum is zero. This provides the sign of Granger causality in addition to statistical significance for causality.

The variables are defined more fully in Table 1.

*significant at the 5% level.

**significant at the 1% level.