Time-Zone Arbitrage in Vanguard International Index Funds

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Abstract

Historically, mutual funds have often calculated their asset values for international mutual funds using stale prices, because some fund components finish trading before the market close. This caused daily fund returns to be predictable. This allows an arbitrage opportunity for investors who move their money at the end of the US trading day to reflect the next day change in European equities. We quantitatively trace the history of this phenomenon, known as time-zone arbitrage, in various mutual funds, particularly the Vanguard Fund Family, before and after the phenomenon became well known. The opportunity for TZA has diminished but not disappeared.

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1. Introduction

> The soaring use of market timing by the average fund owner – not only the illegal late trader nor the unethical time-zone trader – indicated that ordinary investors, using the finest vehicle for long-term investing ever designed, were engaging in excessive short-term speculation in fund shares. There's a lot of money sloshing around the mutual fund system.
>
> John C. Bogle, Founder and for many years CEO of Vanguard [Bogle, 2005, p152].

In this passage John Bogle, describes the phenomenon known as market timing that shocked many investors. Using market timing, some investors were able to securely profit, detracting value from the average buy-and-hold investor. This paper shows that Vanguard international index funds were not immune to the opportunity to profit from stale prices and market timing. However we find no evidence that market timing caused the returns of these funds or of other fund families to sink below those of their corresponding indexes. This appears to be so because, investors with Vanguard and other firms made limited use of market timing opportunities.[2]

In the past, market timers were able to capitalize on short-term structural inefficiencies in the global marketplace. There is no one standard framework for mutual funds to calculate the value of their assets after markets close. Further, accurate and up-to-date values are important to calculate in a globalized trading system where markets across the globe open and close at different times. European markets close at various times until 11:00 a.m. Eastern Time (ET) and Pacific markets close after midnight ET. Information and news never stop, long after the market in one time-zone closes, events and news are released that affect asset prices. Research has shown that increases in globalization, improvements in technology, and liberalized capital flows correspond to a larger correlation between all markets, particularly US market movement and subsequent next-day European movement [Bhargava *et al*, 1998]. When a foreign market closes, the assets traded on that exchange will artificially freeze in value as they are no longer actively

[2] Vanguard, at different times either charged a frequent trading fee (much like all international funds do now) or restricted frequent trading. Some funds at some times had purchase and redemption fees and have inhibited trading by requiring that trades be initiated by mail.

traded – this value for a mutual fund is called net asset value (NAV). These NAV's if used hours later are termed "stale prices."

Historically, U.S.-based mutual funds have calculated their value using stale prices for the assets that trade in foreign markets. The predictability of change in the stale prices when the foreign market opens creates an arbitrage opportunity. Consider an example: an investor stores her money in a U.S. market mutual fund and waits for a market signal such as significant increase in the U.S. market throughout the day. From this signal, she switches her money close to the end of the US trading day to a mutual fund holding a large proportion of European assets, because she expects a similar increase in the European market when the market opens. The investor gains both the return in the U.S. market and the expected corresponding rise in Europe. Similarly, when the U.S. market declines, the investor with funds in Europe can switch back at the end of the day, avoiding the loss in both the U.S. and European markets. This technique of exploiting the market discrepancy is a type of "market timing" or, more specifically, "time-zone arbitrage." Normally, once traders and investors are aware of possible arbitrage opportunities, the market reacts quickly and the opportunities disappear. This does not apply to the case of TZA with mutual funds – there is not an efficient market mechanism to eliminate profitability.

The existence of TZA has been documented in the past. Academics have published studies about the interrelation of markets for decades and the specific trading strategies have been described since 1998. In September 2003 Eliot Spitzer, then-New York Attorney General, publicly announced that he had evidence of mutual funds engaging in illegal trading arrangements [Hogue, 2005]. Most of these charges were levied against funds for allowing late trading - which was clearly illegal - but some charges included colluding with favored investors to exploit TZA. Ultimately, Spitzer recovered over $3.1 billion in mutual fund settlements [Hogue, 2005]. In response to time-zone market timing behavior many funds instituted more stringent trade limits, trade fees and account monitoring [Hogue, 2005]. While time-zone market timing is not explicitly illegal, the practice clearly dilutes shareholder value [Zitzewitz, 2003]. What is illegal is allowing favored investors to engage in market timing while barring others. On the other hand, it is legal for the general market timers to exploit the arbitrage at the expense of the buy-and-hold investors – a fact which has shocked the mutual fund industry [Houge, 2005].

Our analysis of TZA practices focuses on the Vanguard mutual fund family, as it is widely considered among the most reputable funds families and a standard-setter for fund

behavior. It also is the leader in providing international index funds, so it is natural to compare the performance of its international index funds with the international indexes to assess the damage that TZA has done to buy-and-hold investors. Vanguard founder and CEO, John Bogle, has also written extensively about mutual funds and long-term investment strategy. Bogle [2005, p. 151] states,

> The shocking truth about time-zone trading is that it went on for so long without significant defense being erected by managers. It has hardly been a secret. Academics have been publishing papers about it at least since the late 1990s.

This paper analyzes stale prices and time-zone trading strategies in Vanguard funds. We compare Vanguard funds to their competitors and the Spitzer investigated fund families. The contributions of our paper are

1. to reveal how the opportunities and profitability for time zone arbitrage differed between fund families and different funds;
2. to discover if and when the opportunities for time zone arbitrage disappeared;
3. to explore the cost of time zone arbitrage to Vanguard index fund investors;
4. to develop an alternative (and better) signaling mechanism for fund transfers;
5. to use a symmetric criterion for transferring funds back and forth between U.S. and foreign mutual funds. Like some of the previous studies, we perform the profitability calculations using a strategy in which the investors are always fully invested in either domestic or foreign equities.
6. to explore the causes and consequences of Eliot Spitzer's investigation of certain mutual fund families; specifically, did those fund companies he investigated demonstrate markedly inferior performance prior to the investigation, and did they markedly improve behavior after being fingered by his office?

This paper is organized into twelve sections.

Section 2 reviews the existing literature on market timing and stale prices.

Sections 3-5 explain the data and methods used.

Section 6 asks: Was there opportunity for TZA in the Vanguard European Index fund?

Section 7 asks: How profitable was TZA in the Vanguard European Index Fund?

Section 8 asks: How did TZA opportunities compare between fund families?

Sections 9 is a brief history of restrictions on frequent trading.

Sections 10 asks: How long did opportunities for TZA last?

Section 11 explores the morality of time zone arbitrage and its analysis.
Section 12 asks In spite of TZA did international fund returns beat their tracking indexes?
Section 13 concludes.

2. State of the Art

Market-timing in mutual funds was first documented by an academic paper in 1998 [Bhargava, Bose and Dubofsky]. Zitzewitz in 2003 [p. 245] writes that "this arbitrage opportunity has been understood by the industry for 20 years and exploited since at least 1998…" The existing literature on market timing and stale prices in mutual funds focuses on two segments. The first segment documents various signaling mechanisms and trading strategies to prove that large excess returns are possible with TZA in mutual funds. The second focuses on documenting the loss in shareholder value caused by market timing and the possible solutions to prevent time-zone arbitrage. We explore both segments of the literature.

TZA has been documented by several different academic studies. The first publication to document returns from time-zone arbitrage was Bhargava, Bose, and Dubofsky in 1998. They used a 1.5 standard deviation increase in the S&P from the previous day's closing price level to signal the investor to transfer from the S&P500 index to a basket of five foreign equity funds. The investor returns her funds to the U.S. at the end of the first day that the S&P declines. They documented that following this strategy generated a return of 800 basis points a year above that of the S&P500.

Chalmers, Edelen, and Kadlec in 2001 showed the predictability of foreign fund returns using a sample of 943 mutual funds from February 1998 to March 2000. They regressed foreign fund returns on daily lagged S&P index returns (the previous day close to 3:55 p.m.), and returns over the last two hours that the U.S. market was open (1:55 p.m. to 3:55 p.m.). They discovered that the former trigger generates a higher return. Their investment strategy, using cash or a combination of cash and futures markets to reduce risk was more complex than our strategy of switching back and forth between domestic and foreign equity mutual funds. Also, they aggregate funds whereas we look at a set of individual funds. Boudoukh, Richardson, Subrahmanyam and Whitelaw (BRSW) in 2002 analyzed stale prices in mutual funds. BRSW focused on excess profits and Sharpe ratios to demonstrate the benefits of exploiting stale

pricing. They examined the 1997-2001 time period using fifteen international mutual funds to track trading strategy performance. The strategy they employed switched capital between a money market account and the mutual fund based on the movement of the futures market, using the S&P for the European funds and Nikkei 225 futures for the Japanese/Pacific funds. For a signal they used (1) the difference between the closing Nikkei level in Japan and the implied Nikkei level at 4p.m. traded on the Chicago Mercantile Exchange (CME), (2) the within-day change on the S&P 500 and (3) a combination of the two. Ultimately, the combination performed the best. BSRW used two thresholds: 0.5% and 1% expected excess returns to signal a switch from the money market to the mutual fund. On days that the expected excess is less than zero the investor moves out of the international fund. They measured returns to the strategy against a benchmark of buy-and-hold returns of the particular mutual fund.

Like us, BRSW has a section that focuses on Vanguard funds. They used Vanguard International Growth, Vanguard Pacific Equity Index, and the Vanguard European Equity Index to demonstrate an S&P signal trading strategy that moves funds from Prime Money Market fund (which invests in high-quality, short term commercial paper) to a basket of international Vanguard funds or reverse if the signal is negative. BRSW used a time period from January 1997 to November 2000, finding that there is a large excess return from replacing buy-and-hold with either the 0.5% or .25% expected return thresholds over the time period. Their trading strategy, unlike ours, has capital in the international funds less than 10% of the time.

Bhargava and Dubofsky [2001] also consider TZA in Vanguard international index funds, calculate the return from TZA, and call for more fair value pricing.

The Greene and Hodges [2002] study focused primarily on the dilution of value to buy and hold investors caused by volatile fund flows from stale prices and market timing. They used the S&P as an indicator. The trader switches to the international fund if the S&P daily return is positive and holds cash the next day if the S&P is negative. The authors used a time period from January 1, 1993 through December 31, 1997. They used 84 international funds to measure the average return of each strategy. Greene and Hodges also examined the correlation between the movement in a fund's net fund flow and the following day's return. The average correlation is found to be 0.0512 for international funds, exhibiting apparent market timing activity. These results are different from the 2001 findings by Goetzmann, Ivkovic, and Rouwenhorst (GIR), who find almost no correlation between fund flows and fund returns for international mutual

funds. Our paper examines a longer and more recent time period and does not analyze net fund flow.

In 2001 Goetzmann, Ivkovic, and Rouwenhorst documented the inflows and outflows caused by time-zone arbitrage. The authors used a diverse 391-fund sample to test whether the daily S&P 500 index return is a profitable indicator for short-term international investment decisions. They found, through high correlations between the return of the S&P and the international mutual funds next day returns, that almost every fund is vulnerable to stale pricing. They also compared the change in the NAV of the funds to the magnitude of the in/out money flow. This yielded an overall small positive correlation between net fund flows into international funds and next day international fund returns. Not all of their correlations are positive: the spread of the correlations between fund flows and next day fund returns was -0.029 to 0.083.

In 2003 Zitzewitz documented TZA and suggested possible solutions to protect the long-term buy and hold investors. Zitzewitz used the TrimTabs database and filled in missing data with figures from Yahoo to get the daily returns of various mutual funds for January 1998 through October 2001. Unlike the other studies that compared returns to a buy-and-hold strategy, Zitzewitz measured excess returns against a mixture of cash and funds that had the same daily fund exposure. Zitzewitz also analyzed domestic small-cap equities and high-yield and convertible bonds that trade infrequently and had wide bid-ask spreads, making them susceptible to stale pricing. He discovered that excess returns are highest in international equity funds, a finding consistent with the rest of the literature. Among other triggers he uses the change in the S&P 500 index from the previous close until 11:30 a.m. and from 11:30 a.m. until its close. In this paper we use a finer grid of times. In analyzing time zone arbitrage he writes [p. 245]

> These abnormal returns come at the expense of long-term shareholders, dilution of whom has grown in international funds from 56 basis points in 1998-99 to 114 basis points in 2001. .. The speed and efficacy of a fund's actions to protect shareholders from dilution is negatively correlated with its expense ratios and the share of insiders on its board, suggesting that agency problems may be the root cause of the arbitrage problem.

These considerations led us to expect less dilution in Vanguard funds.

The basic framework explaining TZA has been placed. Our paper builds on this literature by using a much longer and more recent time period (January 1st 1997 – December 31,

2007) and employing a strategy that is clearer and more feasible for many investors. This enables us to evaluate when the arbitrage opportunity from market-timing ended. The trading strategy and calculation of the constrained regression is a new methodology that is accessible to the unsophisticated investor and simple to execute.

3. The Futures Data

Our sample uses two different sets of data, mutual fund daily closes adjusted for dividends and five-minute changes in the S&P 500 index. The data used in the regressions are quotes for the S&P500 futures index for the next available settlement date rather than the actual S&P500 index. But as documented below, the two series are very similar, so this choice does not significantly affect the results.

The data track the five-minute movement in S&P 500 futures prices, generally for the next settlement date. To ensure that the S&P futures accurately measure the actual S&P, we calculated the correlation between the day-to-day proportional changes in the S&P futures 4 p.m. price and the S&P 500 adjusted close using daily data from Yahoo. Exhibit 1 shows the correlations between the two proportional changes: every year has an extremely high correlation, the lowest year being a still very high .986 in 1997. The high correlations indicate that the futures data is close enough to the actual S&P that the indicators and signaling will be accurate enough for our purpose.

Exhibit 1:
Correlation between the Proportional Change in the Actual S&P 500 and S&P Futures.

Year	*Correlation*
1997	0.986
1998	0.991
1999	0.987
2000	0.988
2001	0.993
2002	0.998
2003	0.998
2004	0.999

4. Fund Selection

We examine sixteen mutual funds in three categories: Vanguard Family, Vanguard Competition, and families investigated by Eliot Spitzer. Within the Vanguard family we choose to focus on its index funds: **VEURX**: Vanguard European Stock Index, **VEIEX**: Vanguard Emerging Market Index, and **VPACX**: Vanguard Pacific Index. We also used **VINEX**: Vanguard International Explorer, a managed fund of medium sized company stocks.

For our analysis of non-Vanguard funds we selected a fund from several of various fund families that existed for as much of the 11 year period 1997 through 2007 as possible, with a preference for funds which closely tracked the European index, and had neither a value nor a growth orientation. As discussed below, we felt that the TZA opportunities were likely to be greatest for European funds, so we tried to select European funds. At the end of the paper we compare fund performance with a basket of indexes that mimics fund returns. MSCI indexes for international value, international growth and international small company stocks became available after the beginning of 1997, so we tried to select the international funds which did not focus on the characteristics: small, value, or growth.

For the Vanguard competition, we selected four fund families that closely compete with Vanguard for business, attracting customers who value low expenses and investment expertise DFA, Fidelity, GMO, and T. Rowe Price (the first three of which are discussed in Tower and Yang [2008], Zheng & Tower [2005], and Tower[2008]) although DFA and GMO are appropriate only for high wealth investors. Within each fund family, we generally picked the fund with the lowest expense ratio and highest proportion of European assets that were in existence for most of our period, January 1, 1997 –December 31, 2007. We chose those with a high proportion of European assets because the Vanguard European Index Fund is the largest of Vanguard's international index funds, so time-zone arbitrageurs would be likely to feel that their activity would be least likely to be noticed in this fund. European funds tend to be relatively large for other fund companies as well. However, in the case of Vanguard we did not use the Admiral class funds, which had lower expense ratios than the investment class funds, because some of the Admiral class funds were introduced after our time series began. The four funds in the Vanguard competition are **DFIVX**: DFA International Value I, **FIEUX**: Fidelity Europe Fund, **GMOFX**: the GMO Foreign Fund III, and **PRESX**: T. Rowe Price Euro Stock.

The Spitzer category consists of **AEDBX**: AIM European Growth, **EUGAX**: Morgan Stanley European Equity F, **FIECX**: Federated International Equity Fund C, **GSIFX**: Goldman Sachs Concentrated International Equity A, **JAOSX**: Janus Overseas, **MGEBX**: Van Kampen Global Value Equity B, **MWEFX**: MFS Global Equity A, and **PEUGX**: Putnam European Equity Fund A,. We selected one fund each from several of those families investigated by Spitzer[3].

5. The Trading Strategy

The sample of mutual fund data to devise and assess our trading strategy is from Yahoo. These data are easily accessible online. Any unsophisticated investor could easily obtain the data for the purpose of studying or exploiting time-zone arbitrage. He would, however, need to record the data to ascertain patterns, since the data disappears from Yahoo after five days. The S&P futures data was available to us only through 2004, so our Exhibits 1 and 2 terminate then.

Trading hours in Europe briefly overlap with trading hours in the U.S. – about one and a half hours between 9:30 a.m. and 11:00 a.m. This leads us to believe that the European market already reflects the news and information from the early part of the U.S. trading day, leaving the afternoon hours for the information sets behind values in the two markets to diverge. Different European markets close at different times, and some foreign markets close before the U.S. market opens. We regressed proportional changes in international mutual fund adjusted price on the proportional changes in the dividend-adjusted price of the S&P 500 index over various previous periods. The logic of time zone arbitrage tells us that movements in the S&P should be accompanied by subsequent movements in the international mutual fund in the same direction. Consequently, we constrained all regression coefficients to be positive.

We used six distinct time periods: 9:35a.m-4:00p.m., 10:00a.m.-4:00p.m., 10:30a.m.-4:00p.m., 11:00a.m.-4:00p.m., 11:30a.m.-4:00p.m., and previous day's close-4:00p.m. The change in each time period was calculated by dividing the change in the S&P over the period to the 4pm close by the S&P value at the beginning of the period. The mutual fund return was

[3] The four original mutual fund companies the New York Attorney General focused on were Bank of America, Janus Capital Group, Bank One and Strong Capital Management. Since the investigation and settlement many of those original funds have been shut down, so they are not included in our study.

He subsequently investigated eight additional fund families. These are Van Kampen, Goldman Sachs, Morgan Stanley, Putnam, Federated, AIM, Janus, and MFS. Those fund families have been charged, probed or fined by his office. We looked through the reports online from various sources such as *Wall Street Journal, CNN/Money, Business Week* and *Fortune* to get this list of fund families.

calculated by using the proportional change of the end of day adjusted return, where "adjusted" means adjusted for dividends.

We calculated the TZA opportunity model for each year using daily data. We divided the data into annual segments to explore whether the opportunity changed as investors and mutual fund families became aware of the issue. In calculating the profitability of the strategy, we assumed that time-zone arbitrageurs behaved as if the model from the previous year obtained. Thus time-zone arbitrageurs made decisions using current day (and previous day's close) data along with last year's coefficients.

The S&P trade indicator was calculated by multiplying the regression coefficients from the previous year times the corresponding time period proportional change in the S&P and adding them together. We assumed that the trades occur at the US market close of 4:00 p.m. We tested four threshold levels for predicted changes in the international mutual fund: 0.1%, 0.5%, 0.7% and 1%. We assumed that the arbitrageur moves from the US into the foreign mutual fund whenever the indicator exceeds the threshold level, and moves back from Europe into the US whenever the indicator exceeds the threshold level in the opposite direction. For example, for the 1% threshold we assumed that the investor buys the European fund whenever she anticipates that the next day's return on the European fund will exceed 1%, and she sells it when she anticipates that the next day's loss on the European fund will exceed 1%. Programming Excel to perform the calculations is easy.

We measured the profitability of time-zone arbitrage as the annualized excess return of the trading strategy over an annualized benchmark return. The benchmark return is what the return would have been from investing a constant fraction, K, of the portfolio in the foreign mutual fund and the rest of the portfolio in the Vanguard 500 index fund, where K is the fraction of the portfolio which under the arbitrage strategy is invested in the foreign mutual fund. The Vanguard 500 index fund mimics the return of the S&P500 index. This benchmark strategy assumes daily rebalancing. The benchmark return is calculated by weighting each day's return in America and Europe by the proportion of time in each market under the arbitrage strategy: $B(r) = K*\mathrm{R}_e + (1-K)*R_a$, where B(r) is benchmark return, K is the proportion of time in Europe; R_e is the return in Europe; R_a is the return in America.

6. Was There Vulnerability to TZA in the Vanguard European Index Fund?

The regression coefficients of the Vanguard European Index Fund from years 1997 to 2004 are presented in Exhibit 2. The sum of the coefficients demonstrates the strength of the S&P's predictive power on Vanguard Europe's return the following day. Each year has a large coefficient sum, demonstrating a significant ability for market timers to use the S&P signals to exploit the Vanguard Europe Index.

We ignored the constant term in the regressions, focusing on predicted changes in the international funds due to changes in the S&P. For 1997, a 1% change in the S&P overnight, with no further changes predicts a 0.170% change in the same direction for the international fund the following day. A 1% change in the S&P500 index fund between 11:30am and 4:00 pm with no changes before then, results in a predicted change equal to the sum of the coefficients, 0.462%. Thus more recent changes have bigger impacts than earlier changes.

The F statistic of 31.272 indicates that the model is significant at the 0.01% level.[4] The continuously compounded geometric average return of the Vanguard S&P 500 index, including dividends is 27.5% per year, and the continuously compounded return of the Vanguard Europe fund is 23.5% per year.

The years with the lowest sum of the regression coefficients are 2000 and 2001 and the year with the highest is 2003 with 0.527. The F-Test is highly significant in

[4] We use the F-test to measure the significance of the results. The F test is used to derive the statistical significance of the explanatory power of a model over that of an alternative. F is calculated as follows: $$F = \frac{\left(\frac{RSS_1 - RSS_2}{p_2 - p_1}\right)}{\left(\frac{RSS_2}{n - p_1}\right)}$$

where RSS_2 is the residual sum of squares of the dependent variable (the variance not explained by the model); p_2 is the number of parameters in the model; p_1 is the number of parameters in the alternative; n is the number of observations. In our case, our model has p_2 equal to the number of non-zero coefficients (including the constant term), so p_2 is less than or equal to seven. The alternative model is that the dependent variable is independent of any explanatory variables except for a constant, so $p_1 = 1$. We used daily data. There are roughly, 250 daily observations on the stock market in each year, so n is roughly 250. The F test significance table tells us that with these parameters the model is significantly better than the alternative at the 1% level, if the F exceeds 2.067.

every year. In efficient markets one would expect F-Statistics less than 2.067 (the one percent level of significance).

Lastly, it is interesting that each of the six time periods contribute varying amounts to the impacts of the S&P on Vanguard Europe. The lack of constancy of the distribution of the coefficients from year to year shows some variation of the predictive power of the S&P returns.

Exhibit 2.
Time Zone Arbitrage Predictors for Vanguard European Index Fund: Does the S&P predict next day return?

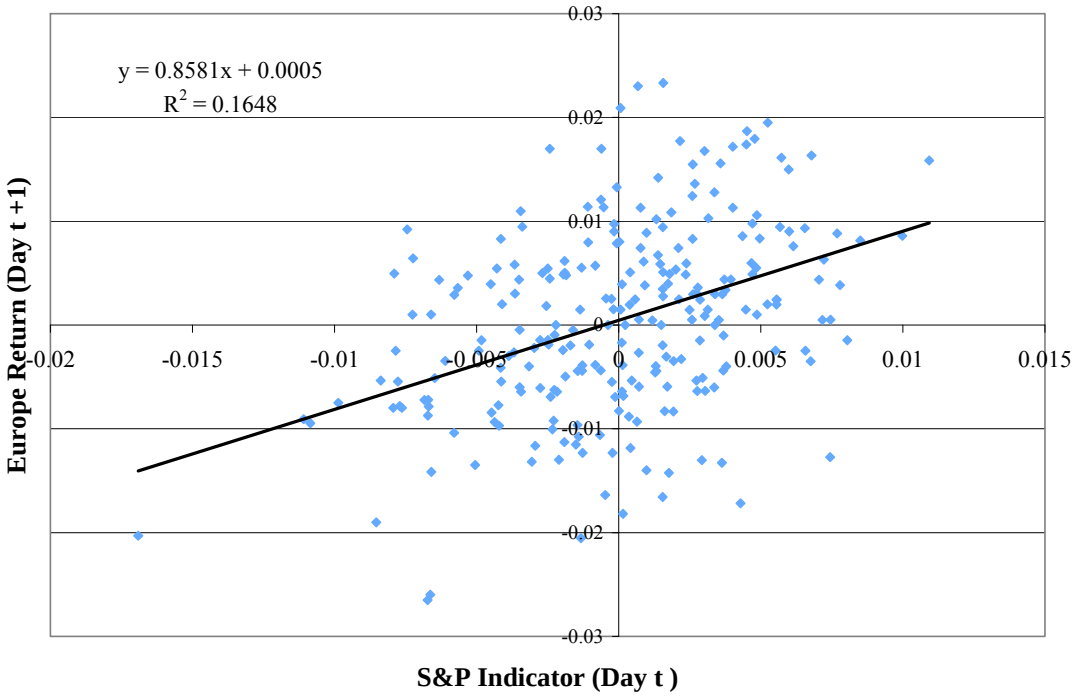
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*
9:35 a.m.-4:00 p.m.	0.204	0.000	0.306	0.000	0.011	0.000	0.000	0.000
10:00 a.m.-4:00 p.m.	0.061	0.014	0.000	0.000	0.164	0.000	0.043	0.000
10:30 a.m.-4:00 p.m.	0.028	0.355	0.000	0.000	0.183	0.416	0.000	0.000
11:00 a.m.-4:00 p.m.	0.000	0.000	0.146	0.000	0.000	0.000	0.361	0.000
11:30 a.m.-4:00 p.m.	0.000	0.151	0.000	0.000	0.000	0.021	0.124	0.000
Previous Day Close-4:00 p.m.	0.170	0.000	0.000	0.377	0.000	0.000	0.000	0.379
Sum of Coefficients[1]	0.462	0.520	0.452	0.377	0.358	0.437	0.527	0.379
Standard Deviation of Europe Return[2]	0.0090	0.0135	0.0090	0.0120	0.0138	0.0172	0.0111	0.0084
Standard Deviation of Unexplained Europe return	0.0073	0.0125	0.0080	0.0107	0.0132	0.0163	0.0104	0.0079
F-Statistic	31.272	10.154	14.910	15.568	4.783	7.352	9.391	7.473
S&P return CC	0.275	0.236	0.178	-0.107	-0.253	-0.266	0.234	0.086
Europe return CC	0.235	0.254	0.155	-0.170	-0.297	-0.198	0.327	0.190

1. Coefficients are sensitivities of next day Europe returns to S&P returns. A change between 11:30 a.m. and 4 p.m. predicts a change equal to the sum of the coefficients.
2. Standard deviations of Europe return are proportions/day. Returns CC are continuously compounded geometric average returns expressed as proportions/year.

The method of calculation is the following. We used Microsoft Excel's solver add-in. This easy-to-use add-in allows one to select weights to minimize a variable subject to constraints. We programmed Excel's solver to select the weights on the returns of the S&P and the constant term that minimize the variance of the return differential between the international mutual fund and the weighted sum of the previous S&P returns augmented by the constant term such that no weight is negative (signifying that the S&P moves the international fund in the same direction on the following day).

Exhibit 3, below, shows the reliability of the S&P indicator with the previous year's coefficients for 1999. For the Vanguard Europe Index Fund in the year 1999 it is apparent that there is a strong impact of the indicator on the actual European return the following day, a regression coefficient of 0.86, meaning that a prediction of a 1 % age point rise results in a next day return on average of 0.86% age points above the mean value. In 1999, the sum of the coefficients was 0.452, also reflecting the arbitrage possibility for profiting from recent changes in the S&P. Had we used the coefficients obtained for 1999 to evaluate predictions in that same year, we necessarily would have obtained a slope of 1, when the actual return is graphed on the predicted return.[5]

Exhibit 3.
Vanguard European Index Fund 1999: Reliability of the Predictions (proportional changes on axes)



[5] Had we chosen to regress the subsequent performance differential of the European fund over that of the S&P500 index fund, we would have obtained a closer fit. However, using the differential as our dependent variable would not have changed our analysis so long as movements in the S&P500 index fund are not autocorrelated.

7. How Profitable Was TZA in the Vanguard European Fund?

To illustrate the possibility of time-zone arbitrage concretely we use a simple trading strategy with the Vanguard European Fund. Initially, 100% of the portfolio is held in an S&P 500 index fund. For our calculations we use the Vanguard fund (VFINX). If on a given day the indicator exceeds the threshold and the assets were not already in the European index than the funds are transferred at the end of the US day to the European Index. The capital is switched back to an S&P fund if the predicted Vanguard return is more negative than the negative threshold.

Exhibit 4 reports the number of fund switches, the fraction of time spent in the European mutual fund, and the returns from the benchmark and strategy. As we can see from Exhibit 4, this trading strategy is highly successful in producing excess returns. Excess returns are highest using the 0.1% threshold and then decrease as the threshold increases. Using a 0.1% indicator the highest annualized excess return was in 2003: 106% per year continuously compounded. The number of switches stayed in the range of 90 to 120 year-to-year and the time spent in the European fund hovered around 50%.

The .1% threshold returns the highest excess return. Even at the 0.5% indicator level, the strategy always made a large excess return over the benchmark. As the threshold for the signals increases, the excess return decreases. At the 1% level the strategy is not reliably more profitable than the benchmark.

With the 0.1% threshold the excess return is greater than 24% per year through 2004. With 0.5% it exceeds 21% per year through 2003, but is still over 4% in 2004. With 0.7% it exceeds 12% per year through 2001. With 1% it is positive only in years 1999, 2000, and 2001.

Exhibit 4.

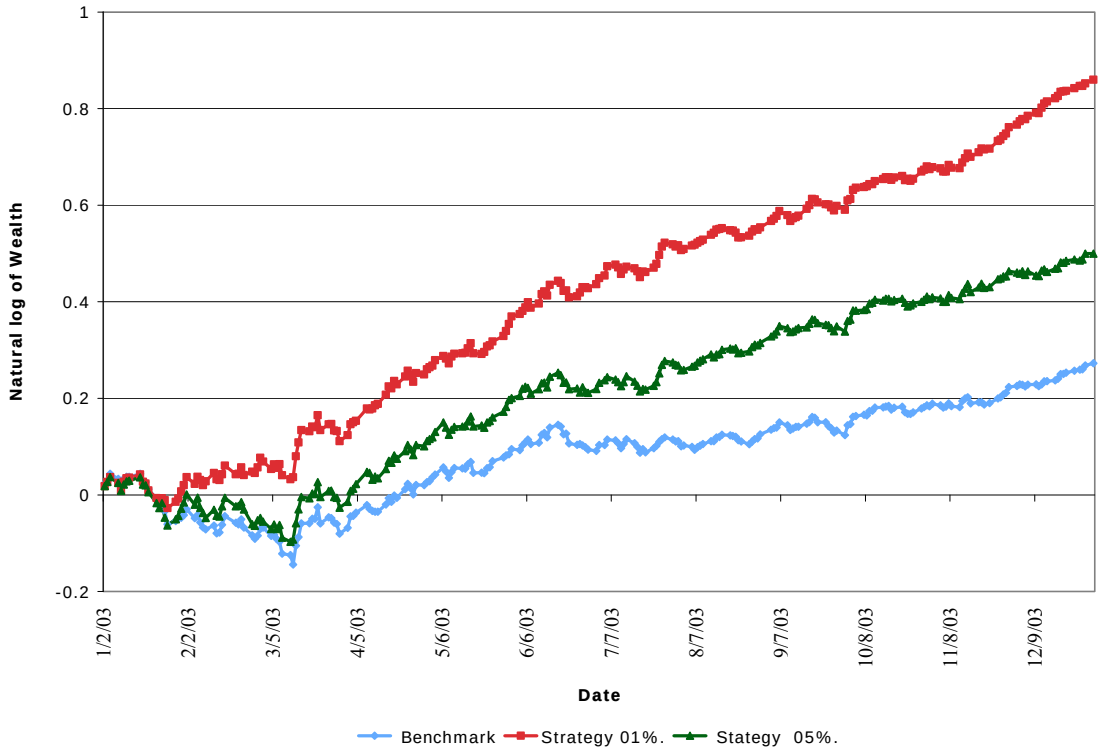
Vanguard Europe: The Return From Time-Zone Arbitrage (proportion/year)

Year	1998	1999	2000	2001	2002	2003	2004
.1% Indicator							
Switches per year	107	120	99	94	109	115	90
Time Share in Europe	0.548	0.508	0.488	0.550	0.494	0.608	0.520
Benchmark Return CC	0.230	0.158	-0.112	-0.315	-0.262	0.278	0.135
Strategy Return CC	0.607	0.547	0.130	0.114	0.315	0.868	0.442
Excess Return CC	0.377	0.390	0.242	0.429	0.576	0.589	0.307
Excess Return Annualized	0.576	0.558	0.245	0.391	0.600	1.060	0.411
.5% Indicator							
Switches per year	29	33	41	21	33	24	14
Time Share in Europe	0.718	0.496	0.512	0.661	0.542	0.608	0.596
Benchmark Return CC	0.231	0.158	-0.111	-0.324	-0.258	0.278	0.284
Strategy Return CC	0.473	0.395	0.115	-0.066	0.043	0.502	0.320
Excess Return CC	0.241	0.237	0.226	0.259	0.302	0.224	0.036
Excess Return Annualized	0.344	0.313	0.227	0.213	0.272	0.331	0.048
.7% Indicator							
Switches per year	14	15	26	7	11	7	2
Time Share in Europe	0.802	0.448	0.603	0.900	0.482	0.773	0.131
Benchmark Return CC	0.231	0.159	-0.109	-0.344	-0.262	0.293	0.094
Strategy Return CC	0.412	0.330	0.008	-0.182	-0.268	0.348	0.132
Excess Return CC	0.181	0.171	0.117	0.162	-0.006	0.056	0.038
Excess Return Annualized	0.250	0.219	0.111	0.125	-0.004	0.077	0.043
1% Indicator							
Switches per year	5	2	6	2	3	1	0
Time Share in Europe	0.226	0.234	0.825	0.992	0.518	0.259	0.000
Benchmark Return CC	0.225	0.161	-0.105	-0.345	-0.260	0.246	0.080
Strategy Return CC	0.200	0.255	-0.089	-0.255	-0.315	0.211	0.080
Excess Return CC	-0.025	0.094	0.015	0.090	-0.055	-0.035	0.000
Excess Return Annualized	-0.031	0.116	0.014	0.067	-0.041	-0.044	0.000

Exhibit 5 shows a chart of wealth arising from the trade strategy at the 0.1% threshold, the .5% threshold and the benchmark in 2003, starting with one dollar. The graph clearly illustrates the consistency of the excess returns from the market timing strategy. The 0.1% strategy performed the best with the 0.5% positioned securely

between the 0.1% strategy and the benchmark. We see from Exhibit 4 that trading 115 times produced a continuously compounded return of 86.8% in that year. From Exhibit 4, the large benchmark return of 27.8% in that year helped generate the larger excess return between the benchmark and 0.1% strategy when total return is used instead of the continuously compounded excess return (106% as opposed to 58.9%).

Exhibit 5.
Natural log of Wealth in 2003 for Arbitrage between Vanguard European index fund and Vanguard S&P500 index fund, starting with one dollar.



8. Were All Fund Families Vulnerable to TZA?

Exhibit 6 displays the regression coefficients of all sixteen mutual funds in 1999. From the grouping of mutual funds, the Vanguard family funds on average demonstrate greater predictive strength than its competitive funds of DFA, Fidelity, GMO and T. Rowe Price. In 1999 Vanguard funds average a .398 sum of coefficients, with competitive funds averaging .337 and Spitzer's funds .419. One should not over analyze

the results of the fund group averages as each fund had distinct load fees, management and investment strategy (e.g. growth vs. value) and country composition. What is important is that market timing opportunities existed for the wide range of funds in all three classes, not only those formally investigated. All the funds exhibit significant F-tests exposing them to the possibility of arbitrage.

Exhibit 6.
Time-Zone Arbitrage Predictors for 1999

	9:35	*10:00*	*10:30*	*11:00*	*11:30*	*Previous Day*	***Sum of Coefficients***	***F***
Vanguard								
VEURX Europe Index	0.306	0.000	0.000	0.146	0.000	0.000	0.452	14.90
VINEX International Explorer (mid size	0.099	0.000	0.012	0.000	0.000	0.179	0.290	15.10
VEIEX Emerging Markets	0.000	0.000	0.000	0.000	0.000	0.395	0.395	13.20
VPACX Pacific	0.000	0.000	0.000	0.000	0.000	0.454	0.454	12.80
Competition								
DFIVX DFA International Value I	0.149	0.000	0.000	0.000	0.000	0.160	0.309	14.40
FIEUX Fidelity Europe Fund	0.293	0.000	0.000	0.105	0.000	0.037	0.435	13.40
GMOFX GMO Foreign Fund III	0.007	0.000	0.000	0.052	0.000	0.208	0.267	7.00
PRESX T. Rowe Price Euro Stock	0.292	0.000	0.000	0.138	0.000	0.000	0.430	14.33
Spitzer's Funds[1]								
MGEBX Van Kampen Global Value Equ	0.188	0.000	0.000	0.000	0.000	0.009	0.197	6.30
GSIFX Goldman Sachs Int'l Equity A	0.235	0.038	0.000	0.027	0.000	0.158	0.458	13.20
EUGAX Morgan Stanley European Equi	0.343	0.011	0.000	0.216	0.000	0.000	0.570	20.00
PEUGX Putnam European Equity Fund	0.328	0.000	0.000	0.167	0.000	0.021	0.516	18.40
FIECX Federated International Equity F	0.167	0.000	0.000	0.000	0.000	0.335	0.503	20.10
AEDBX Aim European Growth	0.340	0.000	0.000	0.000	0.000	0.091	0.431	17.80
JAOSX Janus Overseas	0.278	0.000	0.000	0.000	0.000	0.257	0.535	20.74
MWEFX Global Equity A	0.205	0.000	0.000	0.000	0.000	0.054	0.259	9.13
Vanguard Average	0.101	0.000	0.003	0.036	0.000	0.257	0.398	14.00
Competitors Average	0.150	0.000	0.000	0.053	0.000	0.135	0.337	11.60
Spitzer Average	0.258	0.007	0.000	0.059	0.000	0.095	0.419	15.00

9. Restrictions on Frequent Trading: A Brief history

During the period, Vanguard had rules which restricted frequent trading. But Dan Wiener in 1999 in *The Independent Advisor for Vanguard Investors* noted that Vanguard permitted frequent small trades for rebalancing purposes, so the restriction of frequent trading was not complete.

To some degree that is still the case. The redemption fee is currently applied on a first-in-first-out, fifo, basis. If one has purchased the bulk of his holdings in the Vanguard European Stock Index Fund over 60 days ago, and purchases one percent more and then the next day sells two percent of his holdings—those shares which he has held for more than 60 days, he does not pay the two percent redemption fee. An investor who has sold shares in the European Stock Index Fund in the last 60 days may buy back shares only by mail—not by the internet or by telephone. One can, however, engage in telephone or on line rebalancing every day by using two accounts, say an employer account and an IRA, one for sales and one for purchases.

The existence of opportunities for time zone arbitrage put financial advisors in an awkward position. They have a fiduciary duty to their clients to use strategies to maximize client returns, so those who were aware of opportunities for time zone arbitrage had an obligation to time rebalancing and dollar cost averaging to take advantage of it.

In June 2008 Vanguard Emerging Markets Index Fund has a purchase fee and a redemption fee each of 0.5%, which is paid into the fund. Vanguard European Stock Index Fund, Vanguard International Explorer Fund, Pacific Stock Index Fund all have a redemption fee if held less than two months, which again is paid into the fund.

In two 2005 articles Dale discusses the tightening of restrictions on frequent trading at that time.

Dale [2005a] writes:

> **Vanguard Group** is moving to clamp down on investors who frequently move in and out of its mutual funds.
>
> As of Sept. 30, investors won't be able to buy shares of a Vanguard fund by phone or online within 60 days of selling shares in the same fund. The firm will allow the repurchase of shares within 60 days by mailed check, however.
>
> The mutual-fund company currently allows investors to make unlimited round trips between funds, as long as it doesn't deem the trades large enough to have an adverse impact on managing the funds.
>
> • • •
>
> Vanguard has long charged fees to investors who redeem shares of its funds within a given holding period. For many funds, investors are charged 1% if they sell shares within one year. Beginning Sept. 30, the firm plans to begin levying the 1% fee on fund shares sold through a financial advisor during the specified holding period. The fees will apply to participants in employer-sponsored retirement plans, starting Dec. 31, 2005.

Dale [2005b] writes

> Last month, **Vanguard Group** became the latest fund company to say it will levy redemption fees on participants in employer-sponsored retirement plans that use its funds. Vanguard has long charged the "retail," or individual, investors in many of its funds a 1% fee if they sell shares within a year of purchasing them. Beginning Dec. 31, the company will extend these fees to retirement plans.
>
> Vanguard doesn't expect many plan participants to pay the new fees, because nearly 90% don't make an exchange in a given year, said John Demming, a Vanguard spokesman. Fees could potentially be triggered by annual rebalancing of 401(k) portfolios, but many plan participants don't rebalance within a year, he said.
>
> Employees enrolled in company retirement plans used to fly under the radar when trading in and out of funds within a short time span. But mutual funds are clamping down on the activity, largely because of regulatory probes into rapid trading, also known as market timing.
>
> •••
>
> T. Rowe Price charges redemption fees only on transactions that it believes can be used for market-timing activities… T. Rowe began charging fees on funds in 401(k) plans in January.
>
> Before the SEC proposal [that fund companies assess a mandatory 2% redemption fee on trades within a five-day period], most funds didn't charge redemption fees in 401(k) plans. Fidelity was the first to require that any custodian using its funds track each investor's position. Late in 2003, the company began notifying omnibus account holders that they would be required to assessed and collect redemption fees at the individual investor level in retirement plans—or cease offering Fidelity funds that carried redemption fees.

The SEC [2006] reports, "On March 11, 2005 the [SEC] adopted rule 22c-2

> to help address abuses associated with short-term trading of fund shares… Rule 22c-2 provides that [the vast majority of funds] must consider whether to impose a fee up to two percent of the value of shares redeemed shortly after their purchases ('redemption fee'). The rule also requires such a fund to enter into agreements with its intermediaries that provide the fund management the ability to identify investors whose trading violates fund restrictions on short-term trading."

Thus redemption fees are not required.[6]

10. Is Vulnerability to TZA Gone?

Excess returns earned by time-zone trading come at the expense of the long-term investor. As John Bogle [2005, p.153] states, "Long-term fund investors pay a heavy penalty for investor activity by short-term fund owners. When equity funds hold cash as

[6] One reader reported that he used TZA extensively with Vanguard through the 1990's, within the context of this Vanguard 401-k plan. Since then fair market pricing and stringent frequent trading rules have made TZA unprofitable. Another reader reported receiving a letter from Vanguard in late 1999, which threatened to cut off trading privileges unless he reduced the frequency of his trades. He moved his 401k account to another provider who never complained about frequent trades. Yet another reader wrote "I played the game for about 21 months in my 401k. I was able to grow my portfolio approximately 70% by moving between a stable value fund and a Berstein international fund (during a period of a down market). Near the end of 2003 I had to end this strategy due to menacing letters from my 401k provider, and trading restrictions that they started to impose.

a redemption reserve, long-term returns are diluted." Much of the literature has examined and measured fund dilution from market timing by calculating the profits that arbitrageurs make from buying the fund when prices are stale and subtracting them from the return of the fund [Zitzewitz, 2003].

Our S&P futures data carries only through 2004. We want to discover the history of the TZA vulnerability for a number of mutual funds: the Vanguard index funds, Vanguard's competitors and the Spitzer prosecuted families.

Consequently, we estimated a simpler but feasible model. We wanted to find the benefit from switching out of a US mutual fund into a foreign mutual fund. Consequently, we regressed the proportional return of each mutual fund minus that of the Vanguard 500 index fund on the S&P500 adjusted proportional return from the previous day. The coefficients from these regressions are shown in Exhibit 7. We used all observations from each year, except 2008 data ends on July 9. The regression coefficients indicate the effect of a one percent increase in the S&P 500 index on the next day return as a percent due to switching into the foreign fund. We name the coefficient "return sensitivity."

Exhibit 7 shows shows annual that for all the 16 funds considered there is not a single negative coefficient from 1997 through 2008. In 2007 the average coefficient for the three groups: Vanguard, Vanguard's competitors, and the Spitzer funds are all positive. Thus, TZA vulnerability persisted through June 9, 2008.

Exhibit 8 graphs the average regression coefficients for the Vanguard funds, its competitors and the Spitzer funds. We included in our averages all 16 funds. Over the period the average return sensitivity trended downward, but for each group it was positive in every year. Thus the opportunity for TZA has still not disappeared. John Bogle's concern about the issue was still relevant through June 9, 2008. For early 2008, the average Vanguard fund 15 % of movements in the S&P500 index are reflected in the next-day differential return to investing abroad.

Is TZA a problem for Vanguard's electronically traded funds? In Exhibit 9 we explore this for five of Vanguard's ETF's. We perform the same calculation as in Exhibits 7 and 8. The average return sensitivity is less than 0.037 in each year and is negative in 2007. We conclude that sensitivity to TZA is not present for Vanguard's

ETF's. Since Vanguard's ETF's clone its regular index funds, it is puzzling why the susceptibility to TZA exists for Vanguard's regular mutual funds. For fair pricing all a fund manager would need to do is match the ETF price.[7]

Exhibit 7.
Regression Coefficients for the impact of proportional changes in the S&P500 on Next Day Fund Net Return: 1997-June 9, 2008

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	avg
Vanguard													
VEIEX Emerging Markets	0.493	0.460	0.389	0.427	0.264	0.216	0.461	0.483	0.286	0.396	0.104	0.100	0.362
VEURX Europe Index		0.335	0.274	0.248	0.138	0.269	0.352	0.235	0.159	0.139	0.020	0.178	0.217
VINEX International Explorer (medium stocks)			0.734	0.446	0.335	0.156	0.334	0.248	0.313	0.354	0.136	0.220	0.339
VPACX Pacific	0.592	0.237	0.450	0.311	0.001	-0.039	0.286	0.184	0.157	0.120	0.011	0.108	0.210
Competition													
DFIVX DFA International Value I	0.436	0.295	0.265	0.181	0.226	0.353	0.414	0.078	0.198	0.201	0.097	0.223	0.249
FIEUX Fidelity Europe Fund	0.383	0.257	0.300	0.277	0.373	0.388	0.411	0.194	0.374	0.334	0.210	0.135	0.318
GMOFX GMO Foreign Fund III	0.396	0.265	0.236	0.157	0.150	0.275	0.375	0.089	0.139	0.123	0.016	0.135	0.202
PRESX T. Rowe Price Euro Stock	0.668	0.309	0.419	0.393	0.323	0.342	0.338	0.030	0.215	0.125	0.175	0.195	0.303
Spitzer's Funds													
AEDBX Aim European Growth		0.479	0.334	0.580	0.346	0.324	0.332	0.109	0.326	0.284	0.053	0.224	0.317
EUGAX Morgan Stanley European Equity F	0.437	0.413	0.355	0.385	0.397	0.454	0.469	0.136	0.211	0.139	0.000	0.184	0.309
FIECX Federated International Equity Fund C	0.443	0.384	0.453	0.433	0.294	0.353	0.314	0.065	0.184	0.133	0.115	0.195	0.288
GSIFX Goldman Sachs Int'l Equity A	0.483	0.384	0.365	0.340	0.360	0.355	0.393	0.036	0.198	0.223	0.008	0.183	0.286
JAOSX Janus Overseas	0.849	0.396	0.437	0.291	0.373	0.694	0.606	0.120	0.214	0.145	0.239	0.220	0.397
MGEBX Van Kampen Global Value Equity B	0.376	0.219	0.137	0.131	0.133	0.245	0.310	0.052	0.095	0.067	0.047	0.132	0.165
MWEFX Global Equity A	0.310	0.247	0.207	0.228	0.219	0.215	0.224	0.061	0.225	0.108	0.035	0.120	0.189
PEUGX Putnam European Equity Fund A	0.494	0.436	0.341	0.347	0.333	0.345	0.371	0.068	0.205	0.208	0.132	0.223	0.298
Vanguard Average	**0.542**	**0.344**	**0.461**	**0.358**	**0.185**	**0.151**	**0.358**	**0.287**	**0.229**	**0.252**	**0.068**	**0.151**	0.282
Competitors Average	**0.492**	**0.281**	**0.305**	**0.252**	**0.268**	**0.340**	**0.384**	**0.097**	**0.231**	**0.195**	**0.124**	**0.172**	0.262
Spitzer Average	**0.482**	**0.277**	**0.318**	**0.275**	**0.282**	**0.335**	**0.374**	**0.104**	**0.242**	**0.194**	**0.134**	**0.185**	0.267

[7] Braham [2003] identifies problems with fair value pricing. He noted that two years earlier the SEC permitted mutual funds holding non-U.S. stocks to use fair value. Since then 75% of fund managers have done so. Such permission is effective whenever a "significant event" occurs after markets close. But regulators have not defined "significant event." "Nor has the SEC delineated any specific methodology for calculating fair value" and "methodologies differ widely across the fund industry." "What this ultimately means is that two foreign funds could own exactly the same stocks and price them differently at the end of the day." "This creates a potential for conflicts of interest. For instance, if a fund manager has a big shareholder redemption, he could intentionally mark the fund's value down so he has to pay out less."

Exhibit 8.
Regression Coefficients for the Impact of proportional changes in the S&P500 on next day Fund Net Returns: 1997- June 9, 2008.

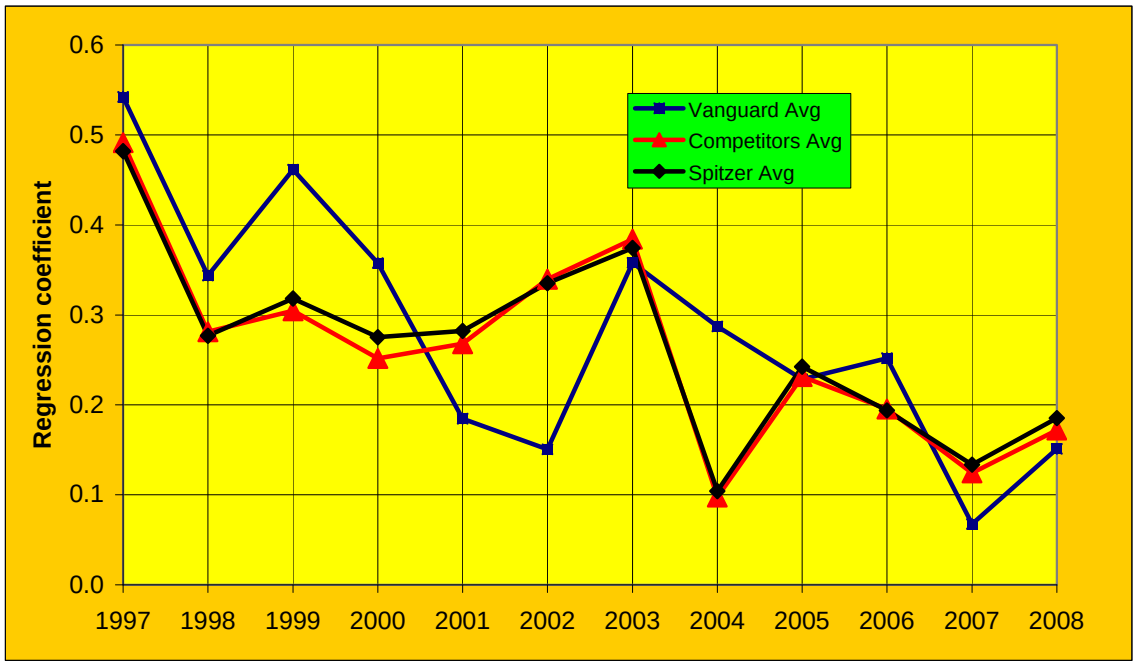


Exhibit 9.

Vanguard ETFs: Regression Coefficients for the Impact of S&P return on Next Day Fund Net Return

Name	Inception	2005	2006	2007
VWO Vanguard Emerging Markets	3/4/2005	-0.065	0.013	-0.197
VEA Vanguard Europe Pacific	7/20/2007			-0.022
VGK Vanguard European	3/4/2005	0.020	0.092	-0.006
VEU Vanguard FTSE All-World ex-US	3/2/2007			-0.017
VPL Vanguard Pacific ETF	3/4/2005	0.103	0.007	0.064
Average		**0.019**	**0.037**	**-0.036**

11. Is Our Inquiry Moral?

Jeffrey Molitor [2002], Director of Portfolio Review at The Vanguard Group in a letter to the editor of *The Financial Analysts Journal* criticizes the decision to publish Boudoukh *et al.* [2002].

> However, your decision to publish an article that outlines how investors can profit by taking advantage of pricing differences in international mutual funds raises serious questions about the policies, oversight, and judgment applied in selecting articles for the FAJ. Specifically, how could an organization whose motto is

> "Setting a Higher Standard for Investment Professionals Worldwide" publish (and, by inference, endorse) an article on how to take advantage of the average mutual fund shareholder? (The article could have been subtitled "Here's How to Steal Money from Your Fellow Shareholders.") Obviously, the ethical shortcomings of this article were abundantly clear to your editors: The article's introduction states: "the gains from these strategies are matched by offsetting losses by buy-and-hold investors." Publishing such a piece in a publication that is aimed solely at financial professionals is a bad idea in the best of times but is abhorrent in a period when investor confidence is already shaken by corporate greed and fraud, bad accounting, and a bear market overall. My concern is not with the accuracy of the article itself (although it should be noted that the use of "fair value pricing" has effectively closed the arbitrage) but rather with the absence of perspective and ethical guidance applied in approving this article. Providing the direction on what represents scholarship, insight, and proper ethics is the responsibility of AIMR's Board. The FAJ is the most public representation of AIMR and should reflect the best, in all dimensions, of what the CFA charter is expected to represent. Publishing articles that may be "technically correct" but inconsistent with the concept of "setting a higher standard" reflects an unfortunate lack of oversight by the Board. AIMR has historically stood for trust, integrity, and high ethics. I hope that this focus will be reflected in future FAJ articles.

This criticism applies also to our efforts in this paper. What can economists do to destroy market distortions? Bhagwati [1988, p.85] in a marvelous rhetorical flourish articulates what he calls the Dracula effect. Just as Dracula shrivels into nothingness when the morning sunlight hits him. "exposing evil to sunlight helps to destroy it." Similarly, it is the role of economists to illuminate the costs and unintended consequences of various distortions. Exhibit 8 shows that when the letter was published fair value pricing had not eliminated the arbitrage opportunity. Nor had the opportunity disappeared in the most recent data available in Exhibit 7 and in 2008. Is it worse to expose a distortion or to mislead investors by pretending that it does not exist?

It is worth recalling Gordon Tullock's [1967] logic. For Tullock the welfare cost of theft is not what is stolen, because that is a transfer from the victim to the thief. It is the cost of the thief's jimmy, the opportunity cost of his time and the costs of locks to make homes secure. To this we should add the reluctance to work and accumulate consumer durables for fear of theft. Similarly, the cost of TZA to the economy is not the profit made from TZA, for that is a transfer from long term buy and hold investors to time zone arbitrageurs. Rather it is the cost of the extra liquidity held by funds, the extra transactions costs imposed on them by TZA, the opportunity cost of the time of the

authors and readers of this paper, and the consequences of reduced diversification into international funds: greater portfolio risk and altered savings behavior.

Additionally does the immorality lie with the mutual fund company that permits the distortion to exist or with the investor who exploits it?

12. Did Fund Returns Beat their Indexes in spite of TZA?

We are curious to discover whether TZA beat the returns of international funds down below that of the indexes, which track them. Exhibits 10 through 12 address this issue.

We use a technique developed by Sharpe [1992] and used recently by Rodriguez & Tower [2008] and Tower & Yang [2008] to find the basket of indexes which best tracks a mutual fund. The indexes we use are MSCI Emerging Markets, Europe, Pacific Ex Japan, Pacific, World Ex US, EAFE, EAFE Value, EAFE Growth and EAFE Small Cap. All indexes are in US dollars, include reinvested dividends and subtract withholding taxes on dividends. The EAFE Value and Growth start at year end 1998, and EAFE Small Cap starts in 2001. The late start of three of these indexes results in gaps in Exhibit 11 for funds whose tracking index should include these indexes.

We search for the basket of indexes which, when rebalanced monthly, most closely tracks that of the mutual fund. Our criterion for close tracking is the minimum variance of the differential between the return of the basket and the return of the mutual fund. We use monthly data from Morningstar's Principia Pro Disks.

Our technique is to regress the fund monthly return on those of the indexes, while constraining all the coefficients to be positive and add to 1. We interpret the regression coefficients to be the portfolio shares of the various indexes in the tracking index basket. That they are all positive reflects the assumption of no short sales. That they add to one reflects the assumption that the index shares in each tracking index must add to one.

The portfolios are described in Exhibit 10. The shares are consistent with intuition. For example, the Vanguard European Index Fund is best tracked by a tracking index consisting of 100% of the MSCI Europe Index.

The R^2s show how well the tracking indexes track the fund. The Aim Europe Growth C Fund has an R^2 of only 0.788, so we have less faith that our tracking index has captured the investment style of the fund than is the case for all the other funds.

Exhibit 10 shows the gross performance differentials –that is gross of expenses. The annual figures show the average geometric return of the fund minus that of the corresponding index basket, continuously compounded, with the expense ratio subtracted, to yield the differential gross return, expressed in percentage points per year.

The bottom three rows show the averages for four groups of funds (Vanguard, Vanguard competitors, all the Spitzer funds and the Spitzer funds that exhibited an R^2 of 0.9 or greater when fitted to their tracking indexes). This last set is included in order to exclude those funds for which we were not able to find good tracking indexes.

The next two columns show the average performance differentials for the period prior to the resolution of Eliot Spitzer's investigation of the mutual fund industry (1997-2002) and post investigation (2004-2007), so we left out 2003, during which the investigation was occuring. We had expected to find that the Spitzer funds performed better after the investigation. In fact their average gross return differential dropped by 4.59 % – 2.23 5 = 2.36% per year or 0.36% per year, depending on whether the average or the average with high R^2s is used. Vanguard's average differential remained approximately the same (dropping by 0.10 % per year) and the competitor's dropped (by 0.82 % per year).

For the whole period, the average gross performance differential for each group was positive (0.98 % for Vanguard, 1.96 % for the competitors, 3.36 % for all Spitzer, and 2.70% for high R^2 Spitzer. We had also expected to seed the worst performance for the Spitzer funds in the 1997-2003 period. In fact, they performed better than the other two groups during that period.

For each group, the average gross differential performance was positive over the whole period, with only one fund showing a negative average differential over the entire period, and one fund showing a negative average return in the pre Spitzer period. This

indicates that for the most part, TZA was not severe enough to cause international mutual fund gross returns to underperform the tracking indexes.[8]

Exhibit 10.
The Tracking Indexes.

	Composition of funds (in percent)									
Fund name and ticker	***EM***	***Europe***	***Pacific Ex Japan***	***Pacific***	***World Ex US***	***MSCI EAFE***	***EAFE Value***	***EAFE Growth***	***EAFE Small Cap***	***R^2 between fund & tracking index returns***
AEBDX Aim Europe Growth C	6	94	0	0	0	0	0	0	0	0.788
DFEMX DFA Emerging Mkts I	75	12	13	0	0	0	0	0	0	0.965
EUGAX MS European Equity A	0	96	0	0	2	2	0	0	0	0.969
FIECX Federated Intl Equity C	6	0	0	0	0	0	0	94	0	0.899
FIEUX Fidelity Europe	13	87	0	0	0	0	0	0	0	0.952
GMOFX GMO Foreign Fund III	0	0	14	7	0	43	36	0	0	0.971
GSIFX Goldman Sachs Concentd Intl Equity A	0	32	0	0	61	7	0	0	0	0.968
JAOSX Janus Overseas	30	0	0	0	0	0	0	70	0	0.902
MEMCX MFS Emerging Markets C	85	13	0	2	0	0	0	0	0	0.966
MSRCX Van Kampen Emerging Markets C	100	0	0	0	0	0	0	0	0	0.969
PEUGX Putnam Europe Equity A	1	97	2	0	0	0	0	0	0	0.975
PRESX T. Rowe Price Euro Stock	1	97	0	0	1	1	0	0	0	0.984
VEIEX Vanguard Emerging Market Index	80	0	20	0	0	0	0	0	0	0.987
VEURX Vanguard Europe Index	0	100	0	0	0	0	0	0	0	0.999
VINEX Vanguard International Explorer	12	27	0	0	0	0	0	0	61	0.975
VPACX Vanguard Pacific Index	0	0	0	98	0	2	0	0	0	0.996

[8]Expenses drag down the fund returns, and any income made from the lending of securities, engaged in by DFA should raise them. We ignored both effects.

However, since investors are concerned with net returns we subtracted average expense ratios over the 11-year period to obtain net return differentials. Again these are positive for all three groups. One should not make too much of these net return calculations, since the expense ratios depend on the class of fund considered and we have ignored front and back end loads.

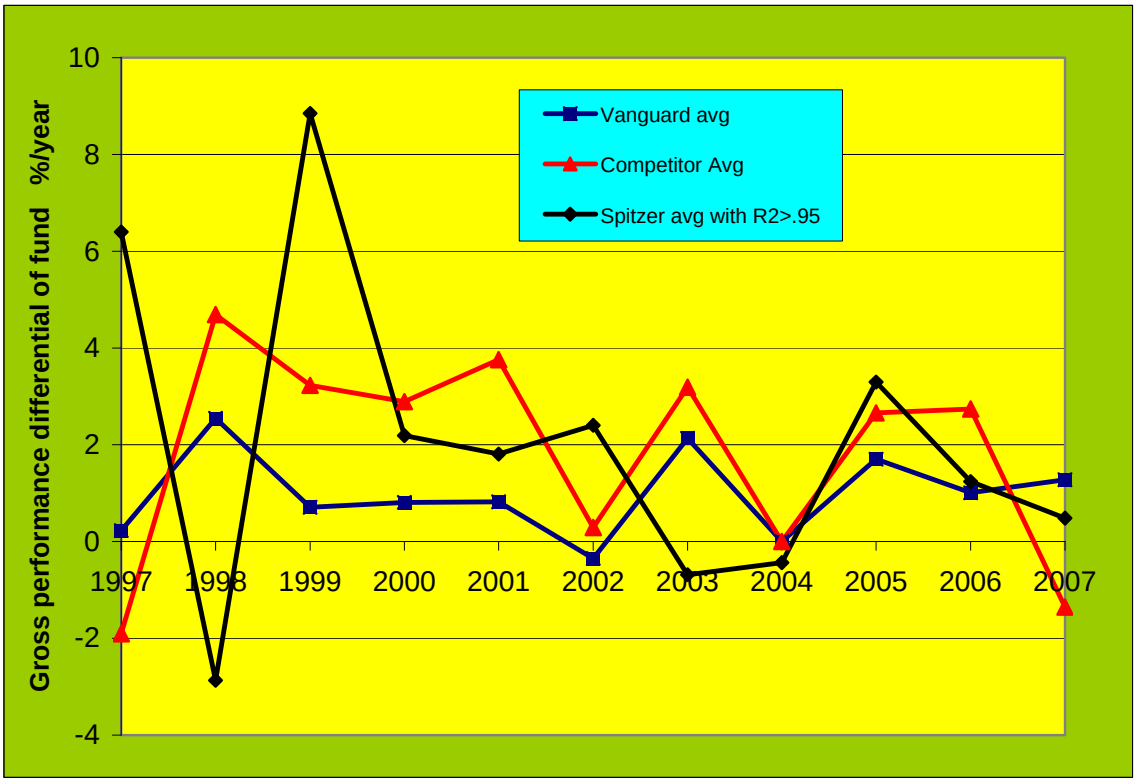
EXHIBIT 11.
Fund Return Differentials in Percent per Year, Continually Compounded

	Gross Differential Returns															
NAME	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	pre Spitzer (1997-2002)	post Spitzer (2004-2007)	whole period	Expense ratio %/year	Net out-performance of tracking index %/year
AEBDX Aim Europe Growth C		14.1	35.93	8.84	-5.48	11.22	4.75	11.27	3.86	5.94	0.74	12.92	5.31	9.12	2.72	6.4
DFEMX DFA Emerging Mkts I	-6.94	12.5	11.12	-1.78	0.75	0.22	7.75	6.11	4.07	-0.18	2.84	0.22	4.12	3.47	0.77	2.7
EUGAX M S European Equity A	-4.75	-1.62	11.43	5.26	3.95	1.19	-5.73	-5.78	0.27	-1.52	2.83	2.58	-1.99	0.5	1.54	-1.04
FIECX Federated Intl Equity C			32.4	-0.28	-5.65	-8.2	2.45	-0.29	-3.14	-1.36	-5.09	4.57	-1.48	1.2	2.46	-1.26
FIEUX Fidelity Europe	4.97	1.84	-1.59	4.03	3.18	-9.62	5.57	7.27	6.36	-5.16	0.76	0.47	2.96	1.6	1.05	0.55
GMOFX GMO Foreign Fnd III			-0.19	5.91	11.17	10.02	-0.1	-0.03	0.23	0.35	-0.45	10.02	0	1.67	0.75	0.92
GSIFX Goldman Sachs Concentrated Intl Equity A	-1.98	-1.31	7.24	-0.52	-0.46	-1.32	-2.02	-4.78	2.19	-3.6	-4.05	0.27	-2.45	-0.97	1.58	-2.55
JAOSX Janus Overseas			29.69	11.43	-4.65	-11.84	0.25	1.34	12.12	17.68	5.25	6.16	7.33	6.81	0.92	5.89
MEMCX MFS Emerg Mkts C	22.74	-13.9	-3.87	8.99	6.81	9.16	3.84	5.61	8.06	2	3.75	4.99	4.65	4.83	0.9	3.94
MSRCX Van Kampen E Mkt C	14.61	4.04	22.96	-7.54	1.68	3.49	4.54	3.57	4.3	7.62	5.04	6.54	5.01	5.85	2.95	2.9
PEUGX Putnam Europe Equity A	1.37	-1.54	6.49	4.75	-2.95	-0.51	-4.06	-0.81	1.66	1.7	-5.14	1.27	-1.33	0.09	1.36	-1.28
PRESX T. Rowe Price Euro Stock	-3.75	-0.24	3.58	3.39	-0.06	0.53	-0.45	-2.71	0.30	-0.43	2.13	0.58	-0.23	0.21	1.06	-0.85
VEIEX Vanguard E Market Index	1	7.44	1.73	2.21	3.44	0.76	5.17	2.45	4.4	0.1	2.98	2.76	3.02	2.88	0.53	2.35
VEURX Vanguard Europe Index	0.06	0.05	0.07	0.04	-0.02	0.07	0.04	0.02	0.01	0.01	0.02	0.05	0.02	0.03	0.29	-0.26
VINEX Vanguard Intl Explorer						-2.71	2.98	4.13	-0.78	5.11	-2.96	-2.71	1.7	0.96	0.61	0.35
VPACX Vanguard Pacific Index	-0.38	0.15	0.32	0.18	-0.95	0.48	0.34	0.20	0.40	-0.10	-0.31	-0.03	0.10	0.03	0.36	-0.33
Vanguard average	**0.23**	**2.55**	**0.71**	**0.81**	**0.82**	**-0.35**	**2.13**	**1.70**	**1.01**	**1.28**	**-0.07**	**0.99**	**0.98**	**0.98**	**0.45**	**0.53**
Competitor Average	**-1.91**	**4.69**	**3.23**	**2.89**	**3.76**	**0.29**	**3.19**	**2.66**	**2.74**	**-1.36**	**1.32**	**2.16**	**1.34**	**1.96**	**0.91**	**0.83**
All Spitzer average	**6.40**	**-0.04**	**17.78**	**3.87**	**-0.84**	**0.40**	**0.50**	**1.27**	**3.66**	**3.56**	**0.42**	**4.59**	**2.23**	**3.36**	**1.80**	**1.62**
Spitzer avg with R^2>0.95	**6.40**	**-2.87**	**8.85**	**2.19**	**1.81**	**2.40**	**-0.69**	**-0.44**	**3.30**	**1.24**	**0.49**	**3.13**	**0.78**	**2.06**	**1.67**	**0.39**

Exhibit 12 below shows the annual figures for the averages in Exhibit 11 for the three groups (excluding all Spitzer). It dramatizes that for all these fund groups the average gross differential return is positive over the whole 11-year period and in the two subperiods.[9]

[9] Schwartz and Potter [2006, p.1] found that "equity funds involved in a scandal outperformed their peers during thee pre- and post-scandal period but significantly underperformed their peers during the scandal

EXHIBIT 12.
Fund Return Differentials in Percent per Year, Continually Compounded



13. Conclusion

We set out to examine the ability of an investor to use lagged S&P data to predict fund returns the following day in Vanguard's international index mutual funds and for samples from other fund families. We have demonstrated that an unsophisticated trader had an opportunity to use a time-zone arbitrage strategy to gain large excess returns. That opportunity had diminished but not completely disappeared even by June 9, 2008.

We found that time zone arbitrage opportunities existed in the Vanguard fund family – and at levels similar to other families. Vanguard is one of the most reputable mutual fund families in that it charges low expenses to all classes of investor, keeps

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period (March 2000-August 2003), even after adjusting for market effects and fund characteristics. The dates reflect the implication that several funds engaged in late trading with Canary Capital Partners in March 2000, and one could read of the first investigations on September 3rd 2003. Our Exhibit 12 does not show such a clear pattern.

transactions costs low, has stayed free of scandal, and was not one of the families investigated by the New York Attorney General. Despite Vanguard CEO and Founder, John Bogle's, testifying to the negative impact of time zone arbitrage we have found that even Vanguard's funds were vulnerable to time zone arbitrage. However, in no year did we find that the Vanguard international index funds underperformed their corresponding indexes, gross of expenses. So we don't see evidence of dilution of buy-and-hold investors' returns by time-zone arbitrageurs to the point that Vanguard underperformed the indexes.

By 2003 the SEC was under tremendous pressure to enact regulations aimed at limiting time zone arbitrage [Hogue, 2005]. There are three main solutions mutual fund can employ to prevent fund dilution. First, funds can correct for the stale prices in NAVs, as was the case in 2007. Second, they can discourage short-term trading with fees and trade limits. They can institute limits on the number of trades one can make a year, as most funds have done. Finally, mutual fund families could require that trades involving stocks traded on foreign exchanges be placed prior to the close of those markets.

The evidence for time-zone arbitrage runs contrary to the "efficient markets" hypothesis which implies that with the exception of long-term trends, future stock prices are very difficult to impossible to predict. One of the most cited advocates of this proposition is Burton Malkiel. In *A Random Walk Down Wall Street*. Malkiel writes [2007, p194]

> Although the preponderance of statistical evidence supports the view that market efficiency is high, some gremlins are lurking about that harry the efficient-market theory and make it impossible for anyone to state that the theory is conclusively demonstrated.

In the case of time-zone arbitrage, the gremlin was institutional complicity with the arbitrageurs or institutional carelessness. Time-zone arbitrage demonstrates that news does not travel instantaneously and that institutions did not adjust prices to reflect all relevant news. In fact, time-zone arbitrage vulnerability, according to our findings, existed for at least ten years.

We have demonstrated that time-zone arbitrage opportunity existed in Vanguard and other international funds long after the market timing strategies became publicly

known. This is an important discovery for both Vanguard and other mutual fund families. We don't know why this arbitrage opportunity has not been eradicated, although one possibility is the difficulty of implementing fair value pricing.

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