Premiums-Discounts and Exchange Traded Funds

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Even though Exchange Traded Funds (ETFs) resemble closed-end mutual funds in many respects, ETFs have the unique feature that additional shares can be created and redeemed by certain institutional investors. The creation–redemption process allows ETF shares to trade continuously during the day as in any publicly traded company at prices determined by supply and demand rather than at the calculated net asset value. This article investigates the extent and properties of the resulting premiums (discounts) of ETFs from their fair market value.

Traditional measures of premiums (discounts) for ETFs are misleading because the net asset value is not accurately represented and/or because the price of the fund is not accurately recorded. This article incorporates these features into an errors-in-variables model. The model measures the standard deviation of the remaining pricing errors and investigates the time variation in this standard deviation.

This article uses data for domestic as well as international ETFs from an end-of-day perspective and from a minute-by-minute intra-daily framework. The overall finding is that, once mismatches in timing are accounted for, the premiums (discounts) for the domestic ETFs are generally small and highly transient, typically lasting only several minutes. The standard deviation of the premiums (discounts) is 15 basis points on average across all domestic ETFs. This standard deviation is substantially smaller than the bid-ask spread.

For international ETFs, premiums (discounts) are much larger and more persistent, frequently lasting several days. An explanation for this difference may rest with the higher cost of creation and redemption for the international products. The bid-ask spreads are also much wider but are comparable with the standard deviation of the premiums. Nonetheless, when compared with closed-end funds where there are no opportunities for creation or redemption, the ETFs have smaller and less persistent premiums (discounts).

INTRODUCTION

Although in some respects, exchange traded funds (ETFs) do resemble conventional index mutual funds, they also differ in two important ways. First, shares of ETFs can be created by some institutional investors who deposit prespecified baskets of shares of the companies present in the fund portfolio in return for shares in the fund. Second, as a result, ETFs shares trade continuously during the day as in any publicly traded company at prices determined by supply and demand rather than at the calculated net asset value (NAV).

As closed-end mutual funds exhibit large and persistent premiums, it is natural to ask whether ETFs also exhibit such premiums. The creation and redemption process for ETFs allows arbitrage opportunities to be exploited profitably whenever the share prices deviate from the NAV of the underlying portfolio. If the creation–redemption process works efficiently, ETF shares should not trade at significant premiums or discounts from the fair value of the portfolio.

The details of the creation–redemption process differ substantially across funds. For the domestic funds, the order to create or redeem is given sometime during the trading day and is exercised at the end of the day. For a creation order, shares of stock and cash must be delivered within a certain number of days, and the ETF shares become available at the end of the day. If there is a discrepancy between the estimated cash account and the closing cash account, this adjustment is made at the settlement. For international funds, the process can be far more complex. In some countries there are substantial taxes that must be paid when shares are transferred. In others, there are prohibitions on transactions made by foreigners so that the account is settled entirely in cash with the trustee acquiring the shares rather than the creator. The delivery period is longer and there is more price risk in assembling the package. The ability to hedge such risks is also much reduced. Altogether, these features make the arbitrage mechanism more complicated, risky and costly for the international transactions than for the domestic. Consequently, one might not be surprised if the pricing is not as fast or accurate in these situations.[1]

This article examines the end-of-day and intra-daily premiums for a collection of 21 domestic and 16 international ETFs, and measures both the magnitude and the persistence of the premiums.

LITERATURE REVIEW

As traditional mutual funds guarantee investors the ability to buy or sell shares in the fund at the closing NAV, investors who notice any discrepancy between the measured NAV and the fair market value have the opportunity to buy at a discount and sell at a premium. The importance of this effect has been documented by Goetzmann et al. [2001]; Chalmers et al. [2001]; and Boudoukh et al. [2002]. The highly profitable trading strategies proposed in these articles are basically conditional schemes as they examine the relation between the official NAV and current market variables in choosing when to trade. Various solutions have been proposed to prevent such arbitrage trading; one is the ETF solution that allows trading at a market price that can differ from the measured NAV.

However, premiums that arise because of inaccurate recording of the NAV must be treated very differently from premiums that arise because of trading at bad prices. In the closed-end pricing literature, early attempts to explain the behavior of fund discounts and premiums focused on the mismeasurement of reported NAVs. There is also a vast literature examining the comovements of pairs of asset prices, leading to measures of correlation and predictability. The literature that examines comovements of prices of essentially the same asset in different markets or in different forms of security is of particular interest here. Two widely studied examples of the same asset trading in different forms at different prices are closed-end mutual funds and futures markets.

In the early mismeasurement literature, three potential explanations were mentioned: agency costs (managerial ability is not reflected in the NAV), tax liabilities (unrealized capital appreciation is not captured by the reported NAV) and illiquidity of assets (assets that have trading restrictions may be overvalued in the NAV calculation). See Boudreaux [1973]; Rosenfeldt and Tuttle [1973]; and Malkiel [1977]. Today the existence of such premiums and discounts is still viewed as a market anomaly in Thaler et al. [1993].

The cash market index futures market literature looks at how quickly the cash market responds to market-wide information that has already been transmitted into futures prices. See MacKinlay and Ramaswamy [1988]; Stoll and Whaley [1990]; Atchinson et al. [1992] and Chan [1992]. Ahn et al. [2002] compare microstructure-based explanations (i.e., stale prices) to partial adjustment-based explanation for portfolio autocorrelations. They conclude that their findings can "most easily be associated" with market microstructure-based explanations.

The source of much of the microstructure noise documented above is the observation that the closing transaction price does not contain all the information on end-of-period value. When there is such staleness in the price, portfolio autocorrelations may arise. Deviation of the observed price from the true price may arise from the random bouncing of transaction prices between bid and ask levels. Roll [1984] shows that the bid-ask price bounce induces negative first-order autocorrelation in observed price changes even when price innovations are serially independent. Scholes and Williams [1977] consider a situation where infrequent trading takes place and provide consistent estimates in such "errors-in-variables" scenarios. For other models of how nonsynchronous trading can explain portfolio autocorrelations, see Cohen et al. [1986]; Atchinson et al. [1987]; Lo and MacKinlay [1988, 1990]; Boudoukh et al. [1994]; and Kadlec and Patterson [1999]. The general finding is that nonsynchronous trading can, at best, partly explain portfolio autocorrelations. An alternative to nonsynchronous trading models assumes partial adjustment or slow adjustment to market-wide information. See Holden and Subrahmanyan [1992]; Brennan et al. [1993]; Foster and Vishwanathan [1993]; Badrinath et al. [1995]; Klibanoff et al. [1998]; Chordia and Swaminathan [2000]; Llorente et al. [2002].

These studies, however, do not use conditioning information and do not assume cointegration.[2] As the basis in these studies closely resembles the ETF premium, especially after corrections for dividends and interest rates, cointegration should be considered as an important part of the analysis. Cointegration is a powerful statistical concept that says that, eventually, deviations between two prices must be corrected even when each of the prices is integrated and each may be very close to a random walk.

DATA AND DESCRIPTIVE STATISTICS

This article examines the premiums of 21 Domestic and 16 International ETFs. The time period covered by the intra-daily statistics runs from April through September 2000 whereas the end-of-day time period has a variable start date depending on the launch date of a particular ETF and ending in September 2000. For the end-of-day analysis, the premium is measured by the percentage difference between the average of the closing bid and ask prices ("midquote") on the ETF and the NAV. For the intra-daily analysis, the premium is measured every minute as the percentage difference between the midquote and the IOPV (indicative optimized portfolio value). IOPV is an official estimate of the value of the portfolio posted every 15 seconds.

The 21 domestic ETFs are divided into three categories: (1) ETFs that close at 4:15 PM and have futures markets for the underlying indexes; (2) ETFs that close at 4:15 PM but do not have futures markets; and (3) ETFs that close at 4:00 PM and do not have futures markets. The eight ETFs considered under category 1 represent broad market indexes that have index futures markets. Three of the four ETFs considered under category 2 represent Dow Jones subsectors with the fourth one representing the S&P SmallCap. The nine ETFs considered under category 3 all represent different subsectors of S&P.

Exhibit 1 shows the end-of-day and intra-daily average premium and standard deviation of premium for the three groups of domestic funds. The standard deviation of last trade-based premium and end-of-day bid-ask spread are also reported.[3] Exhibit 2 shows the same end-of-day and intra-daily statistics for the international funds.

Exhibit 1 shows that, for domestic funds, the end-of-day average premium is 1.1 basis points (bps) with a range from −0.1 (IWM: Russell 2000) bps to 4.6 bps (DIA: DJIA). The average standard deviation of premium is 18.3 bps with a range from 10.1 bps (IYF: DJ Financial) to 34 bps (QQQ: Nasdaq 100). The average standard deviation of last trade-based premium is 42.1 bps with a range from 17.6 bps (IVV: S&P500) to 142 bps (IYV: DJ Internet). In each instance, the standard deviation of last trade-based premium is larger than the standard deviation of premium. The average bid-ask spread (log of Ask/Bid) is 37.7 bps with a range from 8.7 bps (SPY: S&P500) to 79.5 bps (XLB: S&P Basic Industries).

In general, the international funds show larger end-of-day values for each of the statistics. For all international funds except one (EWO: MSCI Austria), the standard deviation of last trade-based premium is greater than the standard deviation of premium. In several cases the differences are very large suggesting that the last trade may be at a price far from the closing NAV when the fund is infrequently traded. According to Exhibit 2, the international funds often have quite large and positive premiums. EWO (MSCI Austria) and EWN (MSCI Netherlands) are exceptions; they have mean discounts: 2 and 6 bps, respectively. Even with these negative values, the average premium for the 16 products is 34.8 bps. These funds have standard deviations of premium that range from 54 bps (EZU: MSCI EMU) to 117 bps (EWW: MSCI Mexico) with an average of 78 bps. The standard deviation of last trade-based premium ranges from 59 bps (EZU) to 211 bps (EWZ: MSCI Brazil) with an average of 100.8 bps. The average end-of-day bid-ask spread is 112.3 bps. While these are larger than for the domestic funds, they are again rather small compared with many traditional costs of trading. This is especially clear when compared with other ways to invest internationally such as closed-end funds that often have persistent discounts of 10 or 20%, or direct investment with its myriad costs and risks.

For domestic funds, the intra-daily average premium is 0.25 bps with an average standard deviation of 11.8 bps. See the bottom row of Exhibit 1. For the international funds, the similar numbers are 23.7 bps and 64.8 bps, respectively. See the bottom row of Exhibit 2. Thus, in terms of the simple measured premiums, domestic funds show small divergences between the prices of the funds and their estimated NAVs. The premiums for the international funds, on the other hand, exhibit some positive bias, which is, at least in part, due to the greater cost and risk in the creation and redemption of the international funds. Nonetheless, both the domestic and international ETFs exhibit smaller standard deviations within the day than at the end of the day.

EXHIBIT 1
Descriptive Statistics: Domestic ETFs

		End-of-Day					Intra-Daily		
ETF	**Index**	**N**	**Premium**	**SD of Premium**	**SD of Last Trade Premium**	**ln(Ask/Bid)**	**N**	**Premium**	**SD of Premium**
Category 1: Domestic ETFs that Close at 4:15 PM and Have Index Futures Market									
DIA	DJIA	682	0.0456	0.2018	0.2165	0.1674	45,239	-0.0079	0.0715
IJH	S&P Midcap	88	0.0222	0.1577	0.3036	0.1770	32,503	0.0257	0.0690
IVV	S&P 500	93	0.0318	0.1673	0.1758	0.0827	35,864	0.0135	0.0788
IWB	Russell 1000	93	0.0297	0.1684	0.4675	0.1662			
IWM	Russell 2000	88	-0.0095	0.2446	0.2821	0.2997	33,072	0.0140	0.1275
MDY	S&P Midcap	1,365	0.0285	0.2853	0.3525	0.2202	46,673	0.0250	0.1189
QQQ	Nasdaq 100	396	0.0079	0.3395	0.3896	0.1674	47,506	0.0129	0.1272
SPY	S&P 500	946	0.0026	0.2141	0.2262	0.0826	47,446	0.0133	0.0690
Category 2: Domestic ETFs that Close at 4:15 PM but Do Not Have Index Futures Market									
IJR	S&P Smallcap	88	0.0250	0.1501	0.3995	0.1514			
IYF	DJ Financial	88	-0.0075	0.1008	0.4103	0.3499			
IYV	DJ Internet	93	0.0382	0.1069	1.4198	0.4409			
IYW	DJ Tech		-0.0200	0.1565	0.8854	0.3681			
Category 3: Domestic ETFs that Close at 4:00 PM and Do Not Have Index Futures Market									
XLB	S&P Basic Industries	448	0.0411	0.2484	0.4835	0.7949	47,610	0.0192	0.2080
XLE	S&P Energy	448	0.0101	0.1611	0.2951	0.5454	47,616	0.0097	0.1202
XLF	S&P Financial	448	-0.0098	0.1664	0.3565	0.5813	46,104	-0.0087	0.1468
XLI	S&P Industrial	448	0.0046	0.1411	0.3799	0.5423	46,413	-0.0070	0.0876
XLK	S&P Tech	448	0.0192	0.1557	0.2450	0.3241	47,588	0.0072	0.0844
XLP	S&P Cons Staples	448	-0.0420	0.2119	0.3818	0.6739	47,540	-0.0425	0.2225
XLU	S&P Utilities	448	0.0086	0.1689	0.4032	0.5506	46,450	-0.0015	0.0981
XLV	S&P Cons Services	448	-0.0185	0.1501	0.3523	0.5833	47,740	-0.0211	0.0852
XLY	S&P Cyclical	448	0.0203	0.1528	0.4134	0.6494	47,159	-0.0111	0.1786
	Average		**0.0109**	**0.1833**	**0.4209**	**0.3771**		**0.0025**	**0.1183**

Part of the explanation of the smaller end-of-day standard deviation is simply the diurnal effect of well-known trading patterns. Markets are more volatile at the open and at the close than in the middle of the day. The variability of the premium is closely related to the variability of the underlying index and, therefore, it is not surprising to see this type of typical effect in the corresponding ETF as well. This pattern is illustrated for DIA in Exhibit 3. The plot gives the standard deviation of the premium for each minute of the day. The typical U-shaped effect is easily seen along with a small increase in volatility around lunchtime.

Some portion of the measured premium is attributable to microstructure effects and the purpose of the methodology proposed in the next section is to correct these errors. To show that these errors are important, the premiums are reexamined for the funds that have active futures contracts. The premium can be measured relative to the IOPV, to the cash index or to the futures price. The first two will potentially suffer from stale prices and may, therefore, show delays in pricing. The latter two will show drift due to dividends, interest rates and portfolio cash balances. Thus a comparison can only be made for deviations around a slowly moving mean.

EXHIBIT 2
Descriptive Statistics: International ETFs

		End-of-Day					Intra-Daily		
ETF	Index	N	Average Premium	SD of Premium	SD of Last Trade Premium	ln(Ask/Bid)	N	Average Premium	SD of Premium
EWA	MSCI Australia	1,210	0.4711	0.8628	1.1186	1.4773	38,727	0.5228	0.7180
EWO	MSCI Austria	1,210	-0.0201	1.0482	0.9691	0.9491	34,288	0.1973	0.8947
EWK	MSCI Belgium	1,210	0.2535	0.7535	1.0271	1.3813	31,434	0.5479	0.6255
EWZ	MSCI Brazil	118	0.3019	0.9713	2.1111	2.1785	14,516	0.3373	1.1152
EWC	MSCI Canada	1,210	0.2116	0.7487	0.9510	0.6509	34,963	-0.0262	0.7991
EZU	MSCI EMU	108	0.1715	0.5431	0.5944	0.9401	13,780	0.0447	0.3064
EWQ	MSCI France	1,210	0.1264	0.6017	0.7636	0.8283	42,783	0.0108	0.3696
EWG	MSCI Germany	1,210	0.2770	0.8124	0.9243	0.9215	45,946	0.1099	0.4722
EWI	MSCI Italy	1,210	0.1044	0.6572	0.8052	0.7950	38,534	0.0093	0.4293
EWJ	MSCI Japan	1,210	0.3056	1.0720	1.1575	1.4342	47,159	-0.0075	0.7290
EWW	MSCI Mexico	1,210	2.1852	1.1659	1.3824	0.4575	42,679	0.5352	1.5641
EWN	MSCI Netherlands	1,210	-0.0624	0.5594	0.7389	1.0124	38,279	0.2448	0.4275
EWP	MSCI Spain	1,210	0.4157	0.6149	0.8210	1.1474	39,140	0.0934	0.4522
EWD	MSCI Sweden	1,210	0.1452	0.6489	0.9162	1.3801	36,910	0.0418	0.4684
EWL	MSCI Switzerland	1,210	0.2158	0.6687	0.9382	1.1327	44,665	0.2537	0.4772
EWU	MSCI UK	1,210	0.4671	0.7494	0.9071	1.2847	44,981	0.8759	0.5248
	Average		**0.3481**	**0.7799**	**1.0078**	**1.1232**		**0.2369**	**0.6483**

We calculate the first-order autocorrelation and the standard deviation of the three premiums (IOPV-based, cash index-based and futures-based) on a minute-by-minute basis for each day in the sample and then average over all days. These statistics are calculated around a daily mean that allows for the slowly moving components. The results are given in Exhibit 4. For all funds except IJH, the autocorrelation is lower for the futures-based premium than for either the IOPV- or cash index-based premium. This reduction in persistence is consistent with the hypothesis that the short-run deviations between price and NAV are due to staleness in the estimates of NAV. The autocorrelation of the IOPV- and cash index-based premiums are similar in size. Except for IJH, the standard deviations of the three premiums are generally of the same size. These autocorrelations are somewhat smaller for the ETFs that are most heavily traded.

METHODOLOGY

These results indicate the importance of building a statistical model to correct for these microstructure effects as most of the funds do not have a futures contract. The natural approach for examination of ETF premiums is the conditional analysis of cointegrated asset prices. The analysis must recognize the potential staleness of the NAV and the possibility of measurement error in the ETF price. The prices, however, must remain cointegrated even with such measurement errors.

To develop the statistical methods it is first necessary to introduce notation. Let p be the log of the measured price of the ETF and let n be the log of the measured NAV at time t. Then

$$\text{premium}_t = p_t - n_t \tag{1}$$

This premium is the fractional difference between the price and the NAV. A discount is, therefore, a negative premium. As premium is found to be normally distributed, then the standard deviation of it is a very familiar and easily quantified measure of the size of the pricing error.

As mentioned earlier, both the price and NAV may be measured with errors. Consider first the problem of measuring the NAV at the end of the day. The portfolio held by the fund is known and is evaluated at the closing transaction prices of each of the assets. This evaluation method introduces two potential sources of error.

First, each closing transaction price could have occurred as a buy or as a sell order, and therefore, be slightly above or below the closing midquote. Second,

EXHIBIT 3
Diurnal Standard Deviation of DIA Premium

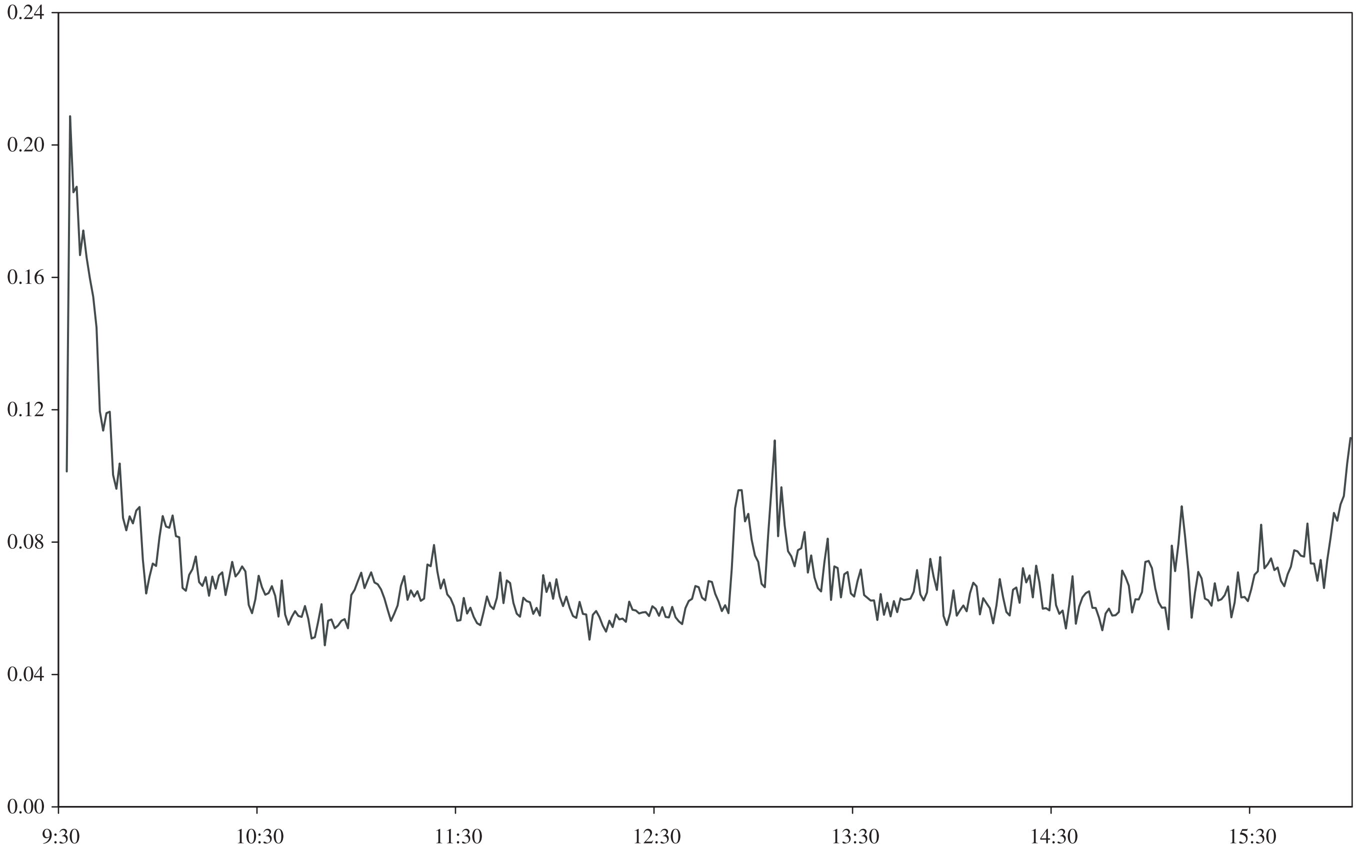


EXHIBIT 4
First-Order Autocorrelation and Standard Deviation: Selected Funds

		Futures-Based		IOPV-Based		Cash Index-Based	
ETF	**Index**	**1st Order Autocorrelation**	**Standard Deviation**	**1st Order Autocorrelation**	**Standard Deviation**	**1st Order Autocorrelation**	**Standard Deviation**
DIA	DJIA	0.3575	0.0006	0.5981	0.0006	0.5771	0.0006
IJH	S&P Midcap	0.8347	0.0010	0.6568	0.0005	0.6666	0.0005
IVV	S&P 500	0.1017	0.0004	0.4924	0.0005	0.5358	0.0006
IWB	Russell 1000						
IWM	Russell 2000	0.7744	0.0009	0.8892	0.0009	0.8892	0.0009
MDY	S&P Midcap	0.7989	0.0012	0.8569	0.0010	0.8639	0.0010
QQQ	Nasdaq 100	0.2487	0.0012	0.4318	0.0010	0.4801	0.0013
SPY	S&P 500	0.3231	0.0005	0.5151	0.0005	0.5472	0.0007
	Average	**0.4913**	**0.0008**	**0.6343**	**0.0007**	**0.6514**	**0.0008**

the closing transaction could have occurred early in the day, particularly for thinly traded stocks. As a result, the transaction may not contain information on its end-of-day value. An institutional investor considering creating or redeeming shares will compare the current value of these shares at the end of the day to the fund share price and will trade regardless of the accounting definition of NAV at the market close. Even though intra-daily premium uses IOPV, the estimated value of the portfolio posted every 15 seconds, IOPV suffers from the same stale quote possibility as the NAV at the market end.

A statistical model for the premium, therefore, must incorporate the long run properties of the data: the ETF price and the underlying value eventually must be the same. Both prices and NAV are integrated processes as they are prices for portfolios of traded assets. However, the premium is a stationary process as long as arbitrage opportunities ensure that deviations are self correcting. Thus the system of measured prices, measured NAVs and premiums is a cointegrated system where the premium would represent the error correction term.

We now formulate a novel statistical model of this measurement error that preserves the cointegration properties of the data. Define $\tilde{n}_t$ as the true value of the underlying portfolio at t.[4] We hypothesize that:

$$n_t = \tilde{n}_t + \theta\left(\tilde{n}_t - n_{t-1}\right) + \phi x_t + \eta_t \tag{2}$$

where x is a set of stationary exogenous or predetermined variables that explain differences between measured and true NAV.[5] When prices change very little, the error is small but when they change rapidly, the error is large and has the effect of making the measured price change by less than the true price. Thus a natural expectation is that θ is negative. This model is roughly consistent with Lo and MacKinlay [1990] where the arrival rates of components of the index are constant, see also Le Baron. The expected time of the last quote is, therefore, constant over time. Consequently, the expected closing price on a portfolio would be a fixed proportion of the true change in portfolio value. For funds with futures prices, which do not suffer from these portfolio problems but which do have noise from expected dividends and interest rates, the futures returns can be used as xs.

The goal of the analysis is to measure the size and persistence of the true premium that can now be defined as

$$p_t - \tilde{n}_t = u_t \tag{3}$$

where u may be autocorrelated if premiums have some dynamic structure. For example, if the premium follows a first-order autoregression, then Equation (3) can be expressed as:

$$p_t - \tilde{n}_t = \rho\left(p_{t-1} - \tilde{n}_{t-1}\right) + \varepsilon_t \tag{4}$$

Assume that the growth of NAV has a constant mean,

$$d\tilde{n}_t = \mu + \xi_t \tag{5}$$

and assume that all three shocks are independent and normally distributed.[6]

The system of Equations (2), (4) and (5) can then be expressed in a state space framework and estimated with the Kalman Filter. See for example Harvey [1989] or Hamilton [1994].

$$\begin{pmatrix} \tilde{n}_t \\ \tilde{n}_{t-1} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} \tilde{n}_{t-1} \\ \tilde{n}_{t-2} \end{pmatrix} + \begin{pmatrix} \mu \\ 0 \end{pmatrix} + \begin{pmatrix} \xi_t \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} p_t \\ n_t \end{pmatrix} = \begin{pmatrix} \rho p_{t-1} \\ -\theta n_{t-1} + \phi x_t \end{pmatrix} + \begin{pmatrix} 1 & -\rho \\ 1+\theta & 0 \end{pmatrix} \begin{pmatrix} \tilde{n}_t \\ \tilde{n}_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \eta_t \end{pmatrix} \tag{6}$$

The Kalman filter will provide forecasts of the true NAV and true premium based on past information. These estimates can be further refined based on subsequent data to estimate what the true NAV was at any time. The parameters of this system can be estimated by maximizing the likelihood with respect to the unknown variance and mean parameters. The standard deviation of the innovation to the true premium, ε, is related to the standard deviation of u by

$$\sigma_u = \frac{\sigma_\varepsilon}{\sqrt{1-\rho^2}} \tag{7}$$

The methodology, however, is greatly simplified if it turns out that the errors in the NAV Equation (2) are small relative to the others. This would generally be expected, as the magnitude of the stale quote error is likely to be smaller than the rate of change of the price or the deviation of the premium. Assuming that Equation (2) has no error term, it can be solved with Equation (3) to eliminate the unobserved true NAV.

$$\begin{aligned} p_t - n_t &= -\frac{\theta}{1+\theta}\left(n_t - n_{t-1}\right) - \frac{\phi}{1+\theta}x_t + u_t \\ &\equiv \alpha \Delta n_t + \beta x_t + u_t \end{aligned} \tag{8}$$

If the first-order autoregressive assumption is sufficient for the premiums, then Equation (8) will simply require an AR(1) error specification. The unconditional standard deviation is estimated by the standard deviation of $\left\{\hat{u}_t\right\}$. Notice that this model is consistent with the cointegration hypothesis as all variables on both sides of the equation are stationary. Because θ is negative, the coefficient α should be positive. This means that rapid increases in NAV should result in especially large premiums because the measured NAV will be an underestimate of the true NAV.

If the variance of the measurement error in Equation (2) is not zero, then Equation (8) is only an approximation. The disturbance in the equation is

$$u_t - \eta_t / \left(1+\theta\right) \tag{9}$$

This additional term has several implications. Because η is correlated with Δn_t, the least squares coefficient estimates of α and β are biased and inconsistent. The estimate of α is biased downward and possibly negative. Thus large increases in NAV could be associated with reduced premium if the increase in NAV is mostly measurement error. The standard deviation of Equation (9) exceeds the standard deviation of u, but the least squares residuals will have a smaller standard deviation as only the part of η orthogonal to the regressors will be left in the residuals. Thus the standard error of the regression Equation (8) will give only a small overstatement of the standard deviation of the premium.

The composite error term in Equation (9) has more complex time series structure. For example, if u is an AR(1), then the composite error is an ARMA(1,1). Thus, for small measurement errors, the standard deviation of the autoregressive error is a conservative estimate of the true premium standard deviation. If the measurement errors are more significant than this, then the model in Equation (6) must be used. In the empirical section, we provide some examples to show the relation between these two estimates.

In some markets, it is possible to improve the measurement of n using futures prices. As, under standard arbitrage assumptions, the futures are priced as:

$$F_t = S_t e^{(r-q)T} \tag{10}$$

with F as the futures price, S as the spot price, T as the remaining time to expiration of the futures contract, q as the continuously compounded dividend rate and r as the continuously compounded interest rate, a futures price implicitly estimates the cash price just by resolving this equation. To incorporate this into the measurement equation for NAV, define

$$A_t = \log\left(F_t\right) - \left(r-q\right)T - n_t \tag{11}$$

Then Equation (2) becomes

$$n_t = \tilde{n}_t + \theta\left(\tilde{n}_t - n_{t-1}\right) + \phi A_t + \eta_t \tag{12}$$

where one might anticipate a value of $\phi = -1$.

Further measurement errors are introduced through the timing of market closing. For many of the domestic broad-based ETFs, the market closes at 4:15 Eastern time while the NAV is calculated at 4:00, when the equity markets close. As a consequence, in daily data there is another important measurement error in the NAV. Calculation of the 4:15 NAV for funds with futures contracts simply requires the change in the futures price between the close of the two markets. Calling this post-market change in futures, *Fpm*, Equation (12) now can be written as,

$$n_t = \tilde{n}_t + \theta\left(\tilde{n}_t - n_{t-1}\right) + \phi A_t + \beta Fpm_t + \eta_t \tag{13}$$

and the premium Equation (8) becomes:

$$p_t - n_t = \alpha\left(n_t - n_{t-1}\right) + \beta_1 A_t + \beta_2 Fpm_t + u_t \tag{14}$$

We refer to Equation (14) as the ***dyna*** model. The regression of premium, therefore, includes the change in NAV, the futures-based cash adjustment and the future returns from 4:00 PM to 4:15 PM. For some ETFs, only a subset of these variables will be available or relevant.

Serial correlation corrections will be needed if autocorrelation remains in the premium in Equation (14). Allowing for a first-order autoregressive error structure as in Equation (4), the estimating equation, then, is

$$\begin{aligned} p_t - n_t &= \rho\left(p_{t-1} - n_{t-1}\right) + \alpha\left(\Delta n_t - \rho\Delta n_{t-1}\right) \\ &\quad + \beta_1\left(A_t - \rho A_{t-1}\right) + \beta_2\left(Fpm_t - \rho Fpm_{t-1}\right) + \varepsilon_t \end{aligned} \tag{15}$$

The coefficients are estimated more efficiently in Equation (15) but the residuals measure only the unpredictable portion of the premium, not the entire premium. When these differ, it is the entire premium that reflects the importance of premiums and discounts. The unconditional error in the premium can be calculated by examining the sum of squared residuals of Equation (14) using the coefficients estimated in Equation (15).

While there may still be errors in the premium due to noisy measurement of p due to bid-ask spread or staleness, these price effects can be almost eliminated by using closing midquotes rather than last trade prices. In fact, we will show later that the standard deviation of midquote premium regression is smaller than that of transaction premium regression.

Once the effects of the independent variables are taken out, the residuals reflect the remaining premium and discount. Thus, the standard deviation of the residuals is a good measure of the size of the pricing errors that actually occur. If the residual variance changes over time, as it is likely to do from the model presented above, heteroskedasticity corrections can measure when it is large and when it is small. We assume the error variance to be proportional to the volatility of the underlying asset. Suppose the residual variance is modeled as

$$\sigma_t^2 = \exp(z_t\delta), \tag{16}$$

where z reflects a vector of variables measuring the volatility of the underlying asset. The simplest version takes $z_t' = (\log(\text{high}_t/\text{low}_t), c)$ where c is an intercept. A more flexible GARCH model sets:

$$\sigma_t^2 = h_t \exp(z_t\delta), \quad h_t = \left(1 - a - b\right) + ae_{t-1}^2 \exp\left(-2z_t\delta\right) + bh_{t-1} \tag{17}$$

where e are the residuals from the model. With either of these formulations of the heteroskedasticity—Equation (16) or Equation (17)—the model is estimated by maximum likelihood with a conventional conditional Gaussian likelihood function given by

$$L = -\frac{1}{2}\sum_t \left(\log(\sigma_t^2) + \frac{e_t^2}{\sigma_t^2} \right). \tag{18}$$

END-OF-DAY PREMIUM: DIA, XLK, AND EWA

Descriptive Statistics

The three models derived in the section Methodology are: the Kalman Filter State Space model, the ***dyna*** model, and the GARCH model. The Kalman Filter State Space model is represented by Equation (6) that provides forecasts of the true NAV and true premium based on past information. The ***dyna*** model of Equation (14) regresses premium on the change in NAV, the future-based cash adjustment and the future returns from 4:00 PM to 4:15 PM. The GARCH model is represented by Equation (15) with the residual variance defined as Equation (17). The GARCH model corrects for autocorrelation if it is present in the premium.

To compare the performance of these models, we consider end-of-day data for three ETFs: DIA (based on broad-based market index DJIA), XLK (based on sector index S&P Technology) and EWA (based on international index MSCI Australia).

The ETF trading time and the underlying index trading time pose very different problems for these three series. DIA trades until 4:15 PM but the NAV is calculated at 4:00 PM. The DJIA futures contract that trades until 4:15 PM can be used to correct the NAV in DIA both for stale quotes and for the timing discrepancies. XLK closes at 4:00 PM and it has no futures contract on it. However, as it is a sector of the S&P500 index, it is possible that staleness in its NAV would be related to the S&P500 measures. EWA closes at 4:00 PM but it trades entirely while the underlying market is closed. As a result, it probably contains a very stale value for NAV. The recorded value of NAV in this case is simply the closing price of the basket in Australia, adjusted for changes in currency values until 4:00 PM Eastern time.

Exhibit 5 reports the end-of-day estimates for the three funds for the three models. Panel A gives the premium, and standard deviations of premium and last trade-based premium. All figures are expressed in percentage terms. For example, the premium of DIA is 4.6 bps, 1.9 bps for XLK, and 47.1 bps for EWA. The standard deviation of last trade-based premium for DIA is 22 bps whereas the standard deviation of premium is 20 bps. The use of the midquote reduces the standard deviation for each of these products particularly for the less actively traded XLK and EWA.

The *dyna* Model

The regression results with the midquote-based premium based on ***dyna*** model are given in Panel B of Exhibit 5. The futures price change from 4:00 PM to 4:15 PM ("FutPM") has a very large and significant effect on DIA. The correction to the NAV is estimated to be 70% of the change in the futures price. The adjustment to the estimated cash value at 4:00 PM ("CashAdj") is only 10% of the prediction based on the futures price. The coefficient of the change in the NAV from one day to the next ("dNAV") is found to be significantly positive. Rising NAV implies that the measured NAV is too low because some quotes are stale and, consequently, the premium is too high. The autocorrelation in the errors is estimated to be 0.13, which is quite small. Therefore, the estimated standard deviation of the true premium (11.8 bps, calculated by simply ignoring the autocorrelation) is almost identical to the standard error of the regression or 11.7 bps. The adjustments to NAV based on the futures prices, correcting for the timing discrepancy and for the estimated cash value, are effective in bringing the standard deviation from 20 bps to 12 bps, almost a 40% reduction.

For XLK, there is no timing mismatch and no futures contract. Hence the cash adjustment for the S&P500 futures

EXHIBIT 5
Results for Three ETFs: End-of-Day Analysis

	DIA (DJIA)	XLK (S&P Tech)	EWA (MSCI Australia)
N	682	448	1,210
A: Base Model			
Average Premium	0.0456	0.0192	0.4711
SD of Premium	0.2018	0.1557	0.8628
SD of Last Trade-Based Premium	0.2165	0.2450	1.1186
B: *dyna* Model: Equation (14)			
SD(True Premium)	0.1175	0.1523	0.8648
Intercept	**-0.0424**	**-0.0311**	**0.4719**
FutPM	**69.7065**		
CashAdj	**10.4748**	**3.7590**	
dNAV	**2.5885**	**-1.3587**	**-6.1369**
AR(1)	**0.1253**	**0.0291**	**0.3551**
SE(Regression)	0.1171	0.1530	0.8092
C: Kalman Filter Model: Equation (6)			
rho	9.91E-06	-1.83E-05	**0.9226**
theta	**-0.0280**	**0.0142**	**-0.2835**
FutPM	**-65.5649**		
CashAdj	**-8.7155**	**-4.3768**	
SD(True Premium)	**0.1162**	**0.1543**	**0.1873**
SD(Measurement Error)	**0.0192**	**0.0210**	**0.6146**
D: GARCH Model: Equation (15)			
Mean Equation			
rho	**0.1484**	**0.0609**	**0.4083**
dNAV	**2.0809**	**-1.7070**	**-5.9001**
FutPM	**71.2336**		
CashAdj	**9.6439**	**3.5434**	
Intercept	**-0.0328**	**-0.0231**	**0.2586**
Variance Equation			
HiLo	**41.7061**	**36.5452**	**37.7495**
ARCH	0.0336	0.0585	**0.0694**

Significant coefficients (at 5%) are presented in bold.

is used in the regression. The adjustment to the estimated cash value is 3.8%. The change in NAV is significant, but now it has the negative sign associated with errors-in-variables: increasing NAV reduces the premium. In other words, when the NAV increases, the premium is now measured relative to a typically overstated estimate of NAV. While the stale quote feature may still be important, it is dominated by the measurement error in NAV. There remains little serial correlation and the final estimate of the standard deviation of the premium is 15.3 bps, which is not different from the standard deviation of the unadjusted premium. Notice that the standard deviation is now higher than the one in the DIA. This is expected because of the reduced transaction volume and narrower sector coverage.

EWA has no futures contract traded in the United States and, therefore, is priced only with reference to the measured NAV. The coefficient on the change in NAV is significantly negative reinforcing the prior expectation that the NAV is measured with large errors. The autocorrelation is estimated to be large and significant. The standard deviation of the true premium is, therefore, bigger than the standard error of the regression and is, in fact, about the same size as the unconditional standard deviation. This reflects the finding that only a small part of the premium can be attributed to the hypothesized forms of measurement error. The mean premium is now noticeably positive at 47 basis points. The finding of a large positive mean premium is characteristic of the international ETFs and will be discussed later.

Kalman Filter and Errors-in-Variables Model

For two of these series (XLK and EWA), there is evidence that the measurement errors on the NAV are important in that changes negatively affect the premium. Therefore, it may be important to estimate the Kalman Filter State Space version of the model given in Equation (6). This estimation procedure identifies the measurement errors in NAV and the premium separately from the time series data. The results are given in Panel C of Exhibit 5.

For DIA and XLK, the estimated standard deviation of the measurement error is much smaller than the standard deviation of the premium, and the premium autocorrelation—measured by rho—is nearly zero. Hence, the model gives practically the same estimated standard deviation of premium as the ***dyna*** model. However, for EWA, the standard deviation of the measurement error in NAV is much bigger and there is autocorrelation of 0.92 in the premium. The estimate of the standard deviation of the premium adjusted for measurement errors according to Equation (7), is now 49 bps. This suggests a substantially better performance of this model for this fund over other models. This model attributes much of the measured premium to errors in the NAV. The model also estimates the persistence of premiums of the error free true premium to be greater than that estimated previously indicating that the correctly measured premium is smaller but lasts longer.

The estimates given by the ***dyna*** model are conservative as argued in the development of the model but give a useful upper bound on the standard deviation of premium.

GARCH Model

The volatility of the premium changes over time. In Panel D of Exhibit 5, Equation (15) is estimated with the GARCH heteroskedasticity correction given by Equation (17). While the parameter values are rather similar to those in the upper panels, the graphs of conditional variance are quite interesting. In Exhibit 6, the standard deviation of the DIA premium is graphed from the basic model with no adjustment for measurement errors in NAV and from the ***dyna*** model. The time variation in the standard deviation is partly a result of variation in the volatility of the DJIA index itself as measured by the daily high/low ratio. It also is due in part to persistent swings in standard deviations that are modeled by GARCH. The reduction in standard deviation is more or less uniform across time, but is particularly effective at times when the standard deviations are greatest.

The standard deviation estimator for XLK is plotted with the premium in Exhibit 7. On the graph, ±1.96 standard deviations form an approximate 95% confidence interval. Clearly this is highly variable but pretty reliable as an indicator of the possible movements. In Exhibit 8, the standard deviation of the EWA premium is plotted. The scale on this plot is noticeably greater with some periods having a standard deviation greater than 2%.

END-OF-DAY PREMIUM: A COMPREHENSIVE VIEW

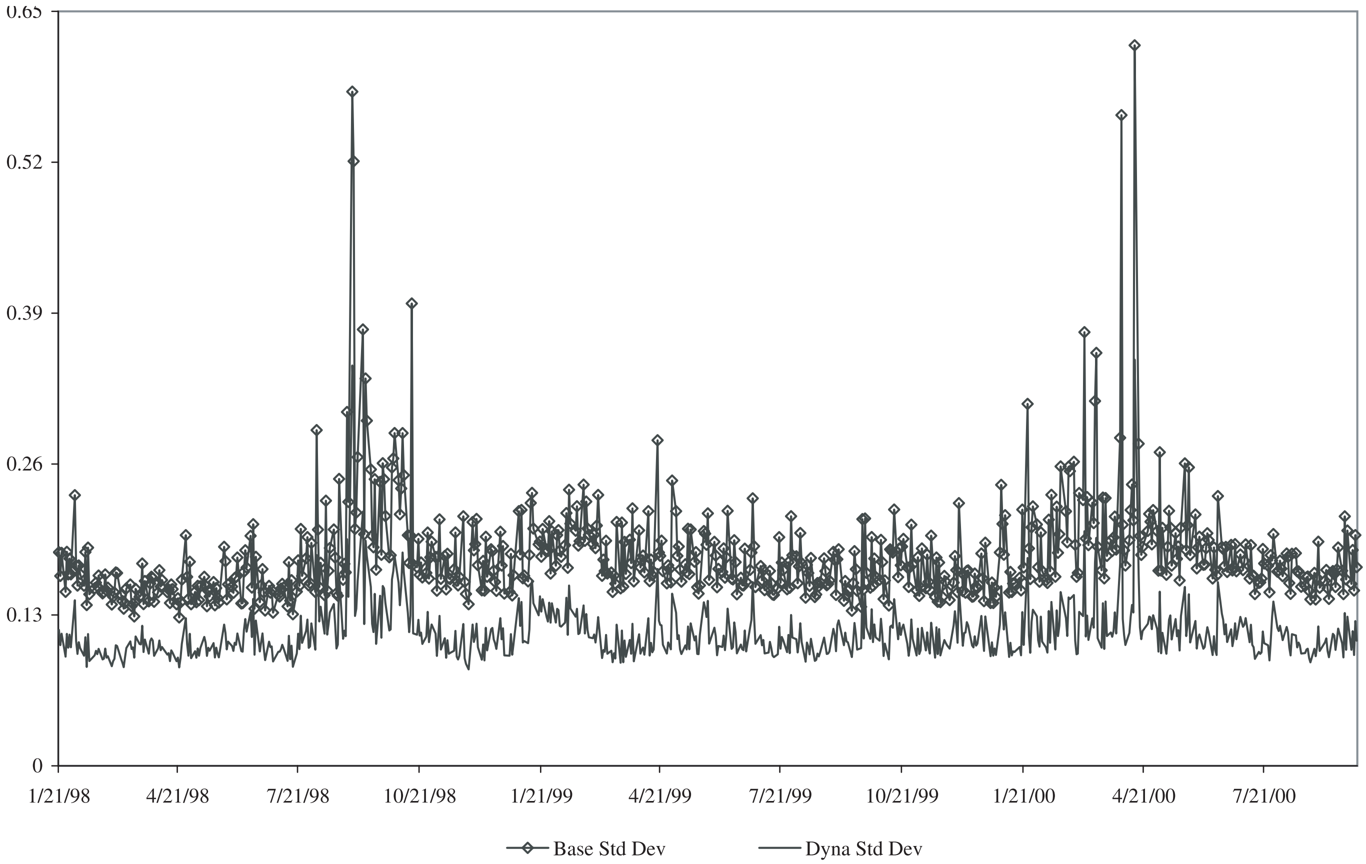
The ***dyna*** model from Equation (14) was estimated for end-of-day data for all funds and the results for the domestic and international funds are reported in Exhibits 9 and 10, respectively. The base model standard deviation of premium is reported as well. For completeness, we report the DIA, XLK, and EWA results once again.

Exhibit 9 shows that for all the domestic funds, the ***dyna*** estimated standard deviation of premium is smaller than the standard deviation of the base premium. These are dramatically smaller for the ETFs that close at 4:15 and those with futures contracts on the index. For the other domestic ETFs, there is little difference between the two standard deviations. The ***dyna*** numbers range from 9 bps (IJR: S&P SmallCap) to 24 bps (XLB: S&P Basic Industries). According to Exhibit 10, the international funds, on the other hand, show little change from the base model standard deviation of premium. In fact, in many cases, the base model standard deviation of premium is smaller than the corresponding ***dyna*** standard deviation.

Exhibits 9 and 10 show the persistence of premiums and discounts for both domestic and international funds. The autocorrelation parameters indicate whether a premium on one day has predictability for the premium on

Exhibit 6

Standard Deviation of DIA Premium from Base and Dyna Models with GARCH



the next day. For the domestic funds, the average autocorrelation estimate is a little over 0.1 indicating that about 10% of today's premium can be expected to remain by the close tomorrow. As the premiums are small to start with, this is quite a small effect. For the international funds, the average autocorrelation is about 30% suggesting that carry over from one day to the next is potentially important.

INTRA-DAILY PREMIUM: A COMPREHENSIVE VIEW

Even though the intra-daily IOPV is not designed for trading, it does give a quick snapshot of underlying index value on a high frequency basis. Nevertheless, the same analysis performed on a daily basis can be performed on an intra-daily basis allowing for the possibility that there are biases in the IOPV due to stale quotes and dynamic adjustment of the true premium to its equilibrium level.

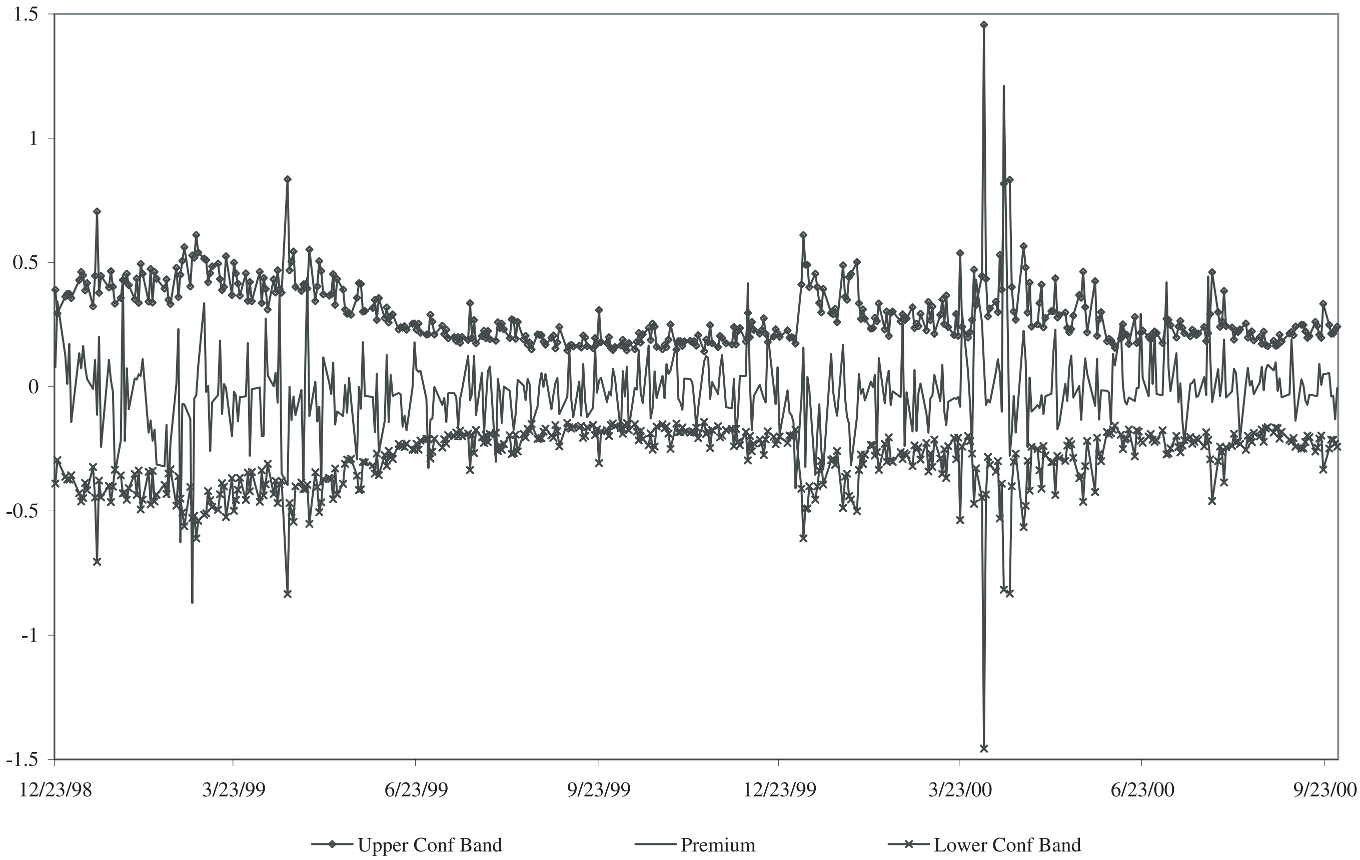
The results of the analysis of intra-daily data are given in Exhibits 11 and 12. Each table also reports the base model standard deviation of premium. The tables report the results for 16 domestic and 16 international ETFs. The other five domestic ETFs do not have complete data.

For the domestic ETFs, Exhibit 11 shows that, except for SPY, the dIOPV coefficient is large negative (ranges from −11 bps to −55 bps) and significant indicating the existence of measurement errors in IOPV. For international ETFs too, the coefficient is large negative (ranges from −11 bps to −45 bps) and significant. Measurement errors seem to be present in international IOPVs as well.

The minute-to-minute change in the S&P futures and an ARMA(1,1) are used in each regression.[7] Generally, the futures coefficient is positive and significant. The AR term is large, close to 1 in many cases, and the MA term is generally negative, when significant. It is clear that the autocorrelation is much greater for these high

Exhibit 7

Confidence Bands of XLK Premium from Dyna Model with GARCH



frequency data sets than it was for the daily data. For the domestic funds, the average autocorrelation is 0.90 while for the international funds it is 0.99. Although the hypothesis that the price and the IOPV are cointegrated might appear tenuous for the international funds, a direct test concludes that these series are cointegrated in every case. While there is some explanatory power in the regressors introduced into these regressions, the estimated standard deviation of the premium is reduced imperceptibly in almost all cases.

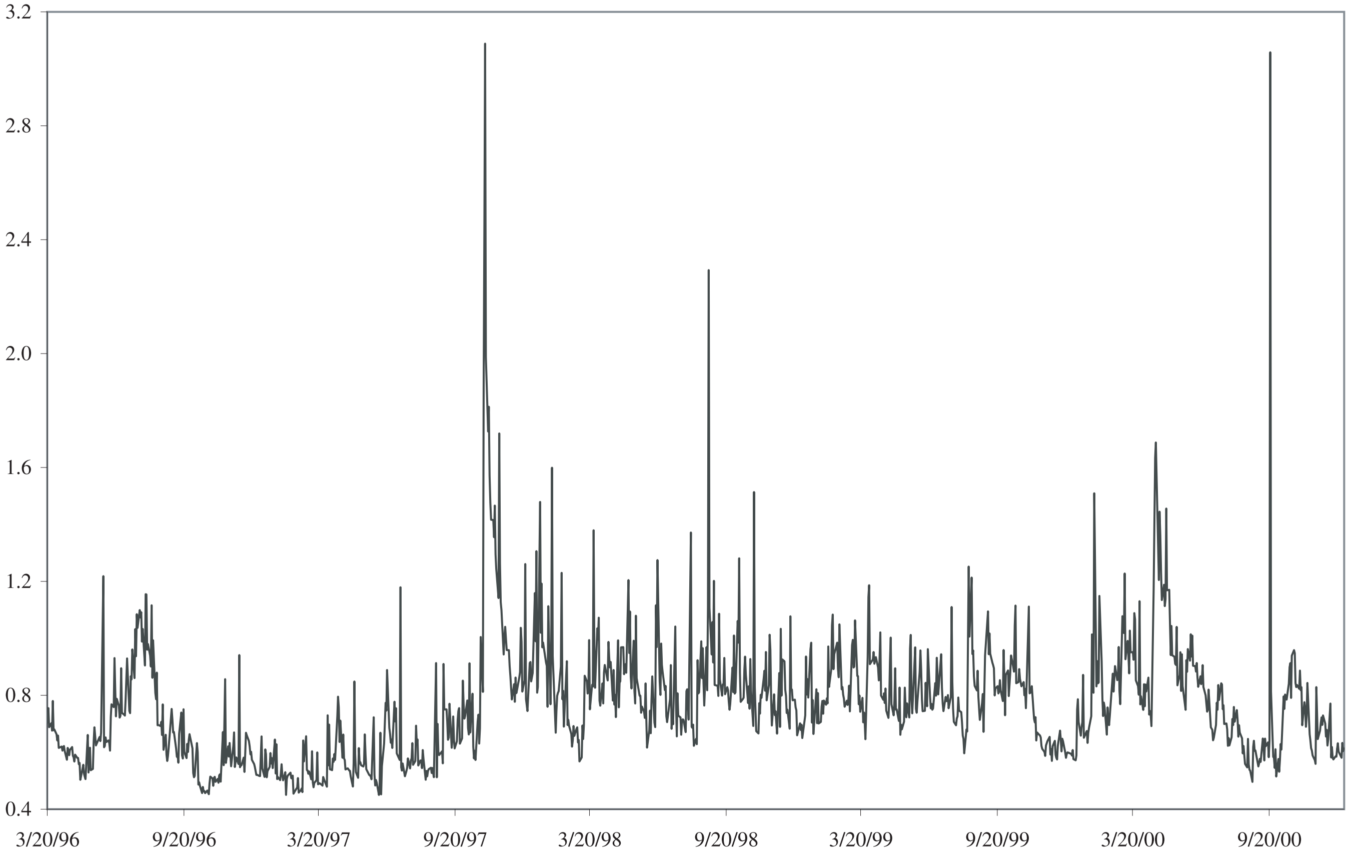
It is also of interest to examine the persistence of the intra-daily premiums. For the domestic funds, the first-order autocorrelation is on average 0.90 indicating that the half-life of a premium is about 5.6 minutes. The half-life is the expected time it takes for the premium to drop to half of its value and is given by $\log(0.5)/\log(\rho)-1$, where log is the natural logarithm. For the international funds, the first-order autocorrelation is 0.99 with a half-life of 68 minutes.

The lengths of the lags can be examined in more detail with these high frequency data. We calculate the length of time that a large premium takes to revert to the mean value. For each asset we define an upper and a lower threshold. We measure the duration of a large premium starting when it first exceeds the upper threshold and continuing until it first crosses the lower threshold. This is done separately for premiums and discounts, and for domestic and international funds. These durations are presented in Exhibits 13 and 14.

From these results it is clear that the typical large duration episode lasts only a few minutes for the majority of the domestic funds. For SPY and DIA, the median duration is 5-7 minutes. The average overall domestic funds is 10 minutes and the distribution is more or less symmetric between premium events and discount events. For the international funds, the average premiums and discounts are 176 minutes with some lasting more than one day.

Exhibit 8

Standard Deviation of EWA Premium from Dyna Model with GARCH



One reason these episodes last so long is the infrequency of trades and quote revisions for the international funds. In Exhibit 15, it can be seen that trades occur on average about every 25 minutes and quotes are revised less frequently, sometimes more than 2 hours apart. This sluggish response to information is only consistent with the absence of arbitrage when the spreads are large. This is indeed the case with these international funds.

The story of the international fund pricing is that the prices move slowly in response to economic news, but that bid-ask spreads are apparently wide enough to prevent arbitrage. Exhibit 1 shows that for domestic funds the spread is 37.7 bps on average, although the average is driven by a few of the sector funds. The broad indices have spreads under 20 basis points. The international funds have spreads that average 112 bps. See Exhibit 2. However, these spreads are small compared with the persistent premiums of closed-end country funds and are smaller than one typically finds for ADRs and other international replication instruments.

CONCLUSIONS

This study has examined the magnitude of premiums and discounts for a wide range of Exchange Traded Funds. These include domestic funds with and without futures contracts, and closing at 4:00 PM or 4:15 PM. These include broad market indices and narrow sector funds. The sector funds range from utilities and basic industries to technology and internet sectors. In almost all cases, the mean premium was less than 5 bps and the standard deviation was less than 20 bps.

We develop a statistical approach to measuring the true premium by correcting some of the measurement errors in net asset value. This reduces further the observed standard deviation. We examine how the standard

EXHIBIT 9

End-of-Day *dyna* Model Regression Results: Domestic Funds

			Base Model	*dyna* Model					
			SD of	SD of					SE of
ETF	Index	N	Premium	Premium	dNAV	FutPM	CashAdj	AR(1)	Regression
DIA	DJIA	682	0.2018	0.1175	**2.5885**	**69.7065**	**10.4748**	**0.1253**	0.1171
IJH	S&P Midcap	88	0.1577	0.1405	**2.7690**	**40.1233**	1.6663	0.1538	0.1436
IVV	S&P 500	93	0.1673	0.0889	**-2.3650**	**83.1178**	**7.1689**	0.1089	0.0911
IWB	Russell 1000	93	0.1684	0.1014	**-3.4844**	**76.2597**	**6.2809**	0.1556	0.1035
IWM	Russell 2000	88	0.2446	0.1672	**8.4666**	**20.4763**	**21.1365**	0.0729	0.1720
MDY	S&P Midcap	1,365	0.2853	0.2234	**6.1950**	**40.1806**	**20.7773**	**0.1188**	0.2224
QQQ	Nasdaq 100	396	0.3395	0.1984	**1.0761**	**66.4744**	**21.5105**	**0.1772**	0.1965
SPY	S&P 500	946	0.2141	0.1008	**2.5410**	**78.3499**	**15.7105**	**0.1253**	0.1003
IJR	S&P Smallcap	88	0.1501	0.0928	0.7516	**76.8738**	2.9680	-0.0672	0.0953
IYF	DJ Financial	88	0.1008	0.0968	**-1.4016**	-6.9733	2.0423	**0.2597**	0.0954
IYV	DJ Internet	93	0.1069	0.1024	-0.3532	-19.5102	3.2273	-0.0097	0.1048
IYW	DJ Tech		0.1565	0.1525	-0.8815	2.7679	1.0562	**-0.3008**	0.1505
XLB	S&P Basic Industries	448	0.2484	0.2405	**-1.5942**		**14.9622**	**0.2735**	0.2326
XLE	S&P Energy	448	0.1611	0.1589	**-1.3751**		3.8475	**0.0958**	0.1590
XLF	S&P Financial	448	0.1664	0.1624	**-0.9827**		**9.6451**	**0.1660**	0.1605
XLI	S&P Industrial	448	0.1411	0.1386	**-1.4660**		**6.0079**	**0.0253**	0.1393
XLK	S&P Tech	448	0.1557	0.1523	**-1.3587**		3.7590	0.0291	0.1530
XLP	S&P Cons Staples	448	0.2119	0.2108	**-1.6599**		2.2546	**0.1990**	0.2077
XLU	S&P Utilities	448	0.1689	0.1615	**-3.0142**		**8.7436**	**0.1919**	0.1591
XLV	S&P Cons Services	448	0.1501	0.1455	**-1.5781**		**8.3074**	**0.2501**	0.1405
XLY	S&P Cyclical	448	0.1528	0.1417	**-2.8659**		**11.1790**	0.0658	0.1415
	Average		**0.1833**	**0.1474**				**0.1055**	

Significant coefficients (at 5%) are presented in bold.

deviation moves over time. The resulting standard deviation of the premium is 9 bps for some funds and averages 14 bps. For the international funds the estimate of the standard deviation averages 77 bps.

From a minute-by-minute point of view, the standard deviations are even smaller. It now becomes possible to see how long episodes of premium or discount last. The domestic episodes generally last only a few minutes with an average across funds of 10 minutes. The international episodes last typically almost 3 hours with some even slower to recover.

The overall impression of the domestic ETFs is of a set of products that are priced very close to their true NAVs with only brief excursions any significant distance away. The international ETFs are less actively traded and less accurately priced; yet they operate in a more stringent environment and may still be performing according to expectations.

ENDNOTES

The American Stock Exchange provided support for this research. The opinions and conclusions expressed here, however, do not necessarily reflect those of the American Stock Exchange. The authors would like to thank Chia Hsun Chan and We Chen Foo for excellent research support.

[1]Bonser-Neal et al. [1990] argue that segmentation of the international capital market from the US capital market can raise a closed-end country fund's price-NAV ratio. In that case, the country fund can trade at a premium. Each fund provides two distinct market-determined prices: the country fund's share price quoted on the domestic market and its NAV, determined by the prices of the underlying shares traded on the foreign market. Barriers to international investment can cause the expected returns on assets of equal risk to differ across countries. If capital markets are integrated internationally, a closed-end country fund's shares and its underlying assets should have similar risk. International investment restrictions can affect the ratio of a country fund's price to NAV if they are binding. All other things constant, binding investment restrictions will raise the price of a fund's shares relative to its

EXHIBIT 10
End-of-Day *dyna* Model Regression Results: International Funds

			Base Model	*dyna* Model					
ETF	Index	N	SD of Premium	SD of Premium	dNAV	FutPM	CashAdj	AR(1)	SE of Regression
EWA	MSCI Australia	1,210	0.8628	0.8648	**-6.1369**			**0.3551**	0.8092
EWO	MSCI Austria	1,210	1.0482	1.0372	**-17.2401**			**0.5199**	0.8878
EWK	MSCI Belgium	1,210	0.7535	0.7541	**-2.7110**			**0.4217**	0.6853
EWZ	MSCI Brazil	118	0.9713	0.9615	-4.7020			**0.3650**	0.9229
EWC	MSCI Canada	1,210	0.7487	0.7220	**-14.9058**			**0.3446**	0.6785
EZU	MSCI EMU	108	0.5431	0.5394	1.9536			**0.0750**	0.5483
EWQ	MSCI France	1,210	0.6017	0.6021	-1.2256			**0.2095**	0.5896
EWG	MSCI Germany	1,210	0.8124	0.8142	-2.2248			**0.2069**	0.7975
EWI	MSCI Italy	1,210	0.6572	0.6581	**-4.0070**			**0.2578**	0.6369
EWJ	MSCI Japan	1,210	1.0720	1.0745	-1.7125			**0.3581**	1.0049
EWW	MSCI Mexico	1,210	1.1659	1.1659	-1.4616			**0.6032**	0.9309
EWN	MSCI Netherlands	1,210	0.5594	0.5590	0.1925			**0.1675**	0.5520
EWP	MSCI Spain	1,210	0.6149	0.6149	-1.3966			**0.1991**	0.6035
EWD	MSCI Sweden	1,210	0.6489	0.6464	**2.5149**			**0.1496**	0.6397
EWL	MSCI Switzerland	1,210	0.6687	0.6687	**-2.9750**			**0.3026**	0.6384
EWU	MSCI UK	1,210	0.7494	0.7500	-1.7983			**0.3625**	0.7001
	Average		**0.7799**	**0.7770**				**0.3061**	

Significant coefficients (at 5%) are presented in bold.

EXHIBIT 11
Intra-Daily *dyna* Model Regression Results: Domestic Funds

			Base Model	*dyna* Model					
ETF	Index	N	SD of Premium	SD of Premium	dIOPV	dFutures	AR(1)	MA(1)	SE of Regression
DIA	DJIA	45,239	0.2018	0.0713	**-10.2319**	**9.4701**	**0.8798**	**-0.3149**	0.0459
IJH	S&P Midcap	32,503	0.1577	0.0690	**-35.7536**	**1.7110**	**0.9333**	**-0.3392**	0.0358
IVV	S&P 500	35,864	0.1673	0.0783	**-10.9811**	**17.3190**	**0.9747**	**-0.6385**	0.0434
IWB	Russell 1000		0.1684						
IWM	Russell 2000	33,072	0.2446	0.1282	**-50.2754**	**5.3920**	**0.9518**	**-0.0297**	0.0405
MDY	S&P Midcap	46,673	0.2853	0.1178	**-55.0938**	**5.1205**	**0.9171**	**-0.0597**	0.0496
QQQ	Nasdaq 100	47,506	0.3395	0.1261	**-13.2941**	**12.7447**	**0.8444**	**-0.3970**	0.0968
SPY	S&P 500	47,446	0.2141	0.0669	**3.9793**	**16.1715**	**0.9274**	**-0.5775**	0.0489
IJR	S&P Smallcap		0.1501						
IYF	DJ Financial		0.1008						
IYV	DJ Internet		0.1069						
IYW	DJ Tech		0.1565						
XLB	S&P Basic Industries	47,610	0.2484	0.2050	**-50.5203**	**0.9423**	**0.9418**	0.0067	0.0685
XLE	S&P Energy	47,616	0.1611	0.1160	**-52.8636**	**-0.4074**	**0.8717**	-0.0017	0.0569
XLF	S&P Financial	46,104	0.1664	0.1458	**-44.3588**	**4.3469**	**0.9182**	**-0.1158**	0.0646
XLI	S&P Industrial	46,413	0.1411	0.0845	**-44.8631**	**1.4248**	**0.9112**	**-0.2752**	0.0460
XLK	S&P Tech	47,588	0.1557	0.0801	**-43.7830**	**8.4962**	**0.6635**	**-0.0904**	0.0635
XLP	S&P Cons Staples	47,540	0.2119	0.2209	**-51.1256**	0.5754	**0.9575**	-0.0074	0.0642
XLU	S&P Utilities	46,450	0.1689	0.0932	**-48.7843**	**1.1473**	**0.8576**	**-0.1105**	0.0528
XLV	S&P Cons Services	47,740	0.1501	0.0830	**-45.2563**	**3.5692**	**0.8473**	**-0.1079**	0.0484
XLY	S&P Cyclical	47,159	0.1528	0.1770	**-46.3656**	**3.1726**	**0.9523**	**-0.1459**	0.0627
	Average		**0.1833**	**0.1165**			**0.8968**		

Significant coefficients (at 5%) are presented in bold.

EXHIBIT 12

Intra-Daily *dyna* Model Regression Results: International Funds

			Base Model	*dyna* Model					
ETF	Index	N	SD of Premium	SD of Premium	dIOPV	dFutures	AR(1)	MA(1)	SE of Regression
EWA	MSCI Australia	38,727	0.8628	0.7177	**-30.0137**	**8.6754**	**0.9954**	0.0087	0.0677
EWO	MSCI Austria	34,288	1.0482	0.8940	**-33.8722**	**7.0502**	**0.9949**	**0.0172**	0.0890
EWK	MSCI Belgium	31,434	0.7535	0.6251	**-21.2468**	**5.1433**	**0.9939**	0.0028	0.0688
EWZ	MSCI Brazil	14,516	0.9713	1.1157	**-26.8445**	0.0288	**0.9961**	-0.0024	0.0967
EWC	MSCI Canada	34,963	0.7487	0.7970	**-24.3869**	**-3.0257**	**0.9804**	**0.1179**	0.1408
EZU	MSCI EMU	13,780	0.5431	0.3062	**-10.8933**	0.4398	**0.9909**	**-0.0526**	0.0435
EWQ	MSCI France	42,783	0.6017	0.3688	**-23.0741**	**4.2270**	**0.9841**	-0.0046	0.0660
EWG	MSCI Germany	45,946	0.8124	0.4718	**-18.6974**	**4.2505**	**0.9894**	**-0.0124**	0.0695
EWI	MSCI Italy	38,534	0.6572	0.4290	**-13.1314**	**2.9695**	**0.9926**	-0.0064	0.0523
EWJ	MSCI Japan	47,159	1.0720	0.7290	**-26.9954**	-0.0155	**0.9954**	**0.0276**	0.0686
EWW	MSCI Mexico	42,679	1.1659	1.5604	**-44.6403**	**15.0147**	**0.9910**	**0.1788**	0.1778
EWN	MSCI Netherlands	38,279	0.5594	0.4270	**-30.9912**	**8.4906**	**0.9907**	-0.0051	0.0586
EWP	MSCI Spain	39,140	0.6149	0.4517	**-20.5170**	**5.2769**	**0.9924**	**0.0112**	0.0549
EWD	MSCI Sweden	36,910	0.6489	0.4681	**-11.7511**	**5.4271**	**0.9898**	**-0.1545**	0.0786
EWL	MSCI Switzerland	44,665	0.6687	0.4763	**-36.9133**	**3.4873**	**0.9917**	-0.0042	0.0614
EWU	MSCI UK	44,981	0.7494	0.5245	**-21.6385**	**5.0133**	**0.9939**	**-0.0334**	0.0599
	Average		**0.7799**	**0.6476**			**0.9914**		

Significant coefficients (at 5%) are presented in bold.

EXHIBIT 13

Persistence of Large Intra-day Premium (in Minutes): Domestic Funds

		Premium			Discount		
ETF	Index	N	Mean	Median	N	Mean	Median
DIA	DJIA	32	12.31	7.50	59	15.83	6.00
IJH	S&P Midcap	15	49.60	8.00	6	21.67	4.50
IVV	S&P 500	22	43.86	7.50	19	19.37	7.00
IWB	Russell 1000						
IWM*	Russell 2000	9	36.78	14.00	9	81.89	34.00
MDY*	S&P Midcap	19	35.79	11.00	17	13.82	12.00
QQQ*	Nasdaq 100	75	8.52	5.00	35	5.49	3.00
SPY	S&P 500	72	13.33	5.50	37	7.73	
XLB*	S&P Basic Industries	76	39.04	19.00	39	44.41	28.00
XLE*	S&P Energy	20	12.10	9.50	9	7.11	3.00
XLF*	S&P Financial	8	18.88	16.50	13	54.69	19.00
XLI	S&P Industrial	31	24.48	8.00	78	20.32	10.50
XLK	S&P Tech	221	4.65	3.00	163	4.34	3.00
XLP*	S&P Cons Staples	21	47.95	13.00	47	58.28	17.00
XLU	S&P Utilities	76	20.30	10.50	84	22.01	9.00
XLV	S&P Cons Services	54	8.80	5.00	80	28.76	10.50
XLY*	S&P Cyclical	4	22.75	10.50	13	11.31	4.00
	Average	**47**	**24.95**	**9.59**	**44**	**26.06**	**11.37**

Products with smaller standard deviations have an upper bound of 25 bps and a lower bound of 10 bps (from the mean) and correspondingly (−25 bps, −10 bps) for discounts. These are not starred.

*Products with large standard deviations. These have an upper bound of 50 bps and a lower bound of 20 bps (from the mean) and correspondingly (−50 bps, −20 bps) for discounts.

EXHIBIT 14

Persistence of Large Intra-day Premium (in Minutes): International Funds

		Premium			Discount		
		N	Mean	Median	N	Mean	Median
EWA	MSCI Australia	38	286.55	221.00	36	294.47	280.50
EWO	MSCI Austria	37	351.35	263.00	25	386.52	243.00
EWK	MSCI Belgium	26	343.15	274.00	35	225.51	149.00
EWZ	MSCI Brazil	23	218.61	130.00	28	205.25	111.00
EWC	MSCI Canada	82	64.88	56.00	72	87.11	49.00
EZU	MSCI EMU	10	96.50	43.50	5	126.40	64.00
EWQ	MSCI France	64	75.28	47.50	42	93.31	54.00
EWG	MSCI Germany	76	88.79	53.50	52	121.19	63.00
EWI	MSCI Italy	37	161.57	125.00	33	158.00	138.00
EWJ	MSCI Japan	51	225.96	139.00	46	243.89	176.50
EWW	MSCI Mexico	105	107.90	41.00	69	52.80	33.00
EWN	MSCI Netherlands	35	173.83	143.00	37	119.89	75.00
EWP	MSCI Spain	43	114.98	76.00	32	161.66	131.50
EWD	MSCI Sweden	47	131.51	113.00	48	139.00	123.50
EWL	MSCI Switzerland	48	158.50	104.50	45	159.16	114.00
EWU	MSCI UK	52	214.10	114.50	43	240.93	144.00
	Average	**48**	**175.84**	**121.53**	**41**	**175.94**	**121.81**

The upper bound is 50 bps and the lower bound of 20 bps (from the mean) for premiums and (−50 bps, −20 bps) for discounts.

EXHIBIT 15

Event Intervals for International Funds (in Minutes)

		Time Between	
ETF	Index	Quotes	Trades
EWA	MSCI Australia	103	27
EWO	MSCI Austria	163	43
EWK	MSCI Belgium	138	33
EWZ	MSCI Brazil	44	67
EWC	MSCI Canada	46	8
EZU	MSCI EMU	36	34
EWQ	MSCI France	44	12
EWG	MSCI Germany	28	5
EWI	MSCI Italy	82	22
EWJ	MSCI Japan	16	2
EWW	MSCI Mexico	29	10
EWN	MSCI Netherlands	85	30
EWP	MSCI Spain	94	30
EWD	MSCI Sweden	86	39
EWL	MSCI Switzerland	68	22
EWU	MSCI UK	40	10
	Average	**69**	**25**

NAV by approximately the amount the marginal domestic investor is willing to pay to avoid these restrictions.

2 See Engle and Granger [1987] for this theory and specification.

3 Even though we use last trade-based premium for comparison purposes, "premium" would refer to midquote-based premium throughout the article unless otherwise stated.

4 Potentially this would be a slightly different number for an investor considering creation from one considering redemption because of the difference between the buying and selling prices of the underlying securities.

5 Miller et al. [1994] define a price process where the measured price this period is a weighted function of measured price last period and true price this period.

6 The normality assumption can be weakened when the Kalman Filter is interpreted as the linear projection rather than the conditional distribution.

7 Bailey and Lim [1992] show that returns on closed-end fund stock prices are more highly correlated with the U.S. market returns than the corresponding foreign indices.

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