Stale Prices and Strategies for Trading Mutual Funds

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Abstract

We demonstrate that an institutional feature of numerous mutual funds, managing billions in assets, generates fund NAVs that reflect stale prices. Since, in many cases, investors can trade at these NAVs with limited transactions costs, there is an obvious trading opportunity. These opportunities are especially prevalent in international funds that buy Japanese or European equities. Simple, feasible strategies generate Sharpe ratios that are many times greater than the Sharpe ratio of the underlying fund. When implemented, the gains from these strategies are matched by offsetting losses incurred by buy-and-hold investors in these funds. In one particular example, we explore the consequences of trading between different Vanguard mutual funds. Compared to an equal-weighted buy-and-hold portfolio of international Vanguard funds with a 34% cumulative return, the strategy produces a 216% return while being in the stock market less than 20% of the time.

1 Introduction

Consider the following quote from U.S. News & World Report (May 24, 1999, p.74):

> *You'd think Frank Chiang would have been happy to see $7 million flowing into his $30 million Montgomery Emerging Asia Fund on a single day last year. The first time inflows surged, the fund manager viewed it as a vote of confidence, but a disturbing pattern would emerge. Money left as quickly as it came in, forcing Chiang to sell good investments to raise enough cash for redemptions. That hurt the fund's performance.*

The above description is not unique to this particular fund. In fact, over the past few years, the financial press has produced numerous similar articles about other funds. Most of these funds have one identifying characteristic – they invest in international assets.

In order to understand the above behavior, note that with the proliferation of mutual funds, it is now possible to buy into and exchange out of no-load mutual funds at essentially zero cost.[1] Moreover, there are approximately 700 no-load mutual funds that invest in international equities, a number of which are very large including at least 25 with assets under management exceeding $1 billion.

When one buys/sells a mutual fund during the day, one does so at the price prevailing at 4:00pm (all times in this paper refer to eastern standard time, unless noted otherwise). These 4:00pm prices are calculated based on the last transaction price of the stocks in that fund. For international funds, this could mean the prior 1:00am/2:00am for Japanese and other Asian equities, and 11:00am/12:00pm for many European equities. However, even when these markets are closed there is information being released that is relevant for the valuation of securities that are traded there. For example, there is considerable evidence in the literature that international equity returns are correlated at all times, even when one of the markets is closed. Moreover, the magnitude of these correlations may be quite large.[2] This phenomenon induces large correlations between observed

[1] There are some limitations on how quickly and how often investors can exchange between funds. These restrictions are discussed in more detail in Section 2 of the paper.

[2] Examples of cross-dependencies between international stock returns can be found in Eun and Shim (1989), Hamao, Masulis and Ng (1990), Becker, Finnerty, and Gupta (1990), Becker, Finnerty and Friedman (1993), and Lin, Engle and Ito (1995), among others.

security prices during the U.S. trading day, and the next day's return on the fund.[3]

In some cases, derivatives on international markets trading in the U.S. provide even more informative signals about the unobserved movements in the prices of securities in these funds. For example, Craig, Dravid and Richardson (1995) look at the relation between Nikkei futures and warrants traded in the U.S. and close-to-open Nikkei returns in Japan. They find a one-to-one relation, which suggests that foreign-based derivatives trading in the U.S. are an efficient predictor of the opening move in the foreign market. Moreover, they find that U.S. stock return indices do not provide incremental information, once the foreign-based derivative return is taken into account. This knowledge can then be used to generate considerable excess returns in the buying and selling of mutual funds. Remarkably, with no transactions costs and perfect liquidity, an investor can purchase funds at stale prices. In the most extreme case, one can buy a Japan fund using 1:00am prices, yet having information about the "true" price some fifteen hours later at 4:00pm.

Given these facts, it is perhaps no surprise that this paper documents extraordinarily high excess profits and Sharpe ratios across two categories of investment funds: (I) Pacific equity funds, and (II) international equity funds.[4] These fund classes are chosen for the staleness of their underlying prices, the size of the fund and the ease of implementing the trading strategy. We consider a strategy of switching between a money market account and the underlying fund class, depending on the signal during U.S. market hours. We also consider various trading costs under different types of implementation procedures.

Since mutual funds do place some limits, though not always enforced, on the frequency and amount of exchanges between funds, we look at strategies with particularly strong signals. Specifically, though the strategy calls for active trading only 5-10% of the time, its returns on average substantially exceed that of a buy-and-hold strategy during an ex post very good market for eq-

[3] A recent literature in finance makes a similar point, e.g., Chalmers, Edelen and Kadlec (2001), Greene and Hodges (2000) and Goetzmann, Ivkovic and Rouwenhorst (2001). A comparison of our paper to these papers is provided in Section 2.

[4] A similar phenomenon occurs in illiquid domestic equity funds. Although markets for the securities in these funds are open until 4pm, some equities trade infrequently; therefore, stale prices are used to calculate end-of-day NAVs. Thus, future NAVs will incorporate information that is known today. Large moves in U.S. markets tend to predict large moves in NAVs the following day. A well-known literature exists on documenting the effect of nontrading on portfolio return autocorrelations (e.g., Scholes and Williams (1979), Lo and MacKinlay (1988), and Boudoukh, Richardson and Whitelaw (1994)).

uities. More interesting is the fact that we can predict the next day's movement over 75% of the time. Sharpe ratios generally range between 5 and 10 on the days we are in the market. The range of Sharpe ratios depends on whether the strategy tries to hedge the movements of equity prices during foreign-trading hours.

In order to illustrate, in a more detailed manner, the mechanics and results of the trading strategy, we provide a case study using three mutual funds from the Vanguard family of funds. This analysis is of special interest to academics since these funds are available through the retirement plans of numerous educational institutions and can be easily traded either on the web or over the phone. We view this exercise as similar to one recently put forward by Stanton (1999), who finds that employees have a large incentive to retire or leave their current employment and liquidate their 401(k) retirement plans when the values of these plans are based on potentially quarter-old stale prices.[5]

The remainder of the paper is organized as follows. In Section 2, we lay the basic foundations underlying trading on stale mutual fund prices, focusing on both the time line and various implementation procedures. This discussion is presented in the context of a recent literature which explores similar ideas. Section 3 presents the empirical analysis, focusing on results across two subsectors of the equity sector of the mutual fund industry – Pacific funds and other international funds. In Section 4, we also look in more detail at a specific case study involving Vanguard funds. Section 5 concludes.

2 Trading Mutual Funds

As noted above, the buying or selling of mutual funds in the U.S. occurs at the close of trade (i.e., 4pm); however, the reported prices of the underlying assets in the fund reflect their last traded price. Thus, investors can in effect purchase portfolios of securities at stale prices. These securities might include small firm stocks, high yield bonds, and foreign assets, all of which have the property that their last transaction rarely falls close to 4pm. The basic idea behind trading mutual funds is as follows. Consider an asset whose "true" price process is such that it is not possible to make abnormal profits by trading in the asset at these prices. In contrast, if it is possible to trade at the

[5]In terms of taking advantage of a structural inefficiency in the market, this paper is also similar in spirit to Scholes and Wolfson (1989), who look and take advantage of dividend reinvestment plans.

observed (stale) prices between trades in the underlying spot market without forcing convergence between observed and true prices, then it is possible to make abnormal profits as long as there is a signal that is correlated with the true price process. For example, suppose a trader is given the option to continue trading at closing prices during the period when the Tokyo Stock Exchange is closed, and that he/she has access to information about the continuous price process (e.g., futures on the Nikkei index traded in the U.S.). This is in effect what mutual funds allow.

2.1 The Funds

Though there are literally thousands of no-load funds that use stale prices, in this paper we restrict ourselves to a select few. First, to avoid the well-known survivorship bias problems that exist for mutual funds (e.g., Carhart, Carpenter, Lynch and Musto (2000)), we consider large International/European funds and all Pacific funds that existed in January 1997 and follow them through November 2000. International funds are chosen to maximize the staleness of the underlying prices of the assets in the fund. As an illustration, Figure 1 graphs the time line of trading for both Asian and European funds. The prices vary from being 15 hours stale for funds investing in Japanese assets to 4-6 hours stale for investments in European assets.

Second, in order to guarantee that individuals could actually implement the trades, these funds must satisfy the following additional criteria: (a) they must be no load, (b) permit exchanges, (c) charge no exchange fees, and (d) cater to retail (rather than institutional) investors. For these funds, the investor can transfer money between say a money-market account and an international equity fund at no cost. Of course, the fund itself faces transactions costs from buying and selling shares, as well as imposing annual management fees.

Are there any limitations on the amount of this type of mutual fund trading? In theory, though the mutual funds allow free exchanges, the prospectus of each fund often limits the number of exchanges, e.g., a typical limit is one trade per month or quarter. Violation of this limit gives the fund the right to revoke exchange privileges or charge an exchange fee. While the prospectus gives the fund much latitude in terms of barring market timers, in practice, these rules do not tend to be strictly enforced. Obviously, the size of the transaction and number of exchange transactions will affect the enforcement of this rule.[6] Table 1 describes the funds used in the study and summarizes

[6]In conversations with professionals in the money management business, as well as first-hand experience, the fund

the rules governing the use of exchanges as described in their prospectuses.

2.2 Implementing the Trading Strategy

Consider an international fund which is subject to stale pricing. After the international market closes, and given a signal about movements in the value of the fund's assets, the investor can decide whether or not to trade the fund using some criteria, examples of which will be explored in Section 3. However, it is important to discuss the details associated with how the trade is implemented in practice.

In general, there are three implementation methods. First, and foremost, an investor can trade directly through the mutual fund complex via automated telephone service or online (if available). The speed of this transaction is as quick as 30 seconds and thus can be implemented close to the 4pm transaction deadline. Second, an investor can put in a trade through a broker. Brokers have the advantage of being able to trade close to the 4pm deadline, but this mechanism has the disadvantage of introducing an intermediary into the process. Third, there are a number of online trading firms that allow mutual fund trading (e.g., Charles Schwab, Etrade, Ameritrade, and Jack White). These transactions are relatively quick and allow trading across mutual fund families (i.e., the monies invested are through the online account); however, the transactions usually involve a fee between $9.95 and $29.95, and execution times are sometimes limited. For example, a number of firms require notice by 3pm. In the next section, we explore the effect of these transaction fees on the returns from trading international mutual funds.

As mentioned in Section 2.1 and documented in Table 1, there are limits on how many trades an investor can make. Therefore, it is also important to consider the optimal strategies employed in practice. First, the investor can trade small amounts in large capitalization funds relatively frequently. That is, by representing a small amount of the fund flow, he/she can essentially escape notice. Second, the investor can trade large amounts very infrequently across a relatively large

families are reluctant to bar investors who violate their "excessive trading" rules within reason. It is an open question whether this is because the underlying information systems are not set up accordingly or their degree of leniency is greater than implied by their prospectuses. Nevertheless, where the radar screen is in terms of a clear violation varies across funds, as do their printed rules. However, the conventional wisdom is that transactions over $1mm are looked at more closely than other transactions.

number of funds, as in the example described at the beginning of this paper.[7] Third, the investor can trade online through third parties. Because third parties send all their mutual fund trades via a batch order, the individual investor can mask his/her identity. As long as the trade size is not too large, or at least is small relative to "random" investors, there is no real opportunity for the fund family to detect the market timer. Of course, trading through a third party is not costless. We explore this effect empirically in Section 3.

Because many of the most profitable strategies involve purchasing foreign equities, this exposes the investor to risk during foreign trading hours. The volatility of stock returns tends to be at its highest during trading hours (see, for example, French and Roll (1986), Barclay, Litzenberger and Warner (1990), and Craig, Dravid and Richardson (1995)). Therefore, it may behoove investors to hedge these risks. Ideally, a complete hedge would involve shorting the appropriate hedging instrument at 4pm and closing out the position at the close of the foreign market the next day. For example, for Japanese equities (assuming they trade at the close), this would occur at 1am. The problem is that, in most circumstances, the hedging instruments are not traded around the clock.[8] This leaves U.S. investors with several choices.

First, because the greatest volatility exists during foreign trading hours, one could simply initiate the hedge at the open of the foreign country's stock/futures exchange, and then take off the hedge at the corresponding close. This way the only volatility faced by the investor is between 4pm and the opening of the foreign country's market. Second, one could initiate a hedge using a foreign-based derivative traded in the U.S. (i.e., so-called quantos) at 4pm and take it off at the open the following day. This exposes the investor to additional risks between the close of the foreign country's market and the open of the U.S. market. Three common types of securities are traded in U.S. markets, which allow the investor to perform these types of hedges:

- Foreign-based futures contracts, such as the Nikkei futures, are traded on the CME.
- Foreign-based index options, such as the Eurotop 100, Nikkei, and Hang Seng, are traded on the AMEX.

[7] Currently, we know of at least sixteen hedge fund companies covering 30 specific funds whose stated strategy is "mutual fund timing".

[8] There are exceptions, for example, the S&P500 futures and Nikkei futures contracts trade around the clock on GLOBEX via the CME.

- Foreign index shares, WEBS, are traded on the AMEX. WEBS cover 17 countries, and match the characteristics of the corresponding Morgan Stanley Capital International Indices.[9]

Third, the investor is exposed to foreign exchange risk, because typically the NAVs of the funds are calculated by taking the stale prices of the assets multiplied by the corresponding exchange rate at 4pm. Investors, therefore, should hedge exchange-rate risk from close-to-close. As a final comment on hedging, the funds themselves may not mimic the properties of the hedge instruments. Thus, the basis risk inherent in any of these strategies can vary substantially across funds. Some of these risks are explored in Section 3 below.

2.3 Existing Literature

There is a growing literature in finance that explores the trading of mutual funds. Our paper's primary focus and contribution relates to (i) the development of trading strategies which are clearly implementable, (ii) a comparison of these strategies using different signals about market movements and under different trading costs scenarios, and (iii) the return and risk tradeoff of these strategies if they were applied in practice. While all the papers in the literature point out how the predictability induced by stale mutual fund prices can be profitable, the focus of this literature is somewhat different.

In particular, Chalmers, Edelen and Kadlec (2001) discuss mutual fund trading in the broader context of a financial intermediary who sets prices mistakenly. They go on to show that, for domestic equity funds especially, much of the predictability is due to nonsynchronous trading. Chalmers, Edelen and Kadlec (2001) propose possible solutions to calculating NAV prices of the funds in the presence of nontrading. In a specific case study of a small cap fund, they show that a market-based adjustment works well in practice.

In contrast, Greene and Hodges (2000) and Goetzmann, Ivkovic and Rouwenhorst (2001) concentrate more on the relation between the predictability of the fund's NAV and the flow of money into and out of the funds. While there is some questions about the quality of the flow data, which

[9]There is an interesting difference between a quanto and WEBS-based hedge. Consider hedging Nikkei-linked assets. Changes in the Nikkei futures quanto traded on the CME reflects changes in the Nikkei level at a fixed exchange rate, while Japan WEBS reflect changes in the dollar value of the assets, thus incorporating both exchange rate and Nikkei level changes.

is partially addressed by both groups of authors, Greene and Hodges (2000) in particular find a strong relation. Because investors who hold the fund during the period when the timing strategies enter and exit the fund suffer reductions in the market value of their holdings that are equal dollar-for-dollar to the abnormal gains, Greene and Hodges (2000) are able to estimate the losses suffered by buy-and-hold investors. Goetzmann, Ivkovic and Rouwenhorst (2001) is most similar to our paper in that they focus on international funds. However, while we concentrate on the types of signals, strategies and risks facing a market timing investor, their focus is on (i) the magnitude of the losses felt by the buy-and-hold investor, and (ii) the methods for adjusting NAV prices to minimize these losses. Their general findings are consistent with Greene and Hodges (2000) albeit on a smaller scale.

3 Trading Analysis

We now turn to the implementation and analysis of two distinct but conceptually similar strategies. The key distinctions between the strategies are the types of assets in the funds and consequently the corresponding signal assets and possible hedging instruments. In each case, we compare the returns and Sharpe ratios of a strategy of switching between a money market account and the mutual fund under different scenarios that address the following questions:

- First, what is the effect of using different instruments to generate the trading signals? For example, for evaluating price movements of Japanese securities during the U.S. trading day, we compare the performance of signals based on U.S. traded Nikkei futures versus within-day S&P 500 returns.

- Second, what is the effect of using different expected return thresholds generated by the above signals? In other words, we study the effect of higher expected return thresholds that are associated with less trading albeit with stronger signals.

- Third, as an alternative to trading less to avoid detection by the fund family, one could use third party online vendors, which significantly reduces the cost of detection. What is the effect of using these online firms to process the trades? Since third party vendors impose nominal costs for exchanging funds, we consider various trading costs under several initial

capital holdings. We look at the tradeoff between trading more frequently at a nominal cost versus less frequently at no cost.

- Fourth, how much risk does an investor face if the position is unhedged during the foreign country's trading hours? We explore both hedged and unhedged returns and Sharpe ratios using widely available (albeit imperfect) hedges.

- Fifth, and lastly, in addition to the Sharpe ratio analysis, what are the properties of the unexpected hedged and unhedged returns? That is, using the signal, we generate an expected return, $E_t[R_{t+1}]$, from the strategy. We explore the properties of $R_{t+1} - E_t[R_{t+1}]$ to better understand the risks facing the investor in implementing the strategy.

3.1 Japan Funds

Perhaps the most natural choices for exploiting stale prices are Japan funds, or Pacific funds with a large component of Japanese equities. These funds are obvious candidates for two reasons. First, the opening hours for the Japanese and U.S. markets do not overlap; therefore, all the new information that comes out during the day in the U.S. is potentially useful since it is not incorporated in same day Japanese closing prices. Second, futures on the Nikkei 225 index trade in Chicago, which not only provides high quality signals, but also provides an excellent hedging instrument.

The strategy, which is both simple and intuitive, is illustrated in the diagram in Figure 1. The Japanese market closes at 1am (or 2am in the summer), and these closing prices are used to set fund NAVs and hence purchase and sale prices which are effective for fund transactions up to 4pm.[10] In other words, the fund's NAV is set using $P_{1:00am}$, but is recorded at 4:00pm. However, beginning at 9:30am, Nikkei 225 futures contracts trade in Chicago. Price movements in this contract are highly correlated with the true, but unobserved, prices of the assets in most Pacific funds.[11] In fact, it is possible to derive an implied Nikkei price, $\hat{P}_{4:00pm}$. If $\hat{P}_{4:00pm} >> P_{1:00am}$, then knowing that the futures price is up (relative to the close of the index in Japan) is a good indication that the market will open up in Japan the following day. This, in turn, makes a positive return for the

[10] Pacific funds may also hold securities that trade elsewhere, e.g., ADRs that trade on the NYSE. For these securities, funds use updated prices; however, they generally constitute a small fraction of any particular portfolio.

[11] See Craig, Dravid, and Richardson (1995) for a detailed analysis of the extent to which the futures market in the U.S. predicts subsequent movements in Japan.

trading day in Japan likely, and hence the NAVs of Pacific funds are likely to increase tomorrow to the extent that their asset returns are highly correlated with that of the Nikkei index.

Of course, this is only useful information because mutual funds are still permitting trade at the old, stale prices. The strategy involves buying the fund when the futures are up and liquidating the position when the futures are down. This strategy contrasts with those documented elsewhere that focus on movements in U.S equity markets (e.g., Goetzmann, Ivkovic and Rouwenhorst (2001)). However, the mutual funds described in Table 1 do not correlate perfectly with the Nikkei index because the funds include other Pacific region-based assets and may have weightings different from the Nikkei index (e.g., a high weighting on technology stocks or other Asian markets). Thus, it may be interesting to consider multiple signals which can capture both pure Nikkei movements as well as movements in equities unrelated to the Nikkei.

In this section, we focus on five no-load Pacific funds, described in Table 1, that satisfy the criteria laid out in Section 2.1. In brief, all five funds allow free exchanges and are actively managed portfolios of securities traded on Japanese and Pacific stock exchanges, with a small percentage invested in ADRs.

In order to understand the potential for excess profit, Table 2A documents several important stylized facts for the fund returns. We calculate the contemporaneous correlation of the fund returns with the Nikkei index return and the Dollar/Yen foreign exchange return, its autocorrelation and its cross-serial correlation with the relevant signals – in this case, with the Nikkei index futures return in the U.S. and the S&P500 index return.

The results strongly indicate stale pricing. First, the contemporaneous correlations with the Nikkei are high for four of the five funds, ranging between 58% and 72%. If the funds actually traded during U.S. hours and were not stale, one would expect these to be much smaller. There are two reasons for the lack of perfect correlation. First, the funds do not attempt to mimic the Nikkei index exactly, that is, they are simply actively managed Pacific funds. For example, consider the difference between fund 4 (i.e., T Rowe Price New Asia) and fund 5 (i.e., T Rowe Price Japan). The former fund covers all Asian markets and focuses on technology, while the latter fund covers only Japan and represents a cross-section across industries. Not surprisingly, their correlations are 35% and 69%, respectively. Second, the funds' NAVs are dollar denominated and hence include the effect of changes in the Yen/Dollar exchange rate. The returns on all five funds are positively

correlated with exchange rate returns. Hence, the correlation with the Nikkei gives us an idea of the "upper bound" on the quality of the signal that we can get.

Second, these funds exhibit some autocorrelation, ranging from 7% to 30%. What this suggests is that the fund's securities either do not all trade at 1:00am, are not updated on a systematic basis or the funds hold some ADRs which are incorporated into 4:00pm prices. Fund 1 (i.e., Warburg Pincus Japan Growth) aside, the autocorrelations are not very large, but this is partly attributable to the fact that Japanese indices exhibit a somewhat anomalous negative autocorrelation (see, Ahn, Boudoukh, Richardson and Whitelaw (2001) for a study of international index autocorrelations).

Third, the signals have considerable correlation, i.e., predictive power, for the funds' returns. In particular, the correlations range between 0.24 and 0.43 for the U.S. traded Nikkei futures and between 0.17 and 0.43 for the within day S&P500 return. Since the S&P500 and Nikkei futures do not contain the same information, this suggests the possible value of multiple signals. Because these positions are tradeable at zero transactions costs, this degree of daily predictability implies large profit opportunities.

3.1.1 Signals

Given the results of Table 2A, it is possible to formalize the obvious trading opportunities inherent in these results. We consider the following three possible signals:

- The difference between the closing Nikkei level in Japan and the implied Nikkei level at 4:00pm (based on the nearest-to-maturity Nikkei futures contract) traded on the CME.[12] For simplicity, we have assumed that the investor trades arbitrarily close to 4:00pm; in practice, an earlier time, say 3:55pm, may be more reasonable.

- The within-day change on the S&P500. This variable is considered more as a check on how much more information is contained in the underlying Nikkei futures. Independent of the fact that the S&P500 and the Nikkei are not close to being perfectly correlated, this measure also misses the eight and one-half early-morning hours between 1:00am and 9:30am. These

[12]The implied level of the Nikkei index can be inferred from pricing the Nikkei futures contract as a Quanto. In particular, the Nikkei futures represents a foreign-based derivative that pays off in dollars. Using results in Dravid, Sun and Richardson (1994), the Nikkei futures price is equal to the Nikkei level, adjusted for the Japanese interest rate and dividend yield over the life of the contract.

can be very important as substantial announcements are made during after-trading hours in Japan (see Craig, Dravid and Richardson (1995)).

- A combination of the above two signals.

Due to the restrictions on excessive trading (albeit sometimes leniently enforced), we consider strategies which ex ante lead to only minimal amounts of trading. In other words, we focus on strategies which provide large daily excess returns, though relatively infrequently. Assuming prices follow a random walk but prices are not updated by mutual funds, expected returns are given by the following equation:

$$E[r^{JPN}_{t_{1am},t+1_{1am}}] = b_1(FUT_{t_{4pm}} - NIK_{t_{1am}}) + b_2 r^{S\&P}_{t_{9am},t_{4pm}}$$

where r^{JPN} represents the return on the Japanese fund which trades at 4pm (but actually represents the earlier 1am prices), FUT and NIK are the Nikkei futures and Nikkei index price, respectively, and $r^{S\&P}$ is the return on the S&P500 from open to close. We define large excess returns in one of two ways – either 0.5% or 1.0%, depending on the frequency of trading desired. Of course, these thresholds translate to excess returns of 125% and 250% on an annualized basis. For example, if $E[r^{JPN}_{t_{1am},t+1_{1am}}] > 0.5\%$, then the investor buys the fund. Each day the investor reevaluates the trade, only selling the fund and going into a money market fund if $E[r^{JPN}_{t_{1am},t+1_{1am}}] < 0$.

Table 2B reports results for the five funds in our sample using the three different signals. The Sharpe ratios are calculated for days when the trading rule places the investor in the funds. These Sharpe ratios are remarkable by any standard, across both threshold levels and across different signals. Sharpe ratios are as high as 10 and almost always above 6, which represent extraordinary levels for financial markets (e.g., see Brown, Goetzmann and Ibbotson (1999) for an analysis of hedge fund performances). In fact, the Sharpe ratios of the funds themselves vary between -0.29 and 0.42 over this same period. The reason for our success is that the strategy predicts the sign of the next day's fund return 75% of the time on average. If markets are roughly a fair game from day-to-day, then we would expect a number closer to 50%. Of some interest, the Sharpe ratios tend to be higher for the higher threshold of 1%, primarily because these trades are based on a stronger signal and are even better at predicting whether the next day's return will be positive.

Generally, the strategy performs better when both signals are used together to predict the fund's return. While the two signals (i.e., the S&P 500 and the Nikkei) perform well individually, there

is always added information in combining them. For some funds, it is especially important. For example, the New Asia Fund (#4) has less ex ante correlation with the Nikkei, and, therefore, the strategy improves with the S&P signal. In particular, at a threshold of 0.5%, the mean return and Sharpe ratio go from 36.44% and 4.81 to 55.11% and 6.33 as we add the S&P signal. Additionally, even though the investor is invested most of the time in the money market fund, the cumulative returns tend to be greater for the trading strategy than for a corresponding buy-and-hold strategy. For example, using the combined signal at a threshold of 0.5%, the annualized mean returns on the strategy are 80.16%, 50.55%, 17.01%, 55.11% and 47.04% across the five funds versus 18.19%, 10.54%, -0.02%, -2.47% and 10.13% for the funds themselves, respectively. Interestingly, even though fund 5 has a better buy-and-hold mean than fund 4, the trading strategy produces higher mean returns on fund 4. This point illustrates one of the benefits of the trading strategy, namely that it is somewhat insensitive to investment managerial expertise/luck. That is, subject to the right signals being used, the strategy always works well because the investor only invests when the broad market moves. Since all of these funds have somewhat diversified portfolios, the result carries through for all funds.

3.1.2 Trading Costs

In Section 3.1.1, we consider two thresholds, namely 0.5% and 1%. We do this to minimize the amount of trading due to the restrictions on excessive trading reported in Table 1. Table 2C documents the number of trades, the percentage of time in the market, and buy-and-hold returns over the four-year sample period. The investor is in the market only a small fraction of the time, especially for the higher threshold. For example, using the 1.0% threshold, the percentage of days in the market vary between 1.40% and 16.09% for the five funds. Furthermore, because sometimes the investor stays in the fund on consecutive days (i.e., there is no sell signal), the actual amount of trading in and out of the fund is quite low. However, at the lower threshold level, the trading is still quite significant. With the lower threshold, trade frequencies vary from eight to thirty-five times a year. Putting aside the lax enforcement of trading restrictions, these amounts generally represent excessive trading under the rules of the prospectuses.

Consequently, we also consider trades made through a third party, such as an online brokerage firm, who send their orders in batch. In theory and practice, these trades are much more difficult

to detect compared to transfers within a fund family. However, unlike direct trades with the fund family, these trades are subject to a fee. It is interesting therefore to document the tradeoff between excessive trading and brokerage fees on the buy-and-hold return. To coincide with actual practice, we consider nominal trading costs of either $14.95 or $29.95 for three levels of initial capital, $10,000, $100,000 and $1,000,000, as well as the case of free exchanges (i.e., no costs).

Several observations are of interest. First, even at the high trading cost and low initial capital level, the trading strategy returns across the five funds are much higher than the buy-and-hold strategy. Specifically, at a cost of $29.95 and $10,000 of capital, the cumulative returns are 1008.58%, 344.92%, 61.59%, 356.62% and 317.08% across the five funds versus 59.32%, 38.40%, -8.59%, -19.89% and 31.71% for the funds themselves, respectively. Second, the issue of transactions costs only matters at the low level of capital, i.e., $10,000. That is, the returns over the four-year period fall by about 15% and 30% for the lower and higher cost trade, respectively. Otherwise, the fixed costs have little real effect. Third, to the extent that many hedge funds are employing this strategy (e.g., see footnote 7), these results suggest that trading restrictions will not prevent this practice. This is because with relatively low amounts of capital the strategy can be processed through third parties at little cost.

3.1.3 Risk

The above strategies are subject to two types of risk – currency risk, and the risk associated with movements in prices between the close of the U.S. market and the close of the Japanese market the following day. Japanese stock market risk can be partially eliminated. Recall that the strategy exploits movements in true prices prior to the close of the futures market, but provides no information about future movements in true prices. Consequently, hedging the risk requires eliminating exposure to the Japanese market after the close in the U.S. This can be done by selling the futures at the close in order to offset the exposure due to the long position in the fund, then closing the position when the futures market opens again in the U.S.[13] An alternative hedge instrument is the WEBS contract that trades on the AMEX. This security is equivalent to an

[13]Note that the optimal closing of the position would be at the close of Japan. For this to happen, the investor essentially needs around-the-clock trading, which takes place for futures contracts on both the S&P500 and the Nikkei on GLOBEX.

open-end index fund. However, unlike funds, this security does trade continuously during the U.S. trading day at market prices rather than NAV. While either the futures or the WEBS can hedge the exposure during the period when the Japanese market is open the next day, it also generates a net short position between the subsequent close of the Japanese market and the open of the U.S. market. Volatility, however, should be relatively lower in this latter period. It is primarily an empirical question whether the hedge improves performance in practice.

Tables 2D and 2E provide an analysis of the risk of the trading strategy using the hedge instrument at the U.S. close and closing the position at the U.S. open the following day.[14] As seen in Table 2D, when the hedge is undertaken, the Sharpe ratios improve in all cases, sometimes by more than 25%. For example, for fund 2, the Sharpe ratios increase from 7.95 to 10.12 and from 10.46 to 13.98, respectively for the 0.5% and 1.0% thresholds. Since these hedges are relatively easy to implement in practice (and at relatively low cost), it suggests substantial benefit. In Table 2E, we compare the volatility and the exposure to market and exchange rate movements for the fund itself and the corresponding unhedged and hedged strategies. Two important points come from this analysis. First, the volatility of the trading strategy is much less than that of the fund, presumably because the strategy is implemented only sporadically on very strong signals. Second, the hedged strategy reduces the exposure (almost completely) to the overall Nikkei market, and this is true across all five funds.[15]

3.2 International Funds

Another natural choice for exploiting stale prices are international funds that concentrate in equity markets in different time zones such as Europe. Though European trading partially overlaps with U.S. trading hours, information that comes out during the latter part of the day in the U.S. is potentially useful since it is not incorporated into closing European prices of the same day. Moreover, the contemporaneous correlation between U.S. and European markets tends to be higher than that between the U.S. and Japan.

[14] We use the CME Nikkei futures as the hedge instrument, and take a position in the contract from its close to open. On days with consecutive large positive signals, this reduces the potential value on the second day if the Nikkei-based information is released between the Japanese close and U.S. open.

[15] There is remaining exposure to exchange rates which we did not try and hedge. In theory, one could use forward contracts to reduce the exposure for the relevant funds.

The strategy for Europe is illustrated in the diagram in Figure 1. The European stock markets have all closed by 12pm, though a number of markets close somewhat earlier. These closing prices are used to set fund NAVs and hence purchase and sale prices, which are effective for fund transactions up to 4pm. Thus, there is at least a four-hour period, possibly more, in which investors can look to U.S. markets to "predict" contemporaneous moves in Europe, which in turn get built into the NAV of international funds the following day.

We focus on those funds with significant assets under management for which the trading strategy is feasible, for a total of 12 funds out of approximately 700 international no-load funds (see Table 1). To be comparable with Section 3.1, we use data from 1/1/1997-11/30/2000. Table 3A documents several important stylized facts about the fund returns. In particular, we calculate the contemporaneous correlation of the fund returns with the Eurotop stock index, its autocorrelation and its cross-autocorrelation with the relevant signals – in this case, with S&P500 returns in the U.S. over different times (i.e., from open-to-close, open-to-12pm, and 12pm-to-4pm).

First, the contemporaneous correlations are substantial, ranging between 0.57 to 0.80. Second, these funds exhibit significant autocorrelation, ranging from 0.07 to 0.30, with the majority being greater than 0.11. What this suggests is that the funds' securities do not all trade at the same time or are not updated on a systematic basis. In fact, we know that they include securities from a cross-section of countries with markets that close at different times. Third, the signals have considerable correlation, i.e., predictive power, for the funds' returns. In particular, the S&P signals from both open-to-noon and noon-to-close have considerable correlation, ranging from 0.20 to 0.35 and 0.18 to 0.37, respectively. Of some interest, because S&P returns are approximately uncorrelated over subperiods within the day, it is beneficial to look at the two signals together. Again, because these positions are tradeable at zero transactions costs, this amount of daily predictability implies large profit opportunities in these international funds.

Similar to the trading strategy for the Japanese-based funds, we consider strategies which either ex ante lead to only minimal amounts of trading or are implemented through third party vendors. We consider expected returns generated from signals in the U.S. stock market,

$$E[r^{Itl}_{t_{12pm},t+1_{12pm}}] = b_1 r^{S\&P}_{t_{9am},t_{12pm}} + b_2 r^{S\&P}_{t_{12pm},t_{4pm}},$$

where r^{Itl} represents the return on the international fund which trades at 4pm (but actually represents the earlier closing prices of international exchanges), and $r^{S\&P}$ is the return on the S&P500

(broken down into periods during the day). As before we define large excess returns in one of two ways, either 0.5% or 1.0%, depending on the amount of trading desired. We also consider nominal trading costs of either $14.95 or $29.95 for three levels of initial capital, $10,000, $100,000 and $1,000,000, as well as the case of free exchanges (i.e., no costs). Also each day, the investor reevaluates the trade and again sells the fund only if $E[r^{Itl}] < 0$.

3.2.1 Signals

We investigate empirically the simulated trading results of the twelve funds described in Table 3A using three different signals - (i) open-to-close S&P returns, (ii) noon-close S&P returns, and (iii) open-to-noon and noon-to-close S&P returns together. Table 3B reports annualized means, Sharpe ratios and % correct sign for these strategies. The Sharpe ratios range from 5.52 to 12.16 across both thresholds, with the majority of them being in the range from 6 to 9, compared to between -0.03 and 0.98 for the buy-and-hold strategies. In terms of the different trading signals, there is a clear benefit to using S&P500 information prior to noon. For example, for the majority of funds and using the 0.5% threshold, the mean return is over 1.5 times higher using either of the signals that incorporate the earlier information. Surprisingly, even though in theory the two-signal strategy should use the information more efficiently by separating out the morning and afternoon S&P500 signals, in practice, using the S&P500 return over the entire day works just as well.

Table 3B also documents the fact that the percentage of days for which we see a positive return when there is a trading signal is usually above 80% for the 0.5% threshold, and even higher for the 1.0% threshold. In contrast, the percentage of positive returns in the entire sample is only slightly above 50%. In order to understand the statistical significance of both these and the aforementioned Pacific fund results, we can perform a simple binomial test. As a representative example, consider fund 1, Warburg Pincus International, and further consider the null hypothesis that the trading results are due to chance. Under this null, the "true" probability of seeing a positive return is 55%, the fraction of positive return days in the full sample. Under these assumptions, the observed 82% value is almost six standard deviations from the mean, which is equivalent to a p-value of 0.00. Alternatively, the Sharpe ratio itself corresponds to a t-test. Since both the mean and the standard deviation are annualized, and we have 3.92 years of data, we can easily provide a test for the null that the mean return for in days is zero. The relevant statistic is the Sharpe ratio times $\sqrt{3.92}$ (i.e.,

the number of years), which is almost uniformly above 10 for all funds.

3.2.2 Trading Costs

Table 3C reports results relating to trading activity and costs. Similar to the results for the Pacific funds, the cumulative return results are impressive for the 0.5% threshold. For every fund, the investor is in less than 20% of the time, yet in almost every case, the strategy's returns exceed those of the fund, sometimes substantially so. Even when the threshold is increased to 1.0%, the strategy still outperforms in the majority of cases.

With respect to trading through a third party, it is true again that, only for the case in which the investor has minimal amounts of capital, are trading costs relevant. Therefore, Table 3C documents the most extreme case, i.e., \$29.95 and \$10,000, for each of the 12 international funds. For the 0.5% threshold, the cumulative returns fall by about 50% and, for three funds, actually fall below the buy-and-hold strategy. Of course, even though the funds' returns drop substantially, the risk is still much less due to the investor being in the market on only a limited basis.

3.2.3 Risk

Similar to the strategies in Section 3.1.1, the above strategy is subject to two types of risk – currency risk and the risk associated with movements in prices between the close of the U.S. market and the close of the various international markets the following day. These risks are more complex than for the Japanese-based funds because the portfolio holdings are spread across a wide array of countries. Nevertheless, the risk can be partially eliminated by hedging the returns with derivatives on a diversified international portfolio, such as the Eurotop 100. Even though instruments did not exist in U.S. markets during this period, one can hedge the volatility within the trading day in Europe. When the hedge is undertaken, the Sharpe ratios improve in many of the cases, but by relatively small amounts, and the hedged returns are essentially uncorrelated with the European index.[16]

[16] For brevity, the results are not reported but are available from the authors upon request.

4 A Case Study: Vanguard

In this section, we illustrate one particular trading strategy initiated in January 1997. This strategy is especially relevant for university academics as it pertains to trading Vanguard mutual funds, which are included in most university 403(b) plans. Among the choices, three funds stand out with respect to the above trading strategies: (I) Vanguard International Growth, (II) Vanguard International European Equity Index, and (III) Vanguard International Pacific Equity Index. Table 1 describes characteristics of these funds in terms of trading. The first fund charges no fee to transfer in or out, while the latter two funds charge 50 basis points for transferring in to the fund.[17] The advantage of the latter two funds, however, is that they are index funds, with very high correlations with the aggregate markets in those two regions. We also employ the Prime Money Market fund, which invests primarily in high quality, short-term commercial paper.

The trading strategy uses the same signals as Sections 3.1.1 and 3.2.1 above with respect to the Pacific Fund, and the International Growth and European Funds, respectively. In particular, for the Pacific-based fund, we use the closing Nikkei futures price relative to the closing price of the Nikkei in Japan and the S&P500 index return. For the European funds we use S&P500 returns open-to-12pm and 12pm-to-close.

For the two funds with transactions costs, those costs are subtracted from the expected return calculations to give a comparison of all three funds net of transaction costs. Denote these net expected return as $E[R_I]$, $E[R_{II}]$ and $E[R_{III}]$ for the three funds described above. Given a threshold κ, a natural trading rule to get into these funds is then[18]

$$\text{Max}(E[R_I], E[R_{II}], E[R_{III}]) > \kappa.$$

Table 4A provides the correlations between the fund returns and the signals for each fund. Similar to Sections 3.1 and 3.2, there is considerable evidence of predictability for the fund returns. For example, the correlations between the Nikkei futures and S&P500 signals and the Vanguard Pacific fund are 35% and 29% respectively, while, for the European funds, the correlations are 18%

[17] Starting in 2001, the two index funds charge no fee for exchanges.

[18] We ignore the option component embedded in the funds with transactions costs. That is, even if the expected return on a fund is less than say the money market rate, it may still be worthwhile to stay in the fund because exiting means foregoing the option of getting in next period and saving the 50 basis points charge.

and 30% for the early stage of the day and 37% and 35% for the latter stage. Clearly, with large enough movements during US trading hours, there are potentially large excess profits available to an active investor.

Table 4B and 4C document the results for three trading thresholds – 0.25%, 0.5% and 1.0% – and for a simple buy-and-hold strategy. As before, the results are striking. For example, both hedged and unhedged strategies have Sharpe ratios ranging from 4.54 to 8.02 for the days that the investor is in the fund; in contrast, the Sharpe ratios of the buy-and-hold strategies range from -0.14 to 0.59. Of course, the higher Sharpe ratios come from the fact that the investor is rarely in the international equity market, and only when it tends to go up. For example, for a threshold of 0.5% daily excess return (net of transactions costs), the investor is in the Pacific fund 9.82% of the time, the European Index fund 4.41% of the time, and the International Growth fund 6.71% of the time. The aggregate number of trades over this four year period is 99, which leads to a cumulative return of 216.87% and 222.63% on the unhedged and hedged strategies, respectively. These cumulative returns contrast with only -4.03% for the Pacific fund, 69.89% for the European index fund and 39.40% for the International Growth fund. Most notably, even though the strategy earns 7 times the return on an equal-weighted buy-and-hold portfolio, the investor is actually in the risk-free, money market account 77% of the time.

As a final indicator of the magnitude of these results, Figure 2 graphs a time-series of the cumulative return on the three strategies versus the buy-and-hold, equal-weighted portfolio of the three funds. Both the higher volatility and smaller cumulative return of the buy-and-hold strategy are apparent. Trading just 21 times over this four year period provides excess returns of 17% to 31% (depending on the hedging strategy) over the equal-weighted portfolio's realized returns with little or no risk.

5 Final Remarks

This paper demonstrates that an institutional feature inherent in a multitude of mutual funds managing billions in assets generates fund NAVs that reflect stale prices. Since, in many cases, investors can trade at these NAVs with little or no transactions costs, there is an obvious trading opportunity. Simple, feasible strategies generate Sharpe ratios that are sometimes one hundred

times greater than the Sharpe ratio of the underlying fund. These opportunities are especially prevalent in international funds that buy Japanese or European equities and in funds that invest in thinly traded securities in the U.S. When implemented, the gains from these strategies are matched by offsetting losses incurred by buy-and-hold investors in these funds.

Are mutual funds aware of these trading opportunities? While we have no direct evidence on this question, actions taken by certain funds to curtail short-term trading and interaction with industry professionals suggest knowledge of the problem. Specifically, some funds are now imposing back-end loads on positions held for periods under a particular threshold. For example, Fidelity announced on March 1, 2000 that they would begin imposing a redemption fee of 1% on investments in international funds that are held for less than 30 days. Moreover, it is widely known that some hedge funds are engaged in actively trading mutual funds to exploit these stale prices (see footnote 7).

Can this type of trading activity be prevented? Imposing redemption fees as described above is one way to discourage short-term trading. These fees dramatically reduce the returns to such strategies, although they do not prevent the strategic timing of purchases. Attempting to correct for stale prices in computing NAVs is a second approach, although it is fraught with complications. Specifically, any correction will be subject to both model risk and estimation risk. Moreover, to the extent that the updating procedure becomes known or can be backed out from the data, traders may be able to exploit the inevitable errors. A third alternative would be to permit purchases only on the basis of the following day's NAV. In other words, funds invested today, would go into the fund tomorrow at tomorrow's closing prices. This procedure would not totally eliminate the effects of stale prices, but it would dramatically reduce them. These issues are discussed in detail by Chalmers, Edelen and Kadlec (2001), Greene and Hodges (2000) and Goetzmann, Ivkovic and Rouwenhorst (2001).

Should mutual funds even worry about trying to prevent these types of strategies? Since the gains are offset by losses to other investors in the fund, it is clear that the funds' fiduciary duty requires them to take some action. That is, all the gains are being offset, dollar-for-dollar, by losses incurred by buy-and-hold investors. Under simple assumptions, the total dollar loss and the percentage loss depend only on the magnitude of the purchases, both in dollar terms and relative to the initial size of the fund, and the anticipated price move. The larger the purchase by market

timers exploiting stale prices, the greater the loss. Moreover, these strategies hurt the long-term performance of the fund and therefore damage the track record and reputation of the fund family and the portfolio managers. Finally, short-term traders may also impose additional costs on the fund in the form of transactions costs or other expenses.

Given these issues, why haven't more funds taken stronger actions to restrict short-term trading? Perhaps these funds are unaware of the problem. A more cynical interpretation is that short-term trading increases average assets under management, the basis for compensation of many portfolio managers. As long as performance is not hurt too badly, managers may have an incentive not to interfere with this activity. Finally, there may be the perception that imposing redemption fees or delaying investments puts the fund at a competitive disadvantage in attracting money relative to its peers. Unfortunately, the profits and Sharpe ratios documented in this paper suggest that this activity will continue to increase, and, therefore, will eventually have to be curtailed.

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Table 1: Trading Limits for Mutual Funds

Fund	Assets $mm 1/97	Trading Restrictions
PACIFIC		
1. Warburg Pincus Jpn. Gw.	20.8	Bar excessive trading; 2% fee within 6 months after 5/2000
2. 59 Wall Street Pac. Bsn	153.8	Bar excessive trading; 2% fee within 30 days after 2001
3. Capstone Nikko	2.9	May penalize "abusive" trading, once per month
4. T Rowe Price New Ai.	2222.0	Right to bar excessive trading (3 times/yr)
5. T Rowe Price Jpn.	165.1	As above
EUROPEAN		
1. Warburg Pincus Intl.	2978.4	Right to bar excessive trading (at discretion)
2. USAA Wld. Gw.	265.5	Right to bar excessive trading (6 times/yr)
3. USAA Intl.	504.2	As above
4. Northern Intl. Gw.	185.7	Right to bar excessive trading (8 times/yr)
5. Mercury Intl. Val.	474.2	None
6. Harbor Intl. Gw.	566.2	None (except a comment about market timing)
7. 59 Wall Street Eur.	146.3	Bar excessive trading; 2% fee within 30 days after 2001
8. Vanguard Star	271.3	Right to bar excessive trading (2+ times/yr)
9. Managers Intl.	259.2	Right to bar excessive trading (at discretion)
10. Janus WWD.	5046.3	Right to bar excessive trading (4 times/yr)
11. Dreyfus Founders	334.8	Right to bar excessive trading (4 times/yr)
12. Liberty Acorn Intl.	1771.7	None
VANGUARD		
1. International Gw.	5521.0	Right to bar excessive trading (2+ times/yr)
2. Pacific Index	1023.3	0.5%. 0.0% after 2001).
3. Europe Index	1541.9	0.5% (0.0% after 2001).

The table lists all the companies used in the study broken up by type. Each fund is allocated a number which is used throughout the tables on the following pages. For each fund, we also list their initial assets as of January 1997. From their prospectuses, we also take the descriptive language regarding market timing for exchanges between funds. Note that all of these funds are no load and allow free exchanges.

Table 2: Pacific/Japan Funds

Panel A: Correlations of Fund Returns

				Signals	
Fund	Nikkei	$/Yen	Autocorr.	S&P500	Fut-Spt
1	0.58	0.09	0.30	0.35	0.38
2	0.72	0.13	0.11	0.43	0.43
3	0.69	0.47	0.07	0.17	0.24
4	0.35	0.09	0.17	0.42	0.32
5	0.69	0.50	0.09	0.27	0.35

This table reports the contemporaneous correlations of fund returns with the Nikkei 225 index and the $/Yen exchange rate return; the autocorrelations of funds returns; and the correlations of returns with the two signals: (1) the lagged S&P500 return from open to close, and (2) the lagged return on the Nikkei 225 from the close of the spot market in Japan to the close of the futures market in Chicago. The sample period is Jan. 1997 to Nov. 2000.

Panel B: Trading Results for Different Signals

		Fund			S&P500			Nikkei			Both		
Fund	Thld	Mean	s.r.	%pos	Mean	s.r.	%pos	Mean	s.r.	%pos	Mean	s.r.	%pos
1	0.5	18.19	0.42	54.15	59.56	6.31	70.62	71.11	7.11	76.60	80.16	7.41	76.50
	1.0				35.91	9.11	83.64	37.56	8.98	82.14	46.23	8.09	79.49
2	0.5	10.54	0.27	53.27	43.06	8.22	76.82	39.97	6.86	75.35	50.55	7.95	75.14
	1.0				19.89	9.59	84.85	19.21	10.07	89.29	26.18	10.46	88.37
3	0.5	-0.02	-0.23	48.17	7.03	2.32	64.71	16.21	5.73	78.05	17.01	5.96	76.19
	1.0				5.04	NA	NA	6.78	3.00	100.0	7.64	7.35	100.0
4	0.5	-2.47	-0.29	49.84	58.92	6.79	73.68	36.44	4.81	72.50	55.11	6.33	74.16
	1.0				28.49	8.55	76.36	15.58	6.22	80.00	32.49	8.84	74.19
5	0.5	10.13	0.21	49.78	32.08	6.96	71.74	43.61	6.21	76.27	47.04	6.42	73.88
	1.0				10.07	6.13	66.67	14.52	6.51	84.21	18.98	8.07	85.19

This table reports trading results using two different threshold expected returns (0.5% and 1.0%) and three different sets of signals (the S&P500 return from open to close, the return on the Nikkei 225 from the close of the spot market in Japan to the close of the futures market in Chicago, and both signals simultaneously. For each strategy and each fund, we report the annualized mean return, the Sharpe ratio for periods when the strategy is invested in the fund, and the percent of days that yield positive returns. The sample period is Jan. 1997 to Nov. 2000.

Panel C: Trading Results with Trading Costs

	Initial		Fund	Thld(0.5)			Thld(1.0)		
Fund	Bal($000)	Cst	B&H	B&H	%in	#buys	B&H	%in	#buys
1		0.00	59.32	1508.18	37.17	139	395.64	16.09	63
	10	14.95	59.08	1258.80			348.34		
	10	29.95	58.84	1008.58			300.89		
	100	14.95	59.30	1483.24			390.91		
	100	29.95	59.27	1458.22			386.16		
	1000	14.95	59.32	1505.69			395.17		
	1000	29.95	59.32	1503.18			394.69		
2		0.00	38.40	578.06	29.46	119	169.84	8.92	39
	10	14.95	38.19	461.68			150.85		
	10	29.95	37.98	344.92			131.80		
	100	14.95	38.38	566.43			167.94		
	100	29.95	38.36	554.75			166.04		
	1000	14.95	38.40	576.90			169.65		
	1000	29.95	38.40	575.73			169.46		
3		0.00	-8.59	90.18	8.52	35	33.80	1.40	5
	10	14.95	-8.73	75.91			32.02		
	10	29.95	-8.86	61.59			30.23		
	100	14.95	-8.60	88.75			33.62		
	100	29.95	-8.62	87.32			33.44		
	1000	14.95	-8.59	90.04			33.78		
	1000	29.95	-8.59	89.89			33.76		
4		0.00	-19.89	694.04	31.66	148	241.02	11.52	59
	10	14.95	-20.01	525.61			206.04		
	10	29.95	-20.13	356.62			170.96		
	100	14.95	-19.90	677.19			237.52		
	100	29.95	-19.91	660.30			234.01		
	1000	14.95	-19.89	692.35			240.67		
	1000	29.95	-19.89	690.66			240.31		
5		0.00	31.71	487.70	27.25	100	104.92	6.31	27
	10	14.95	31.51	402.53			93.86		
	10	29.95	31.31	317.08			82.76		
	100	14.95	31.69	479.18			103.82		
	100	29.95	31.67	470.64			102.71		
	1000	14.95	31.71	486.85			104.81		
	1000	29.95	31.70	485.99			104.70		

This table reports trading results using two different threshold expected returns (0.5% and 1.0%) for two different levels of fixed costs and three different initial starting balances. For each strategy we use both signals. For each strategy and each fund, we report the buy-and-hold return over the full sample period, the percent of time invested in the fund, and the number of purchase transactions. The sample period is Jan. 1997 to Nov. 2000.

Panel D: The Effects of Hedging

					Strategies					
			Fund		Mean		s.r.		%pos	
Fund	Thld	Mean	s.r.	%pos	Unhdg	Hdg	Unhdg	Hdg	Unhdg	Hdg
1	0.5	18.19	0.42	54.15	80.16	83.52	7.41	8.30	76.50	77.73
	1.0				46.23	49.91	8.09	9.43	79.49	83.95
2	0.5	10.54	0.27	53.27	50.55	52.89	7.95	10.12	75.14	82.86
	1.0				26.18	28.67	10.46	13.98	88.37	95.35
3	0.5	-0.02	-0.23	48.17	17.01	19.10	5.96	8.64	76.19	88.89
	1.0				7.64	8.51	7.35	8.83	100.00	100.00
4	0.5	-2.47	-0.29	49.84	55.11	56.46	6.33	6.56	74.16	73.61
	1.0				32.49	33.07	8.84	8.96	74.19	74.19
5	0.5	10.13	0.21	49.78	47.04	52.89	6.42	8.84	73.88	80.00
	1.0				18.98	22.28	8.07	10.67	85.19	87.10

This table reports trading results for both unhedged and hedged strategies using two different threshold expected returns (0.5% and 1.0%). For each strategy we use both signals, and returns are hedged with Nikkei 225 futures traded in Chicago. For each strategy and each fund, we report the annualized mean return, the Sharpe ratio for periods when the strategy is invested in the fund, and the percent of days that yield positive returns. The sample period is Jan. 1997 to Nov. 2000.

Panel E: Analysis of Unexpected Returns

			Fund			Unhdg			Hdg	
Fund	Thld	Vol	$/Yen	Nikkei	Vol	$/Yen	Nikkei	Vol	$/Yen	Nikkei
1	0.5	31.57	0.01	0.14	15.86	0.00	0.17	14.58	0.00	0.00
	1.0				11.70	0.00	0.18	10.76	0.00	0.00
2	0.5	20.37	0.02	0.24	9.72	0.01	0.43	7.60	0.02	0.03
	1.0				5.80	0.00	0.49	4.34	0.01	0.05
3	0.5	21.57	0.22	0.34	6.53	0.16	0.50	4.96	0.20	0.04
	1.0				2.70	0.43	0.13	2.76	0.26	0.02
4	0.5	25.70	0.01	0.03	13.19	0.01	0.01	13.10	0.01	0.02
	1.0				8.11	0.00	0.02	8.16	0.00	0.01
5	0.5	24.35	0.25	0.27	11.94	0.25	0.43	9.58	0.37	0.06
	1.0				6.21	0.25	0.32	5.50	0.29	0.01

This table reports the volatility and correlations with the $/Yen exchange rate return and the Nikkei return from the close of the futures in Chicago to the close of the spot index the following day in Japan for unhedged and hedged unexpected returns. For each strategy we use both signals and two expected return thresholds (0.5% and 1.0%). The sample period is Jan. 1997 to Nov. 2000.

Table 3: International/European Funds

Panel A: Correlations of Fund Returns

				Signals–S&P500		
Fund	Eurotop	$/Euro	Autocorr.	O-C	O-12	12-C
1	0.63	0.03	0.25	0.44	0.34	0.32
2	0.66	-0.04	0.17	0.27	0.23	0.18
3	0.71	0.08	0.16	0.37	0.27	0.28
4	0.68	0.10	0.14	0.36	0.26	0.28
5	0.66	0.11	0.12	0.39	0.25	0.33
6	0.74	0.09	0.12	0.38	0.24	0.33
7	0.80	0.12	0.07	0.36	0.20	0.35
8	0.74	0.09	0.11	0.42	0.28	0.35
9	0.73	0.12	0.13	0.44	0.31	0.35
10	0.68	-0.10	0.25	0.32	0.23	0.25
11	0.58	-0.04	0.17	0.29	0.20	0.24
12	0.57	0.05	0.30	0.49	0.35	0.37

This table reports the contemporaneous correlations of fund returns with the Eurotop index and the $/Euro exchange rate return; the autocorrelations of funds returns; and the correlations of returns with the three signals: (1) the lagged S&P500 return from open to close, (2) the lagged S&P500 return from open to noon, and (3) the lagged S&P500 return from noon to close. The sample period is Jan. 1997 to Nov. 2000.

Panel B: Trading Results for Different Signals

			Fund		S&P500 O-C			S&P500 12-C			S&P500 O-12,12-C		
Fund	Thld	Mean	s.r.	%pos	Mean	s.r.	%pos	Mean	s.r.	%pos	Mean	s.r.	%pos
1	0.5	4.58	-0.03	55.01	29.60	8.42	82.14	16.69	9.39	69.81	29.59	8.35	82.14
	1.0				10.12	8.07	78.95	8.04	14.29	60.00	10.31	8.13	78.95
2	0.5	11.83	0.46	56.29	11.16	6.80	76.00	8.23	19.66	100.0	10.78	5.52	80.77
	1.0				5.17	1.44	50.00	5.04	NA	NA	4.57	NA	NA
3	0.5	7.97	0.20	56.18	16.27	8.06	78.95	10.65	7.49	75.00	16.26	8.24	80.00
	1.0				7.17	9.14	80.00	6.12	13.97	100.0	7.17	9.14	80.00
4	0.5	13.53	0.58	55.94	16.01	7.33	74.51	9.93	7.10	65.22	15.43	7.17	75.00
	1.0				6.83	7.52	80.00	6.22	13.37	50.00	6.83	7.52	80.00
5	0.5	4.90	-0.01	53.67	16.36	7.06	80.33	12.00	7.54	75.76	14.92	6.00	77.59
	1.0				7.05	6.80	80.00	7.16	12.69	100.0	7.50	9.01	83.33
6	0.5	8.12	0.15	52.97	35.33	6.74	78.74	31.27	7.86	79.41	34.31	6.65	79.69
	1.0				16.34	8.61	87.50	14.03	14.36	87.50	15.46	9.85	91.30
7	0.5	14.43	0.52	51.68	23.42	6.00	73.40	21.54	6.46	68.60	26.74	7.42	77.78
	1.0				7.51	4.92	63.64	10.43	11.74	80.00	9.23	6.12	78.57
8	0.5	7.77	0.17	54.68	27.29	7.84	83.33	18.34	7.50	74.63	26.45	7.63	82.52
	1.0				8.73	5.94	76.92	9.09	12.82	83.33	10.38	7.73	80.00
9	0.5	10.10	0.36	55.50	18.95	7.67	77.63	13.39	9.78	81.08	19.63	8.33	78.67
	1.0				7.40	6.19	80.00	7.08	15.13	100.00	7.50	7.84	77.78
10	0.5	23.85	0.98	57.62	24.84	6.90	79.01	16.73	10.58	78.38	23.53	6.85	80.00
	1.0				9.15	8.12	81.82	7.35	27.04	100.0	8.71	7.82	80.00
11	0.5	7.54	0.14	55.97	18.06	7.22	76.36	12.58	9.16	72.00	16.22	6.99	75.00
	1.0				7.70	10.50	80.00	7.24	34.42	100.0	7.53	12.04	80.00
12	0.5	16.07	0.76	58.12	28.88	9.77	85.85	16.79	10.84	85.45	27.44	9.52	85.85
	1.0				10.07	12.16	100.0	8.95	24.71	100.0	10.07	12.16	100.0

This table reports trading results using two different threshold expected returns (0.5% and 1.0%) and three different sets of signals (the S&P500 return from open to close, the return from 12 to close and both the return from open to noon and noon to close. For each strategy and each fund, we report the annualized mean return, the Sharpe ratio for periods when the strategy is invested in the fund, and the percent of days that yield positive returns. The sample period is Jan. 1997 to Nov. 2000.

Panel C: Trading Results with Trading Costs

	Initial		Fund	Thld(0.5)			Thld(1.0)		
Fund	Bal($000)	Cst	B&H	B&H	%in	#buys	B&H	%in	#buys
1		0.00	13.14	208.10	20.24	98	48.19	3.91	19
	10	29.95	12.80	92.45			34.24		
2		0.00	51.06	50.72	6.51	25	19.14	0.10	1
	10	29.95	50.61	32.32			18.48		
3		0.00	30.30	85.82	9.92	53	31.54	1.10	5
	10	29.95	29.91	42.65			28.10		
4		0.00	61.23	79.89	9.52	51	29.82	1.10	5
	10	29.95	60.74	40.36			26.42		
5		0.00	15.91	76.29	10.42	58	33.14	1.10	7
	10	29.95	15.56	30.05			28.35		
6		0.00	25.34	265.67	21.24	106	79.72	4.01	22
	10	29.95	24.96	120.07			62.47		
7		0.00	63.45	175.73	16.43	87	41.91	2.40	14
	10	29.95	62.96	87.18			32.28		
8		0.00	28.15	173.16	18.04	93	48.38	2.91	15
	10	29.95	27.77	79.66			37.89		
9		0.00	42.00	111.23	13.03	70	33.14	1.50	9
	10	29.95	41.57	51.11			27.09		
10		0.00	132.66	143.79	13.73	73	39.34	2.00	10
	10	29.95	131.96	72.17			32.46		
11		0.00	25.03	85.28	9.62	53	33.33	0.80	5
	10	29.95	24.66	41.43			29.82		
12		0.00	77.98	184.43	18.24	96	46.93	2.91	14
	10	29.95	77.44	79.63			36.92		

This table reports trading results using two different threshold expected returns (0.5% and 1.0%) for high fixed costs and a low initial starting balances. For each strategy we use both S&P500 returns from open to noon and from noon to close as signals. For each strategy and each fund, we report the buy-and-hold return over the full sample period, the percent of time invested in the fund, and the number of purchase transactions. The sample period is Jan. 1997 to Nov. 2000.

Table 4: Vanguard Funds

Panel A: Summary Statistics for Fund Returns

				Corr w/ Signals			
Fund	Mean	s.r.	b&h	S&P500 O-12	S&P500 12-C	Nik Fut-Spt	S&P500 O-C
1	10.01	0.30	39.40	0.30	0.35		
2	1.75	-0.14	-4.03			0.35	0.29
3	15.36	0.59	69.89	0.18	0.37		

This table reports the annualized mean return, Sharpe ratio, buy-and-hold return and correlations with the various signals for the three Vanguard funds. The sample period is Jan. 1997 to Nov. 2000.

Panel B: Trading Results

	EW Fund			Unhedged			Hedged		
Thld	Mean	s.r.	b&h	Mean	s.r.	b&h	Mean	s.r.	b&h
0.25	9.04	0.24	34.34	38.44	4.54	325.38	40.40	6.02	362.75
0.50				30.52	6.12	216.87	30.86	7.53	222.63
1.00				11.07	5.28	51.90	13.41	8.02	66.23

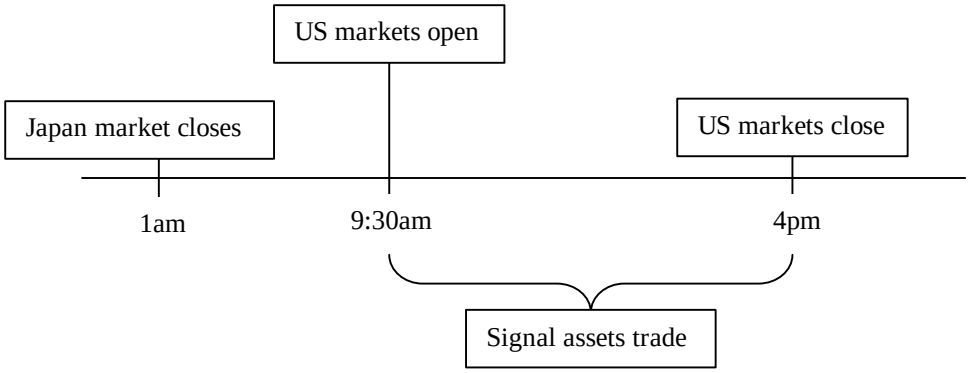
This table reports the annualized mean return, Sharpe ratio and buy-and-hold return for the unhedged and hedged Vanguard strategies (for expected return thresholds of 0.25%, 0.50% and 1.00%) and for an equally weighted portfolio of the three funds. The sample period is Jan. 1997 to Nov. 2000.

Panel C: Descriptive Statistics for Trading Strategy

	%in Fund			#buys Fund		
Thld	1	2	3	1	2	3
0.25	12.22	18.84	9.32	61	75	50
0.50	6.71	9.82	4.41	36	40	23
1.00	1.00	2.20	0.70	6	12	3

This table reports the percent of time and number of buys for each fund for the Vanguard trading strategy. The sample period is Jan. 1997 to Nov. 2000.

A: Japan Funds



B: European Funds

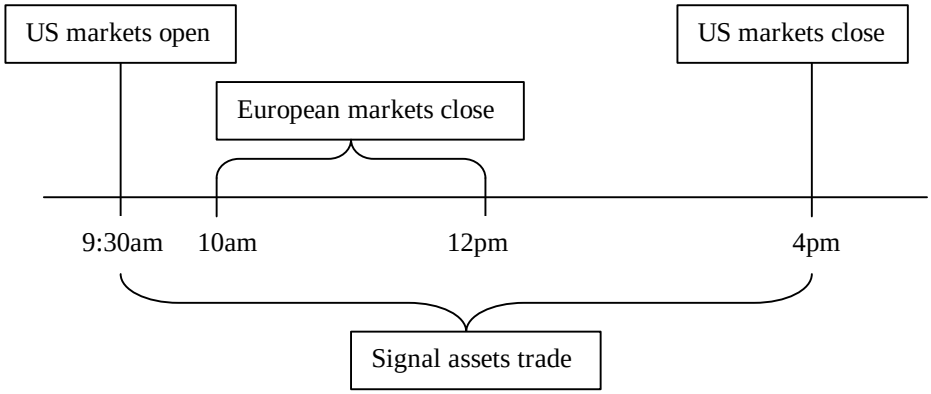


Figure 1: Time Lines

Time lines for the trading strategies associated with Japan funds and European funds. All times are Eastern Standard Time.

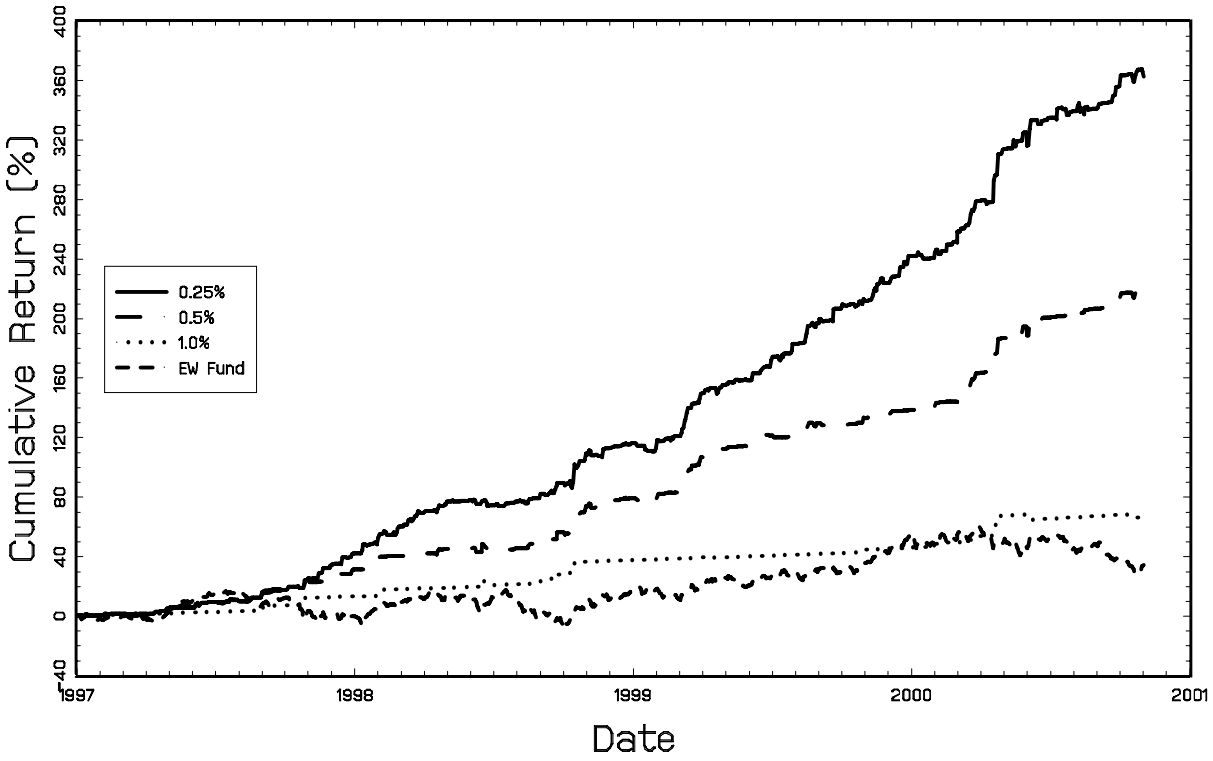


Figure 2: Vanguard Fund Results

Cumulative returns for an equal-weighted portfolio of Vanguard Pacific Vanguard European and Vanguard International Growth funds (short dashed line) and for hedged active strategies using thresholds of 0.25% (solid line), 0.5% (long dashed line) and 1.0% (dotted line).