The Last Great Arbitrage: Exploiting the Buy-and-Hold Mutual Fund Investor

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Current version:

May 8, 2000

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Abstract

This paper demonstrates that an 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. In one particular example, we explore the consequences of trading between different Vanguard mutual funds, motivated via the rules inherent in University 403B plans. Compared to an equal-weighted buy-and-hold portfolio of international Vanguard funds with a 25% cumulative return, the strategy discussed in this paper produces a 139% return while being in the stock market less than 25% 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 year, 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 essentially buy in to and exchange out of no-load mutual funds at zero cost.[1] Moreover, there are approximately 700 no-load mutual funds that invest in international equities, a number of which are very large. For example, at least 25 international equity funds have 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 EST, 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 can mean the prior 1:00am for Japanese and other Asian equities, and 11:00am for many European equities. However, even when these markets are closed there is information being released that is relevant for valuation. For example, there is considerable evidence in the literature that suggests 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 security prices during the U.S. trading day, and the next day's return on the fund.

[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 3 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.

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. As an illustration, 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 movement, 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.

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. Big moves in U.S. markets tend to predict big moves in NAVs the following day.

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 knowing 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 three categories of investment funds: (I) Japanese equity funds, (II) international equity funds, and (III) small capitalization domestic equity funds. All of these fund classes are chosen for the staleness of their underlying prices.[3] 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.

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 average over twice that of a buy-and-hold strategy during an ex post very good market for equities. More inter-

[3] It is well known that returns on portfolios made up of small stocks tend to have large positive autocorrelations (e.g., Lo and MacKinlay (1988)). While there is some debate regarding the cause of these autocorrelations, there is no doubt that staleness in prices can theoretically lead to this phenomenon. See, for example, Boudoukh, Richardson and Whitelaw (1994) for a description of the effect of nontrading and a discussion of the overall debate regarding the source of the autocorrelations of small firm portfolio returns.

esting is the fact that we can predict the next days movement over 75% of the time. Sharpe ratios generally range between **5** and **18** 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.[4]

Finally, we address the natural question – who loses out in this zero-sum game? The simple answer is that any gains are offset by losses of buy-and-hold investors. Specifically, 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. In addition, to the extent that rapid movements of money in and out of funds increase fund expenses, these costs are also borne partly by buy-and-hold investors.

The remainder of the paper is organized as follows. In Section 2, we lay out the theoretical framework for discussing stale pricies and trading opportunities and define our notation. Section 3 discusses various issues related to implementation of the strategies. Section 4 presents the empirical analysis, focusing on results across three subsectors of the equity sector of the mutual fund industry – Japan funds, other international funds, and U.S. smallcap funds. In Section 5, we also look in more detail at a specific case study involving Vanguard funds. Section 6 focuses on the wealth transfers inherent in the trading strategies, i.e, who loses when these institutional inefficiencies are exploited? Section 7 concludes.

[4]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 401K retirement plans when the values of these plans are based on potentially quarter-old stale prices.

2 Stale Prices and Investment Opportunities: The Framework

Consider an asset i, whose "true" price process, P_{it}, is such that it is not possible to make abnormal profits by trading in the asset at these prices.[5] Of course, the properties of the price process depend on the correct model of risk, but they are irrelevant for the purposes of this discussion. For example, the process may be a random walk with a drift that is either fixed or time-varying to reflect the dynamics of expected returns. The "observed" price process, P^*_{it}, equals the true price whenever a trade occurs, but between trades the observed price is fixed at the last traded price. In other words, P^*_{it} looks like a step function with jumps at trade times $\tau_1, \tau_2, \ldots$, as illustrated in Figure 1. This framework is a standard model of nontrading and stale prices (see, for example, Scholes and Williams (1977)). One obvious example of nontrading is when the market itself is closed. For example, it is not possible to trade on the Tokyo Stock Exchange between the hours of 1am and 7pm, so observed prices of Japanese stocks are constant over this period. Of course, this does not imply that true prices are also constant during the same period because price-relevant information may be revealed, perhaps through trading and information revealed during U.S. trading hours. In fact, Japan-based derivatives trade on the CME and AMEX exchanges throughout the U.S. trading day.

As long as the observed and true prices are equal when trade occurs, i.e., $P_{i\tau} = P^*_{i\tau} \quad \forall \tau$, then it is also impossible to make abnormal profits from trading at prices $P^*_{i\tau}$. Even if a trader knows the true price and the market is open, any attempt to exploit the divergence between the true and observed prices ensures that these prices are equal. Of course, the dynamics of the observed price and return processes will inherit certain characteristics because of nontrading, but they do not indicate the existence of trading opportunities. For multiple securities with heterogeneous and non-continuous trading, portfolios will also exhibit apparently anomalous autocorrelations and cross-serial correlations (see, for example, Lo and MacKinlay (1988) and Boudoukh, Richardson and Whitelaw (1994)).

In contrast, if it is possible to trade at the 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.

[5] For expostional clarity, we will ignore the existence of dividends or other intermediate cash flows and distributions.

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. For simplicity, assume the existence of a second asset j that is perfectly correlated with asset i and trades continuously,[6] i.e.,

$$\begin{aligned} P_{jt} &= P_{jt}^{*} \quad \forall t \\ r_{it,t+1} &= b r_{jt,t+1} \\ \text{where } r_{it,t+1} &\equiv \ln(P_{it+1}/P_{it}) \\ r_{jt,t+1} &\equiv \ln(P_{jt+1}/P_{jt}) \end{aligned}$$

Now consider a point in time $\tau_1 + s$ between trades in the original asset (i.e., $\tau_1 < \tau_1 + s < \tau_2$) at which the option to trade at the observed price is effective. Due to the perfect correlation, observing the return on the signal asset, $r^{*}_{j\tau,\tau_1+s}$, is equivalent to observing the true return on the original asset, $r_{i\tau,\tau_1+s}$. If $r_{i\tau,\tau_1+s} > 0$, then the strategy is to buy asset i at the stale price. If this position is held until the next trade in asset i, then the expected return is $r_{i\tau,\tau_1+s} + E_{\tau_1+s}[r_{i\tau_1+s,\tau_2}]$, which is greater than the correct risk-adjusted expected return over the period, i.e., $E_{\tau_1+s}[r_{i\tau_1+s,\tau_2}]$. On average, these strategy will make abnormally high risk-adjusted returns, but it is not a strict arbitrage because the position is risky due to the uncertainty about the return after time $\tau_1 + s$. However, this risk can be eliminated completely if we permit hedging with asset j. By putting on a suitable position in asset j at time $\tau_1 + s$, it is feasible to hedge the uncertain return on asset i thereafter. Consequently, the strategy guarantees a riskless profit of $r_{i\tau_1,\tau_1+s}$.

What happens if the assets are not perfectly correlated? Specifically, consider a world in which the return on asset j is a noisy but unbiased signal of the return on asset i, i.e.,

$$\begin{aligned} r_{it,t+1} &= b r_{jt,t+1} + \epsilon_{t,t+1} \\ E_t[\epsilon_{t+1}] &= 0 \end{aligned}$$

The signal about the true price of asset i is not as precise, but there is still information in the signal asset. Consequently, it is still possible to evaluate the discrepancy in the stale price. In this case the expected return on the strategy, $b r_{j\tau,\tau_1+s} + E_{\tau_1+s}[r_{i\tau_1+s,\tau_2}]$, is still greater than the appropriate

[6]The assumptions of continuous trade in the signal asset and perfect correlation between the two assets are made for ease of expostion only. It is only necessary that the assets have non-zero correlation and that the signal asset trade at different times than the original asset.

risk-adjusted return. Moreover, the hedging of the subsequent exposure is less effective due to the existence of the signal error $\epsilon_{\tau_1+s,\tau_2}$. Overall, hedged or unhedged, the strategy is riskier than when the assets are perfectly correlated, but it still generates abnormal positive returns on average.

To summarize briefly, the option to trade at stale prices is valuable if one has information about the evolution of the true price process. The value of the option to trade depends on the staleness of the prices, the level of potential trade, the quality of the information, and the ability to hedge the original asset during nontrading periods. These are all empirical issues which we address in the Sections 4 and 5.

3 Mutual Funds and Trading

Considering only international equities, there are currently over 700 no-load funds. The majority of these no-load funds allow free exchanges within the mutual fund group. That is, at no cost, the investor can transfer funds between say a money-market account and an international equity fund.[7] Of course, the fund itself faces transactions costs from buying and selling shares, as well as imposing annual management fees.

Nevertheless, these free exchanges provide the investor with a unique opportunity. Specifically, with zero cost and perfect liquidity, they can trade in and out of assets at extremely stale prices. This is because when investors buy/sell a mutual fund during the day, they do so at the price of the assets prevailing at 4pm. These prices are computed using the last traded prices of all the underlying assets. Thus, even if an asset has not traded for over fifteen hours (e.g., Pacific-based stocks), it is still recorded using the stale price. In practice, this means that the investor can purchase foreign equities with a good idea of how they have moved during their nontraded hours (see Section 2), or take advantage of short-term portfolio autocorrelations (e.g., Lo and MacKinlay (1988) and Boudoukh, Richardson and Whitelaw (1994)). The key difference with mutual fund trading is that the transactions costs are zero!

Are there any limitations on the amount of this type of mutual fund trading? In theory, though the mutual fund complexes allow free exchanges, the Prospectus of each fund within the complex

[7] Some funds impose nominal, fixed costs for "free" exchanges; others place restrictions in terms of a percentage fee for exchanging in and out of a fund in a short time period, say 30 days. These tend to be the exception, rather than the rule.

often limits the number of exchanges per year, 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. As an illustration, consider the following strong language from the Prospectus for a T. Rowe Price mutual fund:

> *T. Rowe Price may bar excessive traders from purchasing shares. Frequent trades, involving either substantial fund assets or a substantial portion of your account or accounts controlled by you, can disrupt management of the fund and raise its expenses.*
>
> **Trades placed directly with T. Rowe Price**
>
> *If you trade directly with T. Rowe Price, you can make one purchase and sale involving the same fund within any 120-day period. For example, if you are in fund A, you can move substantial assets from fund A to fund B and, within the next 120 days, sell your shares in fund B to return to fund A or move to fund C. If you exceed this limit, you are in violation of our excessive trading policy. Two types of transactions are exempt from this policy: 1) trades solely in money market funds (exchanges between a money fund and a nonmoney fund are not exempt); and 2) systematic purchases or redemptions.*
>
> **Trades placed through intermediaries**
>
> *If you purchase fund shares through an intermediary including a broker, bank, investment adviser, or other third party and hold them for less than 60 calendar days, you are in violation of our excessive trading policy. If you violate our excessive trading policy, you may be barred indefinitely and without further notice from further purchases of T. Rowe Price funds...*
>
> *In an effort to protect each fund from the possible adverse effects of a substantial redemption in a large account, as a matter of general policy, no shareholder or group of shareholders controlled by the same person or group of persons will knowingly be permitted to purchase in excess of 5% of the outstanding shares of the fund, except upon approval of the fund's management.*

While the Prospectus gives the fund family 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.[8]

There are three methods an investor can use to implement a trade. 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 (especially via the telephone), and thus can be implemented arbitrarily close to the 4pm transaction deadline. Second, an investor can put a trade on through a broker. Brokers have the advantage of being able to trade close to the 4pm deadline, but the disadvantage is that it introduces 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, among others). 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 funds require notice by 3pm.

There are two main types of implementation strategies employed in practice. First, the investor can trade small amounts in large capitalized funds relatively frequently. That is, by representing a small amount of the funds flow, he/she can essentially escape notice. In fact, trading online through third parties can mask their identity even further, albeit at the cost of not being able to trade as quickly as one could directly with the fund. Second, the investor can trade large amounts very infrequently across a relatively large number of funds, as in the example described at the beginning of this paper.

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 other market the next day. For example, for Japanese equities (assuming they trade at the close), this would occur at 1am. The

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

problem is that, in most circumstances, the hedging instruments are not traded around the clock.[9] 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 risks outside of U.S. and the foreign country's trading hours. 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.
- 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.

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.

4 Trading Analysis

We now turn to the implementation and analysis of three 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 report results for both hedged and unhedged strategies.

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

4.1 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 incoporated 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 2A. The Japanese market closes at 1am, 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, using the notation of Section 2, the fund's NAV is set using $P_{1:00am}$, but is recorded at $P_{4:00pm}$. 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 trading day in Japan likely, and hence the NAVs of Pacific funds are likely to increase tomorrow. Of course, this is only useful information because mutual funds are still permitting trade at the old, stale prices. If the futures are up, the strategy buys the fund, and the position is liquidated when the futures are down.

In this section, we focus on three no-load Japanese-based funds, which satisfy two important criteria: (I) they are large in size (i.e., at least \$100 mbillion in assets under management), and (II) they allow free exchanges. In brief, all three funds are actively managed portfolios of securities traded on Japanese stock exchanges, with a small percentage of them trading as ADRs on U.S. exchanges.

In order to understand the potential for excess profit, Table 1A documents several important

[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 susbsequent movements in Japan.

stylized facts for these fund returns. Note that while the full sample covers the period 1/1/1997-9/30/1999, the Scudder and Warburg Pincus funds had later start dates of 4/3/1998 and 4/22/1997, respectively. 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&P index return.

These stylized facts are somewhat startling. First, the contemporaneous correlations with the Nikkei range between 51% 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 mimick the Nikkei index exactly, that is, they are simply actively managed Japan funds. Second, the funds' NAVs are dollar denominated and hence include the effect of changes in the Yen/Dollar rate. The returns on all three funds are significantly positively correlated with exchange rate returns. 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 4% to 18%. What this suggests is that the fund's securities either do not all trade at 1:00am or are not updated on a systematic basis. 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 (1999) for a study of international index autocorrelations).

Third, the signals have considerable correlation, i.e., predictive power, for the fund's returns. In particular, the correlations range between 0.21 and 0.44 for the U.S. traded Nikkei futures and between 0.19 and 0.44 for the within day S&P500 return. Because these positions are tradeable at zero transactions costs, this amount of daily predictability implies large profit opportunities.

Given the results of Table 1A, 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

[12] The implied Nikkei level 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 over

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

Due to the restrictions on excessive trading (albeit sometimes unenforced), 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. Using the notation of Section 2, we note that expected returns are given by the following equation:

$$E[r^{JPN}_{t_{1am},t+1_{1am}}] = b_1(FUT_{t_{4pm}} - NIK_{t_{9:30am}}) + b_2 r^{S\&P}_{t_{9am},t_{4pm}}$$

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, on a daily level, this translates to excess returns ranging from 125%-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 $E[r^{JPN}_{t_{1am},t+1_{1am}}] < 0$.

The above strategy is subject to two types of risk – currency risk, which we will not focus on[13] 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. This latter 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

the life of the contract.

[13]Movements in the yen/dollar exchange rate could be incorporated in the analysis, but it adds little to the main point. Moreover, there is the added complication that some funds already hedge some or all of their exchange rate exposure.

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.[14] An alternative hedge instrument is the WEBS contract that trades on the AMEX. This security is equivalent to an 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,[15] so the hedge may still prove useful. It is primarily an empirical question whether the hedge improves performance in practice.

We investigate empirically the simulated trading results of the three funds – T. Rowe Price Japan, Scudder Japan, and Warburg Japan Growth. We employ the aforementioned trading rules for getting in or out of the fund. We simulate this trading strategy on historical NAVs. We have 715 trading days for T. Rowe, 636 for Warburg, and 388 for Scudder.

Table 2A reports results for the three funds in our sample. The Sharpe ratios of the unhedged strategy are calculated for days when the trading rule places the investor in the funds. These Sharpe ratios are remarkable by any standard, ranging from 5.25 to 10.04 for the 0.5% threshold and 5.58 to 13.79 for the 1.0% threshold. When the hedge is undertaken, these Sharpe ratios improve in all cases, sometimes by more than 25%, and range between 5.55 and 17.00. The Sharpe ratios of being long the funds throughout the respective sample periods vary between 0.48 and 1.79. While this is perhaps partly due to the fund managers' ability to pick stocks, it is primarily due to the difference in the sample periods and investment strategies. The T. Rowe Price fund has data available for nearly three years, including a sharp decline in the value of Japanese equities early in the sample period, while for the other two funds, Warburg and Scudder, data are available only for the latter part of the sample period, during which Japanese equities rallied. Moreover, the latter funds invest heavily in technology stocks, a sector that significantly outperformed the

[14] 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.

[15] See Craig, Dravid, and Richardson (1995) for evidence.

broader market. This point is evident from a closer examination of cumulative returns of the buy and hold strategy documented in Table 2A.

Table 2A also reports cumulative returns over the period relative to a buy-and-hold strategy, as well as the number of days the investor is actually in the market. Several observations are of interest. First, the investor is only in the market 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 are 3.35%, 12.42% and 6.71% for the three funds. Second, 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. For example, the above percentages translate to 3, 31, and 15 trades respectively. This is potentially important because excessive trading might warrant the types of restrictions to be enacted that are described in Section 3. Third, even though the investor is primarily in the money market fund, the cumulative returns tend to be greater for the strategy than for a corresponding buy-and-hold strategy. The exception is the Scudder fund, which had extraordinary ex post returns due to the rally in the Japanese stock market over this period. Fourth, the ability to actually predict the movement in the fund's return the next day is relatively high. In a "fair game", one would expect the number to roughly match that of the fund (i.e., from 44% to 50%). Here, we predict the next day's direction with accuracies as high as 95%. Of course, these calculations are embedded in the Sharpe Ratios described above.

4.2 International Funds

Another natural choice for exploiting stale prices are international funds that concentrate in equity markets in different time zones. The majority of international funds purchase assets that trade in Europe. Though European trading partially overlaps with U.S. 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. Moreover, the contemporaneous correlation between U.S. and European markets tends to be greater, producing potentially greater rewards from trading.

The strategy for Europe is illustrated in the diagram in Figure 2B. The European stock markets have all closed by 12pm though a number of markets close somewhat earlier. For example, the German stock market closes at 10:00am E.S.T. These closing prices are used to set fund NAVs and hence purchase and sale prices which are effective for fund transactions up to 4pm. Using the notation of Section 2, the fund's NAV is set using P_{12pm}, but is recorded at $P_{4:00pm}$. 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 universe of international no-load equity funds includes approximately 700 funds. We focus on those funds with $1 billion or more under management, for a total of 20 funds. This is done in order to investigate a sample of international funds that are relevant and feasible for actual trading, although there is no reason why this analysis cannot be extended to all of the no-load funds. To coincide with Section 4.1, we obtain data from 1/1/1997-9/30/1999.

Table 1B documents several important stylized facts of these fund returns. In particular, over the above data period, we calculate the contemporaneous correlation of the fund returns with the European 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 (e.g., from close-to-open, open-to-12pm, and 12pm-to-4pm).[16]

First, the contemporaneous correlations range between 0.31 to 0.83, but the vast majority are around 0.75. Therefore, even with the unobservability of the fund's positions in countries, the correlations are substantial. Second, these funds exhibit significant autocorrelation. What this suggests is that the fund's 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. The autocorrelations range from 0.06 to 0.25, with the majority of them being greater than 0.10. Third, the signals have considerable correlation, i.e., predictive power, for the fund's returns. In particular, the S&P signals from both open to noon and noon to close have considerable correlation, ranging from 0.2 to 0.3 and 0.3 to 0.4, respectively. S&P signals prior to this period, such as the close-to-open from the previous day, provide little extra information. Not surprisingly, European markets are open during these periods, so information should get incorporated immediately. Of some interest, because S&P returns are approximately uncorrelated over subperiods within the day, it will be beneficial to look at the

[16]One of the difficulties of looking at international funds is that they include an unobservable cross-section of securities from different countries. Thus, even though there are WEBS traded on each country, and some futures and options contracts on Europe, it is difficult to uncover (outside the quarterly and annual reports) the exposure to one market over another. For example, several of these international funds also have an exposure to Japan, or especially to countries that close prior to 12pm in Europe.

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 as well.

Similar to the trading strategy for the Japanese-based funds, we consider strategies which ex ante lead to only minimal amounts of trading. Using the notation of Section 2, we consider expected returns generated from signals in the U.S. stock market.[17] In particular,

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

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. Similar to before, we define large excess returns in one of two ways - either 0.5% or 1.0%, depending on the amount of trading desired. Also each day the investor reevaluates the trade and again sells the fund only if $E[r^{Itl}] < 0$.

Similar to the strategies in Section 4.1, 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 securities market the following day. These risks are more complex than 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. Since the volatility tends to be greatest during trading hours (e.g., French and Roll (1989)), a substantial amount of volatility due to European stock index movements can be hedged. In particular, conditional on buying into the fund, we short the European stock index futures at the open and close out the position at the close of trading. If we stay in the fund, then we have to repeat the hedge the next day, and so on.

We investigate empirically the simulated trading results of the twenty funds described in Table 1B. We employ the aforementioned trading rules for getting in or out of the fund. We simulate this trading strategy on historical NAVs.

[17] During U.S. trading hours, options on European stock indices do trade on the AMEX. However, prices were not available on these contracts over our sample period due to the low liquidity of these contracts.

Table 2B reports Sharpe Ratios for these strategies. The Sharpe ratios, calculated for in-days, are, again, remarkable. They range from 4.79 to 18.77 for the unhedged positions, with the majority of them being in the range from 6 to 9. When the hedge is undertaken, these Sharpe ratios improve in many of the cases, by up to 50%, and consistently range in the 9s and 10s (see Table 2B). These results are in stark contrast to the buy-and-hold strategy of being long the funds throughout the sample period. For example, these Sharpe ratios range between -0.31 and 1.05, with the majority of them falling below 0.5. The results are, of course, much stronger than the Japanese-based funds because of the performance of Japanese markets versus European markets during this sample period.

The cumulative return results are impressive for both the hedged and unhedged strategies 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. Even when the threshold gets increased to 1.0%, the strategy still outperforms in many cases even though the investor is in the fund less than 2.5% of the time! In fact, in this latter case, the number of trades during this 1/97-9/99 period is less than ten for each fund. Table 2B 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 often 100% for the 1.0% threshold. In contrast, the percentage of positive returns in the entire sample is only slightly above 50%.

A simple binomial test can clarify the significance of the strategy's performance. Consider the first fund, Acorn International, and further consider the null hypothesis that the trading results are due to chance, i.e., that the 81.82% of positive returns out of the total of 51 in-signal days are a matter of pure chance. Under this null, the "true" probability of seeing a positive return is 54.97%, the fraction of positive return days in the full sample. Under these assumptions, the P-value of the null is 0.00. The Sharpe ratio itself corresponds to a t-test. Since both the mean and the standard deviation are annualized, and we have 2.75 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 $\sqrt{2.75}$, which is almost uniformly above 10 for all funds.

4.3 U.S. Small Cap Funds

The last sample of sector funds we look at is a sample of no load, small cap, U.S. equity funds. There are over 125 such funds with \$100 million or more under management. The top four have over \$1.5 billion in assets under management, and we focus on these four funds. The funds are DFA Small Company, T. Rowe Price Small Cap, Third Avenue Value and Lazard Small Cap. An important characteristic of small cap funds is that they include stocks that trade relatively infrequently. In fact, a number of the stylized facts in the portfolio autocorrelation literature refer to small firm portfolios. While there is some debate about the cause of the autocorrelations (see, for example, Lo and MacKinlay (1988) and Boudoukh, Richardson and Whitelaw (1994)), there is agreement that it exists using measured prices.

Table 1C documents several important stylized facts of these fund returns. We estimate the contemporaneous correlation of the small-cap fund returns with the Wilshire 5000 futures return, the fund's own autocorrelation and the cross-autocorrelation with the signal, which in our case is simply the lagged return on the Wilshire 5000 futures. First, the contemporaneous correlations range between 0.75 to 0.89, which suggest a close relation between the small-cap movements and the overall small-cap index. Second, these funds exhibit significant autocorrelation (i.e., from 0.14 to 0.22). This is consistent with the aforementioned results in the literature on positive autocorrelation of returns on small firm portfolios. Third, the signals have considerable correlation with the fund's returns. In particular, the Wilshire 5000 movements during the day have predictive power for next day's returns on the funds, that is, the information gets incorporated into fund prices one day later. These correlations range from 0.17 to 0.29, which are quite remarkable in that these trades take place at zero transactions costs. Part of the debate in the short-horizon portfolio autocorrelation literature centers on whether the autocorrelation magnitudes are meaningful given the difficulty of implementing the trades. Here, we have an asset that essentially duplicates these portfolios by construction, yet there is no implementation issue at all.

In contrast to the international funds described in Sections 4.1 and 4.2, the underlying securities of these small cap funds potentially trade up to the 4:00pm close. However, in practice, the last trade in many of these securities is well before this close. The time between the last trade and 4:00pm represents a trading opportunity as shown by the results of Table 1C. Because the Wilshire 5000 futures contract is a derivative on the underlying index itself, the lack of trading of the individual securities in the index has little affect on the "true" value of the futures for contracts with maturities greater than a few days.[18] Thus, movements of the Wilshire 5000 futures contract during the trading day will not completely get incorporated into the fund's returns of that day, and instead spillover to the next day's return. Thus, we use the Wilshire 5000 as a signal to take account of this spillover effect. Because this signal is somewhat weaker in magnitude than the international funds described previously, we lower the threshold to 0.25% and 0.5% for positive expected returns. In particular,

$$E[r^{sml}_{t,t+1}] = b_1 r^{Wil}_{t-1,t},$$

where r^{sml} represents the return on the small cap fund which trades at 4pm (but actually represents the earlier stale prices of its underlying securities), and r^{Wil} is the return on the Wilshire 5000 futures contract. Similar to before, after getting into the position, the investor reevaluates the trade and sells the fund only if $E[r^{sml}] < 0$.

In contrast to the strategies in Section 4.1, the above strategy is subject to only one type of risk – the movements in the underlying prices of the fund. However, conditional on buying into the fund, we short the futures index at the close, and close out the position the next day only if we get out of the fund. Outside of the basis risk between the fund return and the small cap futures contracts, these positions are completely hedged from a timing point of view. We investigate empirically the simulated trading results of the four funds described in Table 1C. We employ the aforementioned trading rules in terms of getting in or out of the fund. We simulate this trading strategy on historical NAVs.

Table 2C reports Sharpe Ratios for these strategies. The Sharpe ratios, calculated for in-days are, again, remarkable. For all but one pathological case (in which almost no trading takes place), The Sharpe Ratios range from 4.39 to 7.34 across the unhedged and hedged positions. This is in stark contrast to the buy-and-hold strategy of being long the funds throughout the sample period. For example, these Sharpe ratios range between -0.29 and 0.49. The cumulative return results are especially impressive for the unhedged and hedged strategies for the 0.25% threshold. For every

[18] See Ahn, Boudoukh, Richardson and Whitelaw (1999) for a theoretical and empirical analysis of the differences between spot and futures contracts under a wide range of assumptions.

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. When the threshold gets increased to 0.5%, the strategy still outperforms in most cases even though the investor is in the fund less than 3.5% of the time! In fact, in this latter case, the number of trades during this 1/97-9/99 period is less than twelve for each fund. Table 2C also documents that the percentage of days during which we see a positive return when there is a trade signal tends to be higher than for the fund itself. The probabilities are not as impressive as those for the international funds, which reflects the weakness of the small-cap signal relative to the 100% stale prices of foreign securities.

5 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. Most university 403B plans allow their employees to access the Vanguard mutual fund system and trade amongst a wide set of mutual funds. Among the choices, three funds especially 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. 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. 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. Because these accounts are tax-free, there are, of course, no tax consequences for the investor in terms of short-versus long-term capital gains. Due to the tax-free status, as a money market account, we employ the Prime Money Market fund, which invests primarily in high quality, short-term commercial paper.

There are three ways to implement the strategy in practice. First, one can call a Vanguard representative and conduct the Exchange over the phone, which realistically takes approximately 2-5 minutes. Second, the exchange can be performed on Vanguard's website, which, conditional on the speed of the investor's access and the Vanguard system being up and running, takes about one minute. The last method, and by far the most speedy, is to use the automated telephone service. Given knowledge of the system, this requires the pressing of 26 numbers and 3 pound signs in a particular order. Since this sequence can be programmed into a phone, or memorized, this trade takes approximately 15 seconds. This means that (i) actual trades can occur very close to the 4:00pm close, and (ii) multiple trades are possible within a short period of time.

The trading strategy uses the same signals as Sections 4.1 and 4.2 above with respect to the Pacific fund, and the International Growth and European funds, respectively. In particular,

- For the Pacific-based fund, the closing Nikkei futures price on the CME at 4:00pm minus the closing price of the Nikkei in Japan at the prior 1:00am, adjusted for the cost of carry via the Quanto pricing formula (see Dravid, Richardson and Sun (1994)).

- For the European-based funds, two signals are employed. The first is the movement of the S&P 500 index between 9:30am and 12:00pm, while the second is the movement between 12:00pm and 4:00pm.

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

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

Similarly, because there are no transaction costs in getting out of the funds, the trading rule in this instance is to compare the expected return of the fund one is currently in to the expected returns, net of transactions costs, of the other funds and, of course, the money market rate. This latter rule is important because two of the funds face transactions costs only on getting into the fund.[19]

Table 3A provides the correlations between the fund returns and the signals for each fund. Similar to Sections 4.1 and 4.2, there is considerable evidence of predictability for the fund returns. For example, the correlation between the Pacific-based signal and the Vanguard Pacific fund is 35%, while, for the European-based funds, the correlations are 17% and 27% for the early stage of the day and 38% and 33% for the latter stage. Clearly, with large enough movements during US trading hours, there are potentially large excess profits available to an active investor.

[19]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.

Table 3B documents 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 very strong. For example, both hedged and unhedged strategies have Sharpe Ratios ranging from 3.79 to 9.73 for the days that the investor is in the fund; in contrast, the buy-and-hold strategies range from -0.05 to 0.72. Of course, the higher Sharpe Ratios come from the fact that the investor is rarely in the international equity market, 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 14.27% of the time, the European Index fund 3.92%, and the International Growth fund 5.45%. The aggregate number of trades over this two and three-quarter years is 64, which leads to a cumulative return of 138.89% and 127.92% on the unhedged and hedged strategies, respectively. These cumulative returns contrast with only 1.05% for the Pacific-based fund, 53.96% for the European index fund and 19.59% for the International Growth fund. Most notably, even though the strategy earns anywhere from 2.5 to 100 times the return, 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 3 graphs a time-series of the cumulative return on the three strategies versus a buy-and-hold, equal-weighted portfolio of the three funds. Not only is the excess volatility apparent in the buy-and-hold strategy, but also its much smaller cumulative return. Putting aside the question of who loses in the implementation of this strategy (see Section 6 below), it is clear that University academics, and for that matter others who have access to these accounts, would benefit tremendously from even marginal amounts of "timed" trading. Trading just 10 times over this three year period provides excess returns to the equal-weighted portfolio's realized returns with little or no risk.

6 Who Loses?

Given the high levels of abnormal returns documented in Sections 4 and 5, a natural question is from where do these profits come? Is investing in mutual funds a zero-sum game, and if so, who is absorbing the corresponding losses? The simple answer is that 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.

Consider a no-load fund with total assets under management of A, based on end-of-day stale prices. Assume market timers get a signal that implies an expected gross return of R over the following day. These market timers invest X dollars in the fund at the stale prices and cash out the following day. For simplicity, assume that this inflow is held as cash, i.e., it is not invested overnight. Further assume that the invested assets earn a gross return of R. Of course, actual fund value will depend on news that comes out the following day as well, but in expected value terms the analysis is correct. Absent market timers, the value of the fund's original assets is AR, and the holders earn a gross return of R. When market timers are present, the value of their final holdings is

$$(AR + X)\frac{A}{A + X}.$$

The first term represents the total value of the fund, and the second term is the fraction of this fund belonging to the original holders. Note that the market timers buy in based on the stale value A. For $X = 0$, we get the original result, but as X increases the value declines, reaching A in the limit. For returns, in the base case with no market timers, the original holders earn R. With market timers, they earn

$$\frac{AR + X}{A + X} \leq R.$$

In the limit, they earn a zero return and the market timers get all of the gains.

In order to quantify the magnitude of these effects, consider the example of the Montgomery Emerging Asia Fund with which we began the paper. In this case, $A = 30$ and $X = 7$. Assume the signal implied an expected return of 2%, i.e., $R = 1.02$. Instead or earning 2%, the original holders have an expected return of 1.6%, a significant drop on a daily basis, which corresponds to a loss of more than \$113 thousand. Of course, this loss by the original holders is a gain to the market timers. They earn the same 1.6% (i.e., \$113 thousand on a \$7 million investment), but at little or no risk. Compounded over many days and across many funds, these gains imply astronomical Sharpe ratios and cumulative returns as demonstrated previously.

In addition, initial investors may suffer other costs. For example, large inflows and outflows may increase administrative and management expenses, reducing overall performance. To the extent that additional purchases are invested immediately, short-term trading also increases trading costs and decreases returns. Without flow of funds data from individual mutual funds, it is impossible to say how much investors in specific funds or in the fund market as a whole have lost over time; however, the empirical results in Sections 4 and 5 show that potential losses are enormous.

7 Conclusion

This paper demonstrates that an 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 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.

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. 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.

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. 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 cyincal 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 in 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.

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A: Japan Funds

Fund	$r^{NIK}_{t,t+1}$	$r^{FX}_{t,t+1}$	$FUT_t - NIK_t$	$r^{S\&P}_{t_{9am},t_{4pm}}$	$r^{Fund}_{t-1,t}$
Scudder Japan Equity	0.505	0.317	0.210	0.186	0.046
Warburg Pincus Japan Growth	0.668	0.112	0.440	0.435	0.179
T. Rowe Price Japan	0.718	0.557	0.357	0.268	0.041

B: International Funds

Fund	$r^{EUR}_{t,t+1}$	$r^{Fund}_{t-1,t}$	$r^{S\&P}_{t-1_{4pm},t_{9am}}$	$r^{S\&P}_{t_{9am},t_{12pm}}$	$r^{S\&P}_{t_{12pm},t_{4pm}}$
Acorn Intl	0.637	0.220	0.008	0.343	0.395
American 2Oth Century Intl Growth	0.804	0.180	-0.025	0.288	0.343
Bankers Trust Intl Equity	0.752	0.151	-0.011	0.273	0.319
DFA Intl Small Co	0.306	0.144	0.022	0.276	0.222
Mutual Discovery	0.776	0.248	-0.043	0.237	0.315
Glenmede Intl	0.680	0.106	-0.011	0.280	0.279
Harbor Intl	0.774	0.137	-0.033	0.214	0.280
Harbor Intl Growth	0.774	0.110	-0.036	0.209	0.310
Hotchkis & Wiley Intl	0.732	0.150	0.000	0.241	0.347
Janus Worldwide	0.748	0.221	-0.056	0.236	0.239
Lazard Intl Equity	0.725	0.064	-0.015	0.258	0.304
T Rowe Price European Stock	0.827	0.043	-0.067	0.164	0.338
T Rowe Price Intl Stock	0.769	0.113	-0.030	0.247	0.303
Scudder Global	0.781	0.179	-0.015	0.247	0.270
Scudder Greater Europe Growth	0.794	0.091	-0.039	0.240	0.379
Warburg Pincus Intl Equity	0.672	0.223	0.026	0.333	0.291
Scudder Intl	0.755	0.092	-0.008	0.264	0.355
SEI Intl Equity	0.743	0.074	-0.010	0.272	0.362
Vanguard Intl Growth	0.772	0.136	-0.007	0.280	0.334
Vanguard Star Total Intl	0.741	0.115	-0.021	0.259	0.338

C: U.S. Small Cap Funds

Fund $r_{t,t+1}$	$r^{WIL}_{t,t+1}$	$r^{Fund}_{t-1,t}$	$r^{WIL}_{t-1,t}$
DFA US 6-10 Small Co	0.884	0.214	0.260
T Rowe Price Small Cap Stock Value	0.746	0.224	0.286
Third Avenue Value	0.747	0.137	0.165
Lazard Small Cap	0.823	0.214	0.252

Table 1: Fund Return Correlations

Contemporaneous daily correlations between fund returns and relevant indices and cross-serial correlations between fund returns and the relevant signals. Panel A is Japan funds, Panel B is international funds, and Panel C is U.S. small cap funds. NIK denotes to the Nikkei 225 index, FX denotes the dollar/yen exchange rate, FUT denotes the Nikkei futures contract on the CME, $S\&P$ denotes the S&P500 Composite index, EUR denotes the Eurotop 100 futures contract, and WIL denotes the Wilshire 5000 futures contract. The sample period is 1/1/97-9/30/99 except for Scudder Japan, which starts on 4/3/98, and Warburg Pincus Japan, which starts on 4/22/97.

A: Japan Funds

	Sharpe Ratio			Cumulative Return			Percent Profitable				
Fund	Strat	Hdgd	Fund	Strat	Hdgd	Fund	Strat	Hdgd	Fund	%In	#Trd
				0.5% Threshold							
Scudder Jap	5.25	6.04	1.79	36.19	38.41	102.93	66.67	75.00	44.85	12.63	16
Warburg Pincus Jap	10.04	11.73	1.51	467.39	471.82	146.01	68.61	75.18	50.31	34.43	78
T. Rowe Price Jap	6.48	8.62	0.48	277.18	315.40	45.98	65.69	77.45	44.34	28.39	62
				1.0% Threshold							
Scudder Jap	5.58	5.55	1.79	15.50	15.65	102.93	66.67	66.67	44.85	3.35	3
Warburg Pincus Jap	13.79	17.00	1.51	171.66	176.45	146.01	86.11	91.67	50.31	12.42	31
T. Rowe Price Jap	7.27	9.52	0.48	74.54	79.48	45.98	84.21	94.74	44.34	6.71	15

B: International Funds

	Sharpe Ratio			Cumulative Return			Percent Profitable				
Fund	Strat	Hdgd	Fund	Strat	Hdgd	Fund	Strat	Hdgd	Fund	%In	#Trd
				0.5% Threshold							
Acorn Intl	8.51	8.54	0.82	71.15	62.51	46.38	81.82	83.64	54.97	13.57	51
Amer 2Oth Cent Intl	7.68	8.84	0.79	131.02	105.86	59.53	76.84	84.21	51.75	20.98	76
Bankers Trust Intl Eq	7.68	7.90	0.60	84.76	65.59	43.27	75.76	81.82	52.17	15.66	58
DFA Intl Small Co	7.67	7.48	-0.31	38.13	37.24	0.22	66.67	66.67	43.36	6.85	23
Mutual Discovery	7.17	8.77	0.58	25.14	21.89	32.33	81.82	90.91	57.06	2.80	11
Glenmede Intl	8.97	8.80	0.64	56.18	48.25	41.77	76.32	78.95	50.21	9.09	37
Harbor Intl	6.21	5.72	0.54	55.78	39.85	40.56	76.74	74.42	53.01	10.21	42
Harbor Intl Grw	4.79	4.30	0.26	75.19	52.54	24.04	70.00	75.71	49.51	16.92	61
Hotchkis & Wiley Intl	5.78	4.87	0.38	49.30	36.96	28.83	75.56	71.11	51.89	10.91	43
Janus Worldwide	7.72	8.33	1.05	56.78	45.07	76.86	76.92	79.49	55.24	9.23	37
Lazard Intl Eq	6.80	6.56	0.57	83.71	63.57	43.09	73.53	77.94	53.15	15.94	60
T. Rowe Price Euro	5.90	5.98	0.66	66.10	48.56	48.89	72.55	80.39	51.89	11.19	47
T. Rowe Price Intl	6.38	6.14	0.38	71.41	52.74	30.26	77.36	79.25	51.75	13.57	48
Scudder Global	6.65	6.72	0.73	31.86	27.43	43.57	71.43	80.95	53.99	5.59	21
Scudder Greater Euro	7.80	7.79	0.92	115.06	89.19	66.80	82.93	80.49	53.15	18.88	69
Warburg Pincus Intl	7.59	7.99	0.12	80.96	68.57	16.44	78.57	84.29	53.57	16.64	61
Scudder Intl	8.05	8.24	0.67	117.44	94.61	49.10	76.74	83.72	54.13	19.30	70
SEI Intl Eq	7.48	7.94	0.47	113.38	91.33	35.67	76.74	81.40	49.65	19.30	70
Vanguard Intl Grw	7.01	7.62	0.33	97.94	78.22	27.68	72.15	83.54	51.75	18.32	66
Vanguard Star Tot Intl	7.15	7.49	0.32	100.23	79.55	27.34	74.36	80.77	50.49	18.32	66
				1.0% Threshold							
Acorn Intl	18.77	17.02	0.82	24.02	23.10	46.38	100.00	100.00	54.97	0.98	5
Amer 2Oth Cent Intl	8.45	10.62	0.79	35.84	29.77	59.53	90.91	90.91	51.75	2.80	11
Bankers Trust Intl Eq	8.34	12.56	0.60	26.65	26.98	43.27	85.71	100.00	52.17	1.96	7
DFA Intl Small Co	6.92	7.49	-0.31	17.05	17.11	0.22	50.00	50.00	43.36	0.28	2
Mutual Discovery	5.81	12.15	0.58	15.66	15.96	32.33	50.00	100.00	57.06	0.28	2
Glenmede Intl	6.13	5.58	0.64	21.11	19.50	41.77	75.00	75.00	50.21	1.26	4
Harbor Intl	9.82	11.16	0.54	23.60	21.78	40.56	80.00	80.00	53.01	0.98	5
Harbor Intl Grw	8.20	10.63	0.26	34.26	29.92	24.04	85.71	100.00	49.51	1.82	7
Hotchkis & Wiley Intl	9.82	10.37	0.38	23.51	22.19	28.83	80.00	80.00	51.89	0.98	5
Janus Worldwide	11.12	9.94	1.05	22.66	20.24	76.86	75.00	75.00	55.24	1.26	4
Lazard Intl Eq	6.04	8.61	0.57	25.60	25.98	43.09	85.71	85.71	53.15	1.96	7
T. Rowe Price Euro	6.09	8.89	0.66	25.78	23.67	48.89	66.67	83.33	51.89	1.54	6
T. Rowe Price Intl	8.59	8.86	0.38	22.44	20.78	30.26	80.00	80.00	51.75	0.98	5
Scudder Global	5.83	11.18	0.73	16.14	16.51	43.57	50.00	50.00	53.99	0.28	2
Scudder Greater Euro	8.62	10.07	0.92	33.47	29.91	66.80	88.89	100.00	53.15	2.10	9
Warburg Pincus Intl	8.37	8.48	0.12	21.45	21.01	16.44	66.67	83.33	53.57	1.82	6
Scudder Intl	8.30	9.93	0.67	32.65	28.90	49.10	88.89	88.89	54.13	2.38	9
SEI Intl Eq	7.37	9.30	0.47	32.36	28.73	35.67	88.89	77.78	49.65	2.38	9
Vanguard Intl Grw	7.09	9.64	0.33	25.92	26.25	27.68	85.71	85.71	51.75	1.96	7
Vanguard Star Tot Intl	8.96	11.12	0.32	33.63	30.23	27.34	87.50	87.50	50.49	2.24	8

C: U.S. Small Cap Funds

Fund	Sharpe Ratio Strat	Sharpe Ratio Hdgd	Sharpe Ratio Fund	Cumulative Return Strat	Cumulative Return Hdgd	Cumulative Return Fund	Percent Profitable Strat	Percent Profitable Hdgd	Percent Profitable Fund	%In	#Trd
0.25% Threshold											
DFA US 6-10 Small Co	6.95	11.43	0.30	85.37	61.16	25.11	63.41	79.27	53.43	18.46	61
T. Rowe Price Small Cap	7.34	9.70	-0.29	47.17	38.42	3.74	68.75	77.08	52.87	11.19	37
Third Avenue Value	4.39	4.33	0.49	27.35	23.52	33.34	47.06	47.06	50.91	4.90	15
Lazard Small Cap	4.74	5.81	0.07	57.92	41.19	14.08	56.16	69.86	52.17	15.80	54
0.5% Threshold											
DFA US 6-10 Small Co	6.85	12.85	0.30	29.04	26.21	25.11	75.00	83.33	53.43	3.36	11
T. Rowe Price Small Cap	5.60	8.52	-0.29	18.50	17.58	3.74	75.00	100.00	52.87	1.54	4
Third Avenue Value	-11.13	-3.45	0.49	11.25	13.97	33.34	50.00	50.00	50.91	0.42	2
Lazard Small Cap	5.33	8.53	0.07	25.02	23.29	14.08	66.67	88.89	52.17	2.66	8

Table 2: Trading Results

Trading results based on the strategies described in Section 4. Sharpe ratios are for the days when the strategy is invested in the fund. Cumulative returns are buy-and-hold returns over the full sample. "Percent Profitable" indicates the percentage of days for which the return is positive. "%In" indicates the percentage of days during which the active strategies were invested in the fund. "#Trd" indicates the number of purchases for the active strategies. "Strat", "Hdgd" and "Fund" refer to the unhedged active strategy, the hedged active strategy and the underlying fund, respectively. Panel A is Japan funds, Panel B is international funds, and Panel C is U.S. small cap funds. The sample period is 1/1/97-9/30/99 except for Scudder Japan, which starts on 4/3/98, and Warburg Pincus Japan, which starts on 4/22/97.

A: Correlations

Fund	$FUT_t - NIK_t$	$r^{S\&P}_{t_{9am},t_{4pm}}$	$r^{S\&P}_{t_{9am},t_{12pm}}$	$r^{S\&P}_{t_{12pm},t_{4pm}}$
Vanguard Intl Equity Index Pacific	0.354	0.283		
Vanguard Intl Equity Index European			0.166	0.375
Vanguard Intl Growth			0.272	0.328

B: Trading Results

			Pacific		European		Intl Growth	
	Sharpe Rat.	Cum. Ret.	%In	#Trd	%In	#Trd	%In	#Trd
Vanguard Intl Eq Idx Pac	-0.05	1.05	100	1	0	0	0	0
Vanguard Intl Eq Idx Euro	0.72	53.96	0	0	100	1	0	0
Vanguard Intl Growth	0.19	19.59	0	0	0	0	100	1
		0.25% Threshold						
Unhedged Startegy	3.79	159.54	21.96	54	7.55	30	11.75	43
Hedged Strategy	5.57	189.35	21.96	54	7.55	30	11.75	43
		0.5% Threshold						
Unhedged Startegy	4.96	138.89	14.27	31	3.92	14	5.45	19
Hedged Strategy	6.06	127.92	14.27	31	3.92	14	5.45	19
		1.0% Threshold						
Unhedged Startegy	6.55	35.35	1.68	6	0.56	1	0.70	3
Hedged Strategy	9.73	43.89	1.68	6	0.56	1	0.70	3

Table 3: Results for Selected Vanguard Funds

Correlations (Panel A) and trading results (Panel B) for selected Vanguard funds. The trading strategies are described in Section 5. NIK denotes to the Nikkei 225 index, FUT denotes the Nikkei futures contract on the CME, and $S\&P$ denotes the S&P500 Composite index. Sharpe ratios are for the days when the strategy is invested in the fund. Cumulative returns are buy-and-hold returns over the full sample. "%In" indicates the percentage of days during which the active strategies were invested in the fund. "#Trd" indicates the number of purchases for the active strategies. The sample period is 1/1/97-9/30/99.

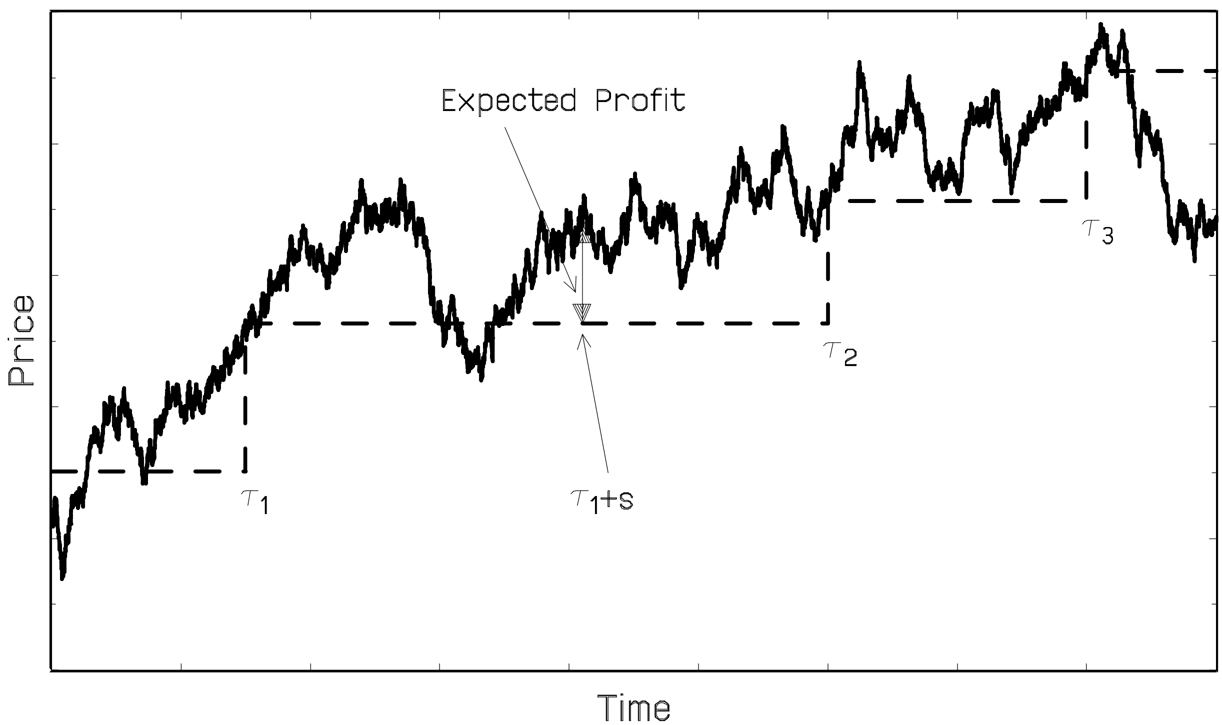
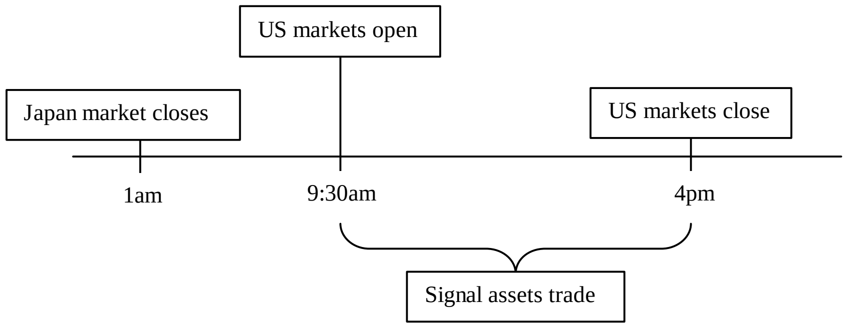


Figure 1: The True and Observed Price Processes

A schematic of the true (solid line) and observed (dashed line) price processes under nontrading. Trade times are labeled τ_i, and the profit opportunity is the option to trade at stale prices at time $\tau_1 + s$ when knowing the true price.

A: Japan Funds



B: European Funds

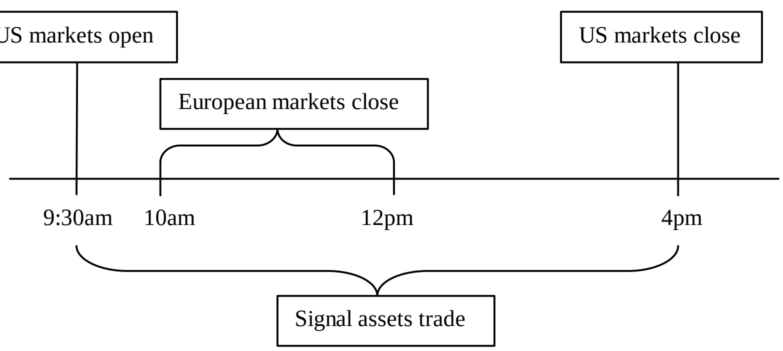


Figure 2: Time Lines

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

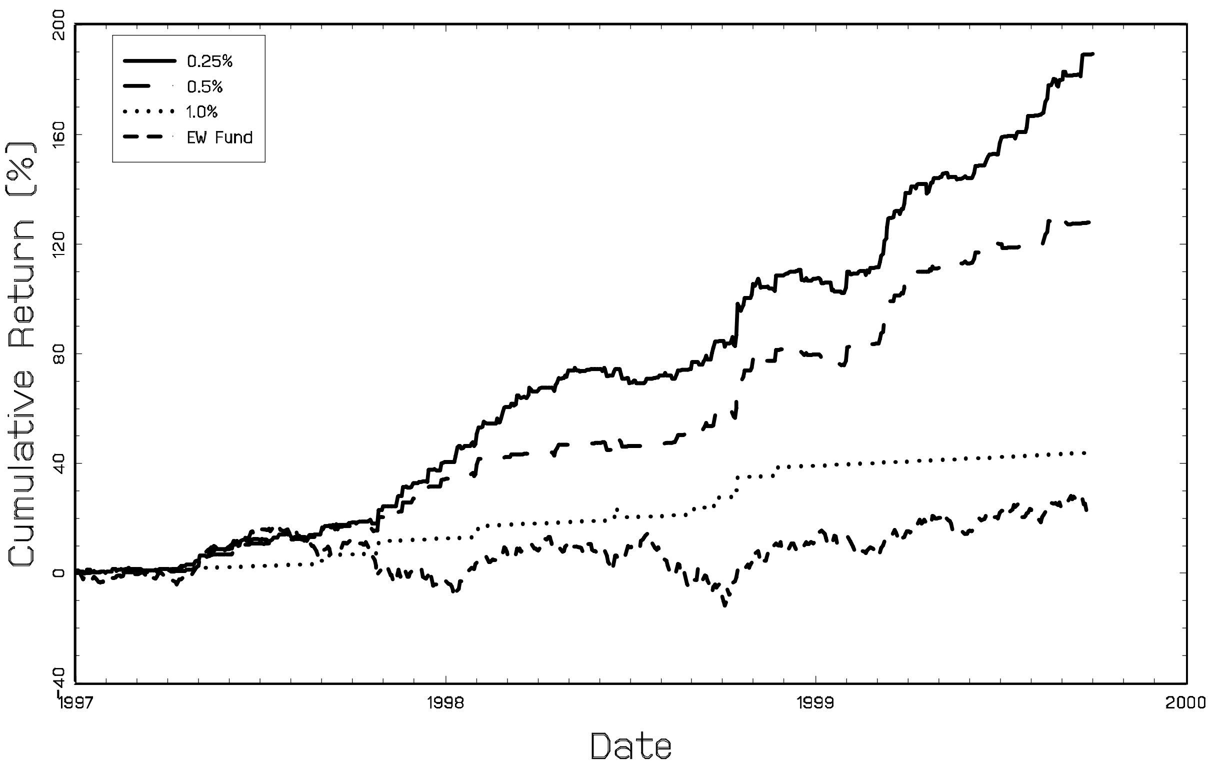


Figure 3: Vanguard fund Results

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).