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 register their last trades before the market close. These stale prices have 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. The thesis quantitatively traces 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.

I. 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 CEO of Vanguard (Bogle, 2005, p152).

In this passage John Bogle, one of the most respected mutual fund experts, describes a phenomenon called market timing that shocked the mutual fund industry. Using market timing, some investors were able to securely profit, detracting value from the average buy-and-hold investor. This paper shows that Vanguard Index Funds were not immune to stale prices and market timing.

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. Accurate and up-to-date values are more difficult to calculate in an increasingly dynamic global market. Markets around the world open and close at different times. European markets close at various times until 11 a.m. Eastern Standard Time (EST) and Pacific markets close around 1 a.m. EST. 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, technology, and liberalized capital flows have corresponded to a larger correlation between all markets, particularly US market movement and next day European movement (Bhargava, 1998). When a foreign market closes, the assets traded on that exchange will artificially freeze in value as they are no longer actively 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 market. 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 time-zone arbitrage with mutual funds – there is not an efficient market mechanism to eliminate profitability.

The existence of time-zone arbitrage has been documented in the past. Academics 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 time-zone arbitrage. By the time the dust cleared, Spitzer had recovered over $3.1 billion in mutual fund settlements. In response to time-zone market timing behavior many funds instituted trade limits, trade fees and account monitoring. 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 and others not. Meanwhile it is legal for the general market timers to exploit the arbitrage at the expense of the buy-and-hold investors – this shocked the mutual fund industry (Houge, 2005).

My analysis focuses on the Vanguard mutual fund family, as it is considered one of the most reputable funds and sets a standard for fund behavior. Vanguard founder and CEO, John Bogle, has also written extensively about mutual funds and long-term investment strategy. Bogle (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 thesis will analyze stale prices and time-zone trading strategies in Vanguard funds. I will compare Vanguard funds to their competitors and the Spitzer prosecuted fund families. The contributions of this paper are 1. to find how the opportunities and profitability for time zone arbitrage differed between fund families and different funds; 2. to discover when and if the opportunities for time zone arbitrage disappeared; 3. to explore the cost of time zone arbitrage to Vanguard index fund investors; 4. the development of an alternative (and better) signaling mechanism for fund transfers; 5. using a symmetric criterion for transferring funds back and forth between U.S. and

foreign mutual funds. Like some of the previous studies, I perform the profitability calculations using a strategy in which the investors are always fully invested in either domestic or foreign equities.

This paper is organized into five sections. Section II reviews the existing literature on market timing and stale prices. Section III explains the data and methods used to explore how long time zone arbitrage opportunities persisted. Section IV presents and analyzes the incentives to engage in time zone arbitrage and the profitability of employing various trading strategies. Section V concludes with policy implications and possibilities for future research.

II. Literature Review

Market-timing in mutual funds was first documented by academic papers in 1998 (Bhargava, Bose and Dubosfsky). 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 the large excess returns possible with time-zone arbitrage 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. The first strand of the literature is the focus of my paper.

Time-zone arbitrage 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 days close 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 a return of more than 800 basis points a year. Chalmers, Edelen, and Kadlec in 2001 show predictability 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 (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.), discovering that the former trigger generates a higher return. Their investment strategy is more complex than our strategy of switching back and forth between domestic and foreign mutual funds.

Boudouck, Richardson, Subrahmanyam and Whitelaw (BSRW) in 2002 analyzed stale prices in mutual funds. BSRW focused on excess profits and Sharpe ratios to prove 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 switches 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 the difference between the closing Nikkei level in Japan and the implied Nikkei level at 4p.m. traded on the Chicago Mercantile Exchange (CME), the within-day change on the S&P 500 and a combination of the two. The combination performed the best. BRSW 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 performance returns against a benchmark of buy-and-hold returns on the particular mutual fund.

Like my paper, BSRW have a section that focuses on Vanguard funds. BSRW use Vanguard International Growth, Vanguard International Pacific Equity Index, and the Vanguard International European Equity Index to demonstrate an S&P signal trading strategy that moves investment from Prime Money Market fund (invests in high-quality, short term commercial paper) to a basket of international Vanguard funds or reverse if the signal is negative. BSRW use a time period from January 1997 to November 2000. They find there is a large excess return between buy-and-hold, and 0.5% and .25% over the course of the time period respectively. Unlike my simulations, their trading strategy has capital in the international funds less than 10% of the time.

The Greene and Hodges study focused primarily on the dilution impact caused by volatile fund flows from stale prices and market timing. They used the S&P as a signal indicator. The trader switches to the international fund if the S&P is positive and hold 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. GH also examined the correlation between the movement in a funds 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 very 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. My paper examines a longer and more recent time period and does not analyze net fund flow. Net fund flow is a measure of volume of activity not ability to engage in market timing.

In 2001 Goetzmann, Ivkovic, and Rouwenhorst published an article documenting the extreme 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. Another method they used was comparing 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 fund flows and next day fund returns. More important was the spread of the correlations between fund flows and next day fund returns: -0.029 to 0.083.

In 2003 Zitzewitz documented time zone arbitrage and detailed 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 the Jan 1998 – Oct 2001. Unlike the other studies that compare returns to a buy and hold strategy, Zitzewitz measured excess returns against a mixture of cash and funds that has the same daily fund exposure. Zitzewitz also analyzed domestic small-cap equities and high-yield and convertible bonds that trade infrequently and have wide bid-ask spreads. He found 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. This paper uses 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 to an expectation of less dilution in Vanguard funds.

Given the literature review, the basic framework explaining time-zone arbitrage has been placed. My thesis builds on the existing literature by using a much longer and more recent time period (January 1st 1997 - March 10th 2005) and employing a strategy that is clearer and more realistic. Also, I am able to evaluate when the arbitrage opportunity from market-timing ended in the Vanguard international funds. The trade

strategy and calculation of the regression is a completely new methodology that is accessible to the common unsophisticated investor and highly executable.

III. Data and Methods

The sample uses two different sets of data, mutual fund daily adjusted closes and five minute changes in the S&P 500 index. The data used in the regressions are quotes for the S&P500 three-month futures index rather than the actual S&P500 index. But as documented below, the two series are very similar, so this choice does not affect the results much. The lowest correlation was 0.986.

I examine fourteen mutual funds in three categories: Vanguard Family, Vanguard Competition, and Elliot Spitzer's prosecuted funds. Within the Vanguard family I choose to focus on Vanguard European Stock Index (VEURX), Vanguard International Explorer (VINEX), Vanguard Emerging Market Index (VEIEX) and Vanguard Pacific Index (VPACX). For the Vanguard competition, I selected three fund families that closely compete with Vanguard for business, attracting customers who value low expenses and investment expertise (Tower and Yang, and Tower). Within the fund families, I generally picked the funds with the lowest expense ratio and highest proportion of European assets. However, in the case of Vanguard I 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 my time series began. The three funds in the vanguard competition are the GMO Foreign Fund III (GMOFX), Fidelity Europe Fund (FIEUX), and DFA International Value I (DFIVX). The Spitzer category includes Van Kampen Global Value Equity B (MGEBX), Goldman Sachs Concentrated International Equity A (GSIFX), Morgan Stanley European Equity F (EUGAX), Putnam European Equity Fund

Class (PEUGX), Federated International Equity Fund C CLA (FIECX), AIM European Growth (AEDBX), and MFS Global Equity A (MWEFX)[2].

The data tracks the five minute movement in S&P 500 future prices. To ensure that the S&P futures correlate to the actual S&P, I calculated the correlation between the day-to-day proportional change in the S&P futures 4 p.m. price and the S&P 500 adjusted close on the 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.

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

The sample in Exhibit 1 is the daily adjusted close prices for the S&P500 index from Yahoo Finance for January 1, 1997-December 31, 2004. The sample of mutual fund data is from the same time period and same source. These data are easily accessible

[2] 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 funs have been shut down and data on their international funds dating back to the late 1990s is no longer on Yahoo, so they are not included in my study.

online. Any common investor could easily obtain the data for the purpose of studying or exploiting time-zone arbitrage.

Europe trading hours briefly overlap with trading hours in the U.S. – about two hours between 9 a.m. and 11 a.m. This fact would lead 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. I regressed proportional changes in international mutual fund adjusted price on the proportional changes in the dividend-adjusted price of the S&P500 index over various previous periods. The logic of time zone arbitrage tells me that movements in the S&P should be accompanied by subsequent movements in the international mutual fund in the same direction. Consequently, I constrained all regression coefficients to be positive. I used six distinct time periods: 9:35a.m-4p.m., 10:00a.m.-4p.m., 10:30a.m.-4p.m., 11:00a.m.-4p.m., 11:30a.m.-4p.m. and previous day's close-4p.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 calculated by using the proportional change of the end of day adjusted return.

I 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: $F = \dfrac{\left(\dfrac{RSS_1 - RSS_2}{p_2 - p_1}\right)}{\left(\dfrac{RSS_2}{n - p_1}\right)}$

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 my case, my 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 $p_1 = 1$. I 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.

I calculated the time-zone arbitrage opportunity model using annual data. I used annual data to explore whether the opportunity changed as investors and mutual fund families became aware of the issue. Then in calculating the profitability of the strategy, I assumed that investors behaved as if the model from the previous year obtained. Thus investors 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 with the corresponding time period proportional change in the S&P and adding them together. I assumed that the trades occur at US market close of 4 p.m. I tested four threshold levels for predicted changes in the international mutual fund: 0.1%, 0.5%, 0.7% and 1%. I 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 I 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%.

I 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: $B(r) = K * R_e + (1 - K) * R_a$, 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.

IV. Results

Vanguard Europe

First, look at the correlation coefficients of the Vanguard Europe Index Fund from years 1997 to 2004 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.

I 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 international fund the following day. A 1% change in the S&P500 index fund between 11:30am and 4 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 standard deviation of Europe return is the mean square deviation of return from mean return for the mutual fund expressed as a proportion per day. The standard deviation of unexplained Europe return is the standard deviation of the return which is not explained by the model. The dimension of standard deviation is proportion/day.

The F statistic of 31.272 indicates that the model is significant at the 0.01% level. The continuously compounded return of the Vanguard S&P500 index, including dividends is 27.5%/year, and the continuously compounded return of the Vanguard Europe fund is 23.5%/year.

The years with the lowest sum of the regression coefficients are 2000 and 2001 and the year with the highest is 2003 with .527. The F-Test is highly significant in every

year. In efficient markets one would expect coefficients 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 total year impacts of the S&P on Vanguard Europe. The lack of consistency of the distribution of the coefficients shows some variation of the predictive power of the returns.

The method of calculation is the following. I 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. I programmed solver to select the weights on the returns of the S&P and the constant term which 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).

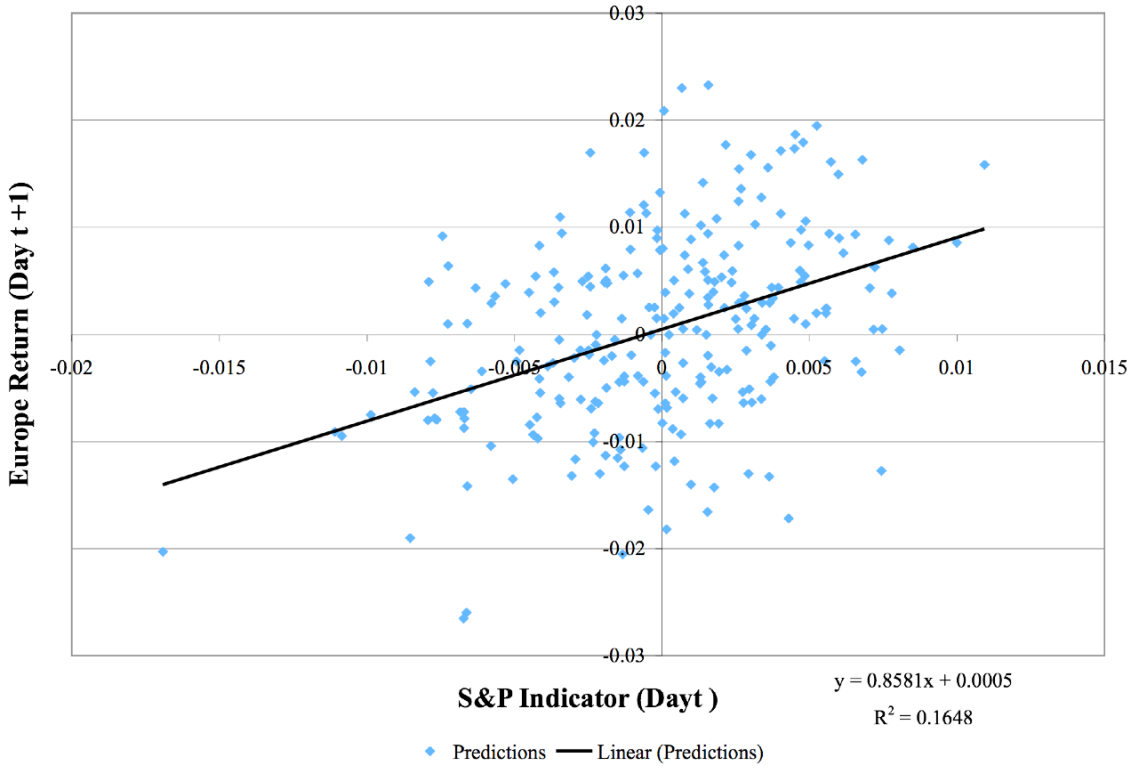
Exhibit 2.
Time Zone Arbitrage Predictors for Vanguard Europe: Does the S&P predict next day return?

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

Exhibit 2: 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.

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 relationship, 0.85, between the indicator and the actual European return the following day: a prediction of 1 percent results in a next day return on average of 0.86% above the mean value. In 1999, the sum of the coefficients was .452, also reflecting the arbitrage possibility for profiting from late day changes (after 11:30 a.m.) in the S&P. Had I used the coefficients obtained for 1999 to evaluate predictions in that same year, I necessarily would have obtained a slope of 1.

Exhibit 3.
Vanguard Europe 1999: Reliability of the Predictions



Vanguard Trading Strategy

To illustrate the possibility of time-zone arbitrage concretely I use a simple trading strategy with the Vanguard Europe Fund. Initially, 100% of the given portfolio weight is held in an S&P 500 index fund. If on a given day the indicator exceeded the stated threshold and the assets were not already in the European index than the funds transferred at the end of the US day to the European Index. The capital 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 .1% threshold and then decrease as the threshold increases. Using a .1% indicator the highest annualized excess return was in 2003 with 106%/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 .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 .1% threshold the excess return is greater than 24% through 2004. With .5% it exceeds 21% through 2003, but is still over 4% in 2004. With .7% it exceeds 12% through 2001. With 1% it is positive only in years 2000, 2001 and 2002.

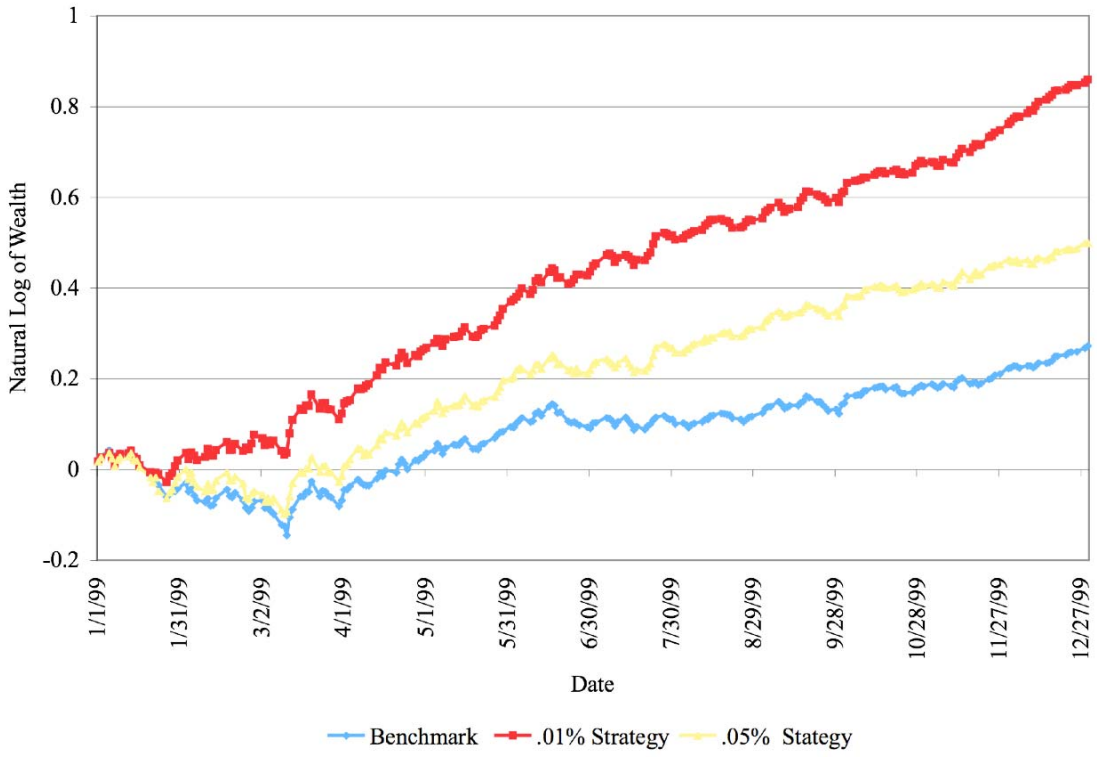
Exhibit 4.
Vanguard Europe: The Return From Time-Zone Arbitrage

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 .1%, 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 the graph that trading 115 times produced a continuously compounded return of 86.8% in that year. From the graph, the large

benchmark return of 27.8% in that year generated a 106% excess return between the benchmark and 0.1% strategy.

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



Vanguard against other funds

Exhibit 6 displays the regression coefficients of all fourteen mutual funds in 1999. From the grouping of mutual funds, the Vanguard family funds on average demonstrate greater predictive strength than their direct competitive funds of GMO, DFA and Fidelity. 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 goals (e.g. growth vs. value). 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 Vanguard funds exhibit the significant results 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	14.9
VINEX International Explorer (small stocks)	0.099	0.000	0.012	0.000	0.000	0.179	0.290	15.1
VEIEX Emerging Markets	0.000	0.000	0.000	0.000	0.000	0.395	0.395	13.2
VPACX Pacific	0.000	0.000	0.000	0.000	0.000	0.454	0.454	12.8
Competition								
GMOFX GMO Foreign Fund III	0.007	0.000	0.000	0.052	0.000	0.208	0.267	7.00
FIEUX Fidelity Europe Fund	0.293	0.000	0.000	0.105	0.000	0.037	0.435	13.4
DFIVX DFA International Value I	0.149	0.000	0.000	0.000	0.000	0.160	0.309	14.4
Spitzer's Funds[3]								
MGEBX Van Kampen Global Value Equity B	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	13.2
EUGAX Morgan Stanley European Equity F	0.343	0.011	0.000	0.216	0.000	0.000	0.570	20.0
PEUGX Putnam European Equity Fund A	0.328	0.000	0.000	0.167	0.000	0.021	0.516	18.4
FIECX Federated International Equity Fund C	0.167	0.000	0.000	0.000	0.000	0.335	0.503	20.1
AEDBX Aim European Growth	0.340	0.000	0.000	0.000	0.000	0.091	0.431	17.8
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	14.0
Competitors Average	0.150	0.000	0.000	0.053	0.000	0.135	0.337	11.6
Spitzer Average	0.258	0.007	0.000	0.059	0.000	0.095	0.419	15.0

[33] 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 and data on their international funds dating back to the late 1990s is no longer on Yahoo, so they are not included in my study.

Vanguard and Shareholders

Unfortunately, excess returns earned by time-zone trading come at the expense of the long-term investor. As John Bogle states, "Long-term fund investors pay a heavy penalty for investor activity by short-term fund owners. When equity funds hold cash as 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). Because the Vanguard funds I analyze are indexes that are supposed to mirror a particular market I can compare the Vanguard index return to the return of a non-vanguard market index. Using data form Morningstar, I compare the yearly gross return of Vanguard Europe to the MSCI Europe Index return. The gross return is obtained by adjusting the net return upwards by the audited expense ratio plus transactions cost, approximated by 0.008 times the turnover percent. We corrected for the turnover ratio[4]. As shown in Exhibit 6 below, the average premium investors realized post January 2005 was +.40% over the MSCI Europe index. Before January 2005 the average premium was +.12% - the difference in average premium being .28%. The significance of this result is measured by the t-Test. The result was a P value of .2206, meaning the odds that the out performance after January 2005 can be explained by randomness are 11.03%.

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

[4] Time zone arbitrage probably increased the turnover rate, so by explicitly including the turnover rate we are probably underestimating the cost of time zone arbitrage. Note we got a smaller number than the 0.48% per year gotten by Greene and Hodges, and mentioned in their abstract. Interesting that Zitzewitz estimates a cost of between 56 and 114 basis points.

permitted frequent small trades for rebalancing purposes, so the restriction of frequent trading was not complete. The existence of opportunities for time zone arbitrage also put financial advisors in an awkward position. They have a fiduciary duty to their clients to use strategies to maximize their returns, so those who were aware of opportunities for time zone arbitrage had an obligation to time rebalancing to take advantage of it.

Exhibit 5.
Vanguard Europe Return to Investors (%/year)

	VEURX Total Return %	*VEURX Gross Return*	***Investor Premium***
2007	13.82	13.71	0.11
2006	33.42	32.80	0.62
2005	9.26	8.79	0.47
2004	20.86	20.53	0.33
2003	38.70	38.49	0.21
2002	-17.95	-17.97	0.02
2001	-20.31	-21.04	0.73
2000	-8.21	-8.37	0.16
1999	16.66	17.04	-0.38
1998	28.86	28.87	-0.01
1997	24.23	24.33	-0.10
Average Premium since Jan 2005	***0.40***		
Average Premium before Jan 2005	***0.12***		
Difference in Average Premium	***0.28***		

Vanguard moves to ETFs

On March 10th, 2005 Vanguard established an exchange traded fund (ETF) which tracks the performance of the Vanguard European Index. When I regressed the change in VEURX on the changes in the S&P on the previous day for the year of 2004 the result was 0.246. The same process for the time period of March 10th 2005 through December

30th 2005, after the ETF was created, resulted in a .006 coefficient. I conclude that the introduction of Vanguards ETF eliminated the opportunity for time-zone arbitrage. Vanguard must have changed its pricing system around the time of the introduction of its European ETF.

V. Conclusion

In this paper, I 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 pre-2005. I have demonstrated that an unsophisticated trader had an opportunity to use a time-zone arbitrage strategy to gain large excess returns. That opportunity appears to no longer exist with Vanguards switch to ETFs.

It is interesting that I proved that time zone arbitrage opportunities existed in the Vanguard fund family – and at rates similar to it's competitors. Vanguard is one of the most reputable mutual funds and was not one of the funds named by the New York Attorney General. Despite Vanguard CEO and Founder, John Bogel, testifying to the negative impact of time zone arbitrage I have proven that even Vanguard funds returns seemed to be diluted.

By 2003 the SEC had tremendous pressure to enact regulations aimed at limiting time zone arbitrage. There are two main solutions mutual fund can employ to prevent fund dilution. Funds can correct for the stale prices in NAVs and/or discourage short-term trading with fees and trade limits. Presently, most mutual funds have instituted limits on the number of trades one can make a year. Another alternative would be for mutual fund families to require that trades involving stocks traded on foreign exchanges be placed prior to the close of those markets.

The evidence for time-zone arbitrages runs contrary to the "efficient markets" hypothesis that states 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 who published a reputable and high-selling book called *A Random Walk Down Wall Street*. Malkiel writes (194),

> 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.

Of course, time-zone arbitrage disproves the assumption that news travels instantaneously and that prices move to reflect all relevant news. In fact, time-zone arbitrage, according to my findings, existed for at least seven years.

Further research could be done to examine what funds other than Vanguard have used to limit market timing and with what success. And there is opportunity for further research in how to calculate NAV's that adjust for stale prices fairly.

I've demonstrated that time-zone arbitrage opportunity existed in Vanguard international funds long after the market timing strategies became publicly known. This is an important discovery for both Vanguard and other mutual fund families. Correcting this arbitrage opportunity takes active effort on behalf of the mutual fund or market regulators.

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