Stale Prices and Strategies for Trading Mutual Funds

Jacob Boudoukh, Matthew Richardson,
Marti Subrahmanyam, and Robert F. Whitelaw

We demonstrate that an institutional feature of numerous mutual funds—funds managing billions in assets—generates fund net asset values that reflect stale prices. Because investors can trade at these NAVs with limited transaction costs in many cases, obvious trading opportunities exist. These opportunities are especially prevalent in funds that buy Japanese or European equities. Simple, feasible strategies generate Sharpe ratios (excess return divided by standard deviation) that are many times greater than the Sharpe ratio of the underlying fund. We illustrate the potential of the strategy for three Vanguard Group mutual funds. A particular issue to keep in mind is that when the strategies are implemented, the gains from these strategies are matched by offsetting losses incurred by buy-and-hold investors in these funds.

> 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.
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This description is not unique to a 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 (that is, non-U.S.) assets.

Approximately 700 no-load mutual funds invest in international equities, and many of them are very large—at least 25 have assets under management exceeding $1 billion (money amounts throughout are in U.S. dollars). With the proliferation of mutual funds, a U.S. investor can now buy into and exchange out of no-load mutual funds at essentially zero cost.[1] Moreover, when a U.S. investor buys/sells a mutual fund during the day, the investor does so at the price prevailing at 4:00 p.m. [All times in this article refer to U.S. Eastern Standard Time (EST) unless noted otherwise.] These 4:00 p.m. prices are calculated on the basis of the last transaction price of the stocks in that fund. So, for funds of Japanese and other Asian equities, the price could be the prior 1:00 a.m./2:00 a.m. price, and for many European equities, it could be the 11:00 a.m./12:00 p.m. price. When these markets are closed, information flow does not cease; information relevant for valuation of the securities traded in the closed markets is still being released. For example, the literature contains considerable evidence that international equity returns are correlated at all times, even when one of the markets is closed. Moreover, the magnitude of the 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 international funds.[3]

In some cases, derivatives on international markets trading in the United States provide even more informative signals than U.S. market returns about the unobserved movements in the prices of securities in international funds. For example,

Jacob Boudoukh is director of the Caesarea Center at Arison School of Business, Interdisciplinary Center, Israel, and associate professor of finance at Stern School of Business, New York University. Matthew Richardson is professor of finance at Stern School of Business, New York University. Marti Subrahmanyam is Charles E. Merrill Professor of Finance at Stern School of Business, New York University. Robert F. Whitelaw is professor of finance at Stern School of Business, New York University.

Craig, Dravid, and Richardson (1995) examined the relationship between Nikkei futures/warrants traded in the United States and close-to-open Nikkei returns in Japan. They found a one-to-one relationship, which suggests that non-U.S.-based derivatives trading in the United States is an efficient predictor of the opening move in the international market. Moreover, they found that, once the non-U.S.-based derivative return is taken into account, U.S. stock return indexes do not provide incremental information. This knowledge can be used to generate considerable excess return in the buying and selling of mutual funds. Remarkably, an investor can purchase funds at stale prices with no transaction costs and perfect liquidity. In the most extreme case, one can buy a Japan fund using 1:00 a.m. prices while having information about the "true" price some 15 hours later at 4:00 p.m.

Given these facts, it is perhaps no surprise that we document extraordinarily high excess profits and Sharpe ratios (excess return divided by standard deviation) for two categories of investment funds: Pacific/Japan equity funds and international/Europe equity funds.[4] These fund classes were chosen for the staleness of their underlying prices, the size of the funds, and the ease of implementing the trading strategy. We discuss a strategy of switching between a money market account and the underlying fund class in response to the signal during U.S. market hours. We also discuss the trading costs of various types of implementation procedures. In addition, because mutual funds do place some limits, although they are not always enforced, on the frequency and amount of exchanges between funds, we examine the added benefits of using a strategy based on particularly strong signals.

To illustrate the mechanics and results of the trading strategy, we provide a case study of three mutual funds from The Vanguard Group's family of funds. This analysis is of special interest to academics because these funds are available through the retirement plans of numerous educational institutions and can be easily traded either on the Internet or over the phone. This exercise is similar to one recently presented by Stanton (1999), who found that employees have a large incentive to retire or leave their current employment and liquidate their 401(k) retirement plans when the values of the plans are based on potentially quarter-old (stale) prices.[5]

Trading Mutual Funds

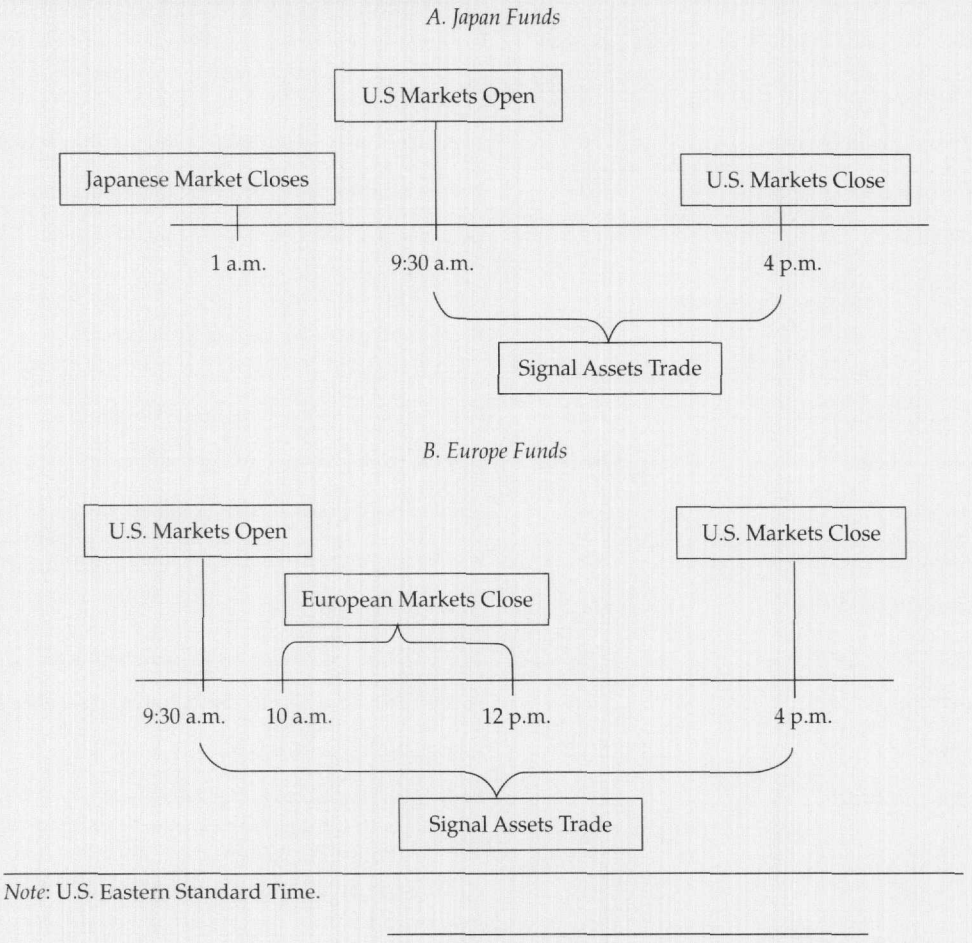
The buying or selling of mutual funds in the United States occurs at the close of trade (i.e., 4:00 p.m.), but the reported prices of the underlying assets in the fund reflect their last traded prices. Thus, investors can, in effect, purchase portfolios of securities at stale prices. Securities particularly subject to stale prices include small-company stocks, high-yield bonds, and non-U.S. assets, all of which have the property that their last transaction rarely falls close to 4:00 p.m.

The basic idea behind trading mutual funds is as follows. Consider an asset whose "true" price is such that it does not allow one to make abnormal profits by trading in the asset at that price. Now consider an asset that can be traded at the observed (stale) price between trades in the underlying spot market without forcing convergence between observed and true prices; in this case, one can make abnormal profits—as long as some signal is correlated with the true price process. For example, suppose a trader is given the option to continue trading at closing prices during a period when the Tokyo Stock Exchange is closed and that the trader has access to information about the continuous price process (e.g., futures on the Nikkei 225 Index traded in the United States). This situation is what mutual funds allow.

The Funds. Although thousands of no-load funds use stale prices, we restricted ourselves to a select few for this study. First, to avoid the well-known problems of survivorship bias that exist for mutual funds (e.g., see Carhart, Carpenter, Lynch, and Musto, forthcoming 2002), we limited the study to large international/Europe funds and Pacific/Japan funds that existed in January 1997. We chose international funds because European and Asian markets are closed during either all of or the latter part of the U.S. trading day, thus maximizing the staleness of the underlying prices of the assets in a fund at 4 p.m. As an illustration, **Figure 1** graphs the time line of trading for Japan funds (in Panel A) and for Europe funds (in Panel B); the time period during which "signal assets" (e.g., derivatives) trade in the U.S. and international markets are closed is indicated in each. Note that 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, to guarantee that individuals could actually implement the trades, the chosen funds had to satisfy the following additional criteria: (1) carrying no load, (2) permitting exchanges, (3) charging no exchange fees, and (4) catering to retail (rather than institutional) investors. For such funds, investors can transfer money between, say, a money market account and an international equity fund at no cost. Of course, the fund itself faces transaction

Figure 1. Time Lines for Trading Strategies



Note: U.S. Eastern Standard Time.

costs from buying and selling shares, as well as imposing annual management fees.

Does this type of mutual fund trading have any limitations on the amount that can be traded? In theory, although the mutual funds allowed free exchanges, the prospectus of each fund often limited the number of exchanges (a typical limit was one trade per month or quarter). Violation of this limit gave the fund the right to revoke exchange privileges or charge an exchange fee. But although the prospectus might give the fund much latitude in terms of barring market timers, in practice, these rules were not strictly enforced. Obviously, the size of the transaction and number of exchange transactions would affect the enforcement of limitations.[6] **Table 1** describes all the funds used in the study, grouped by type, and summarizes the rules described in their prospectuses for the use of exchanges. The numbers assigned the funds in Table 1 are used throughout the rest of the article to identify the funds.

Implementing a Trading Strategy. Consider an international fund that is subject to stale pricing. After the international market closes and given a signal about movements in the value of the fund's assets, an investor can decide whether or not to trade the fund using some chosen criteria, examples of which will be explored in the "Trading Analysis" section. How is the trade implemented?

In general, three implementation methods are possible. First and foremost, an investor can trade directly through the mutual fund complex online (if available) or via automated telephone service. The speed of this transaction can be as quick as 30 seconds; thus, it can be implemented close to the 4:00 p.m. transaction deadline. Second, an investor can put in a trade through a broker. Brokers can also trade close to the 4:00 p.m. deadline, but this mechanism has the disadvantage of introducing an intermediary into the process. Third, a number of online trading firms (e.g., Charles Schwab & Company, E*TRADE Group, and Ameritrade) allow mutual fund trading. Transactions through these firms 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

Table 1. Mutual Funds in Study: Size and Trading Limits

Fund	Assets as of January 1997 ($ millions)	Trading Restrictions
Pacific/Japan		
1 Warburg Pincus Japan Growth	20.8	Bars excessive trading; 2% fee within 6 months after May 2000
2 59 Wall Street Pacific Basin	153.8	Bars excessive trading; 2% fee within 30 days after 2001
3 Capstone Nikko	2.9	May penalize "abusive" trading (once/month)
4 T. Rowe Price New Asia	2,222.0	Right to bar excessive trading (3 times/year)
5 T. Rowe Price Japan	165.1	Right to bar excessive trading (3 times/year)
International/Europe		
1 Warburg Pincus International	2,978.4	Right to bar excessive trading (at discretion)
2 USAA World Growth	265.5	Right to bar excessive trading (6 times/year)
3 USAA International	504.2	Right to bar excessive trading (6 times/year)
4 Northern International Growth	185.7	Right to bar excessive trading (8 times/year)
5 Mercury International Value	474.2	None
6 Harbor International Growth	566.2	None (except a comment about market timing)
7 59 Wall Street Europe	146.3	Bars excessive trading; 2% fee within 30 days after 2001
8 Vanguard Star	271.3	Right to bar excessive trading (2+ times/year)
9 Managers International	259.2	Right to bar excessive trading (at discretion)
10 Janus Worldwide	5,046.3	Right to bar excessive trading (4 times/year)
11 Dreyfus Founders	334.8	Right to bar excessive trading (4 times/year)
12 Liberty Acorn International	1,771.7	None
Vanguard		
1 International Growth	5,521.0	Right to bar excessive trading (2 times/year)
2 Pacific Index	1,023.3	0.5% fee for purchases (zero after 2001)
3 Europe Index	1,541.9	0.5% fee for purchases (zero after 2001)

Note: All funds are no load and allow free exchanges.

execution times are sometimes limited. For example, a number of online trading firms require notice by 3:00 p.m. In the next section, we explore the effect of transaction fees on the returns from trading international mutual funds.

As mentioned previously and documented in Table 1, there are limits on how many trades an investor can make. Therefore, another important consideration is the optimal strategy that can be used in practice. First, an investor can trade small amounts in large-capitalization funds fairly frequently. That is, by representing a small amount of the fund flow, the investor can essentially escape notice. Second, an investor can trade large amounts infrequently across a relatively large number of funds, as in the example described at the beginning of this article.[7] Third, an 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 or her identity. As long as the trade size is not too large, or at least is small relative to "random" investors, the fund family has no real way to detect the market timer. Of course, trading through a third party is not costless.

Because many of the most profitable strategies involve purchasing non-U.S. equities, the investor is exposed to the risks of international markets during the non-U.S. markets' trading hours. Moreover, the volatility of stock returns tends to be at its highest during trading hours.[8] Therefore, it may

behoove investors to hedge these risks. Ideally, a complete hedge would involve shorting the appropriate hedging instrument at 4:00 p.m. and closing out the position at the close of the non-U.S. market the next day—for example, for Japanese equities (assuming they trade at the close), at 1:00 a.m. The problem is that in most circumstances, the hedging instruments are not traded around the clock.[9] U.S. investors must thus make choices.

First, because the greatest volatility exists during non-U.S. trading hours, one could simply initiate the hedge at the open of the non-U.S. country's stock/futures exchange and then take the hedge off at the corresponding close. This way, the only volatility one would face would be between 4:00 p.m. and the opening of the non-U.S. country's market.

Second, one could initiate a hedge using a non-U.S.-based derivative security traded in the United States (i.e., so-called quantos) at 4:00 p.m. and take it off at the open the following day. However, this method exposes the investor to additional risks between the close of the non-U.S. country's market and the open of the U.S. market. Three common types of securities are traded in U.S. markets that would allow the investor to perform this second type of hedge:

- Non-U.S.-based futures contracts, such as the Nikkei futures, are traded on the Chicago Mercantile Exchange (CME).
- Non-U.S.-based index options, such as the Eurotop 100 Index, Nikkei indexes, and the Hang Seng Index, are traded on the Amex.
- Non-U.S. index shares (WEBS, or World Equity Benchmark Shares) are traded on the Amex. WEBS cover 17 countries and match the characteristics of the corresponding Morgan Stanley Capital International index.[10]

Third, the investor is exposed to foreign exchange risk because, typically, fund NAVs are calculated by taking the stale prices of the assets multiplied by the corresponding exchange rate at 4:00 p.m. Investors should, therefore, hedge exchange rate risk from close to close.

Finally, investors should keep in mind that 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 among funds. Some of these risks are explored in the "Trading Analysis" section.

Existing Literature. A growing body of literature in finance explores the trading of mutual funds. We focus in this section on the literature that is most relevant to our primary focus and contribution: (1) the development of trading strategies that are clearly implementable, (2) a comparison of strategies that use different signals about market movements and involve different trading costs, and (3) the return–risk trade-off of these strategies when they are applied. Although all the papers in the relevant literature point out how the predictability induced by stale mutual fund prices can be profitable, the focus of various works differs.

In particular, Chalmers, Edelen, and Kadlec (2001) discussed mutual fund trading in the broad context of a financial intermediary who sets prices mistakenly. They showed that, for U.S. domestic equity funds especially, much of the predictability is a result of nonsynchronous trading. Chalmers et al. proposed possible approaches to calculating NAV prices of the funds in the presence of nontrading. In a specific case study of a small-cap fund, they showed that a market-based adjustment works well in practice.

In contrast, Greene and Hodges (forthcoming 2002) and Goetzmann, Ivkovic, and Rouwenhorst (2001) concentrated on the relationship between the predictability of the fund's NAV and the flow of money into and out of the fund. Although the quality of the flow data is questionable (a problem that was partially addressed by both groups of authors), Greene and Hodges, in particular, found a strong relationship between NAV predictability and money flows. Because investors who hold the fund during the period when the timing strategies call for entering and exiting the fund suffer reductions in the market value of their holdings that are equal dollar for dollar to the abnormal gains, Greene and Hodges were able to estimate the losses suffered by buy-and-hold investors.

The study by Goetzmann et al. is the most similar to our study, in that they focused on international funds. However, whereas we concentrate on the types of signals, strategies, and risks facing a market-timing investor, their focus was on (1) the magnitude of the losses suffered by the buy-and-hold investor and (2) the methods for adjusting NAV prices to minimize these losses. Their general findings are consistent with those of Greene and Hodges, albeit on a smaller scale.

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 in different scenarios that address the following questions:

- 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 results of using signals based on U.S.-traded Nikkei futures with the results of using within-day S&P 500 returns.
- What is the effect of using different expected excess return thresholds generated by the signals? In other words, we examine the effect of higher expected return thresholds that are associated with less trading albeit with stronger signals.
- What is the effect of using online firms to process the trades? As an alternative to minimizing trading to avoid detection by the fund family, one could use third-party online vendors, which significantly reduces the cost of detection. But because third-party vendors impose nominal costs for exchanging funds, we consider various trading costs in the cases of several initial capital holdings. We look at the trade-off between trading more frequently at a nominal cost versus trading less frequently at no cost.
- How much risk does the U.S. investor face if the position is unhedged during the non-U.S. country's trading hours? We explore Sharpe ratios and both hedged and unhedged returns with the use of widely available (albeit imperfect) hedges.
- Finally, in addition to Sharpe ratios, what are the properties of the unexpected hedged and unhedged returns? That is, using the signals, we generate expected returns, $E_t(R_{t+1})$, from the strategies. We explore the difference between the actual and expected returns, $R_{t+1} - E_t(R_{t+1})$, to understand the risks facing the investor in implementing the strategy.

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 about Japanese equities that comes out during the day in the United States is potentially useful because it is not incorporated in same-day Japanese closing prices. Second, futures on the Nikkei 225 Index trade in Chicago, which provides not only high-quality signals but also an excellent hedging instrument.

The strategy is both simple and intuitive. As Figure 1 shows, the Japanese market closes at 1:00 a.m. (or 2:00 a.m. in the summer); these closing prices are used to set fund NAVs and, therefore, purchase and sale prices that are effective for fund transactions up to 4:00 p.m.[11] In other words, the fund's NAV is set using $P_{1:00am}$ but is recorded at 4:00 p.m. Beginning at 9:30 a.m., however, 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.[12] In fact, an investor can derive an implied Nikkei price, P_{4pm}. If $P_{4pm} \gg P_{1am}$, 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 indication, in turn, means that a positive return for the trading day in Japan is likely. 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 information is useful only 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 et al.).

However, not all the Pacific/Japan mutual funds described in Table 1 correlate perfectly with the Nikkei; some funds include other Pacific-region-based assets and may have weightings different from the Nikkei (e.g., a high weighting on technology stocks or on non-Japanese Asian markets). Thus, we will consider multiple signals that can capture both pure Nikkei movements and movements in equities unrelated to the Nikkei.

In this section, we focus on five no-load Pacific/Japan funds, described in Table 1, that satisfy the criteria laid out previously. In brief, all five funds allow free exchanges and are actively managed portfolios of securities traded on Japanese and Pacific stock exchanges; a small percentage of funds is invested in American Depositary Receipts (ADRs).

To understand the potential for excess profit, **Table 2** reports the contemporaneous correlation of each fund return with the Nikkei return and with the dollar/yen foreign exchange return, the fund return's autocorrelation, and its cross-serial correlation with the relevant signals—in this case, the Nikkei futures return in the United States and the S&P 500 return—for the sample period, January 1997 through November 2000. The results strongly

Table 2. Pacific/Japan Funds: Correlations of Returns, January 1997–November 2000

				Signals	
Fund	Nikkei	US$/¥	Autocorrelation	S&P 500	Future Spot
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

Note: The signals are the lagged S&P 500 return from open to close and 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.

indicate stale pricing. First, the contemporaneous correlations with the Nikkei for four of the five funds are high, ranging between 58 percent and 72 percent. If the funds actually traded during U.S. hours and were not stale, one would expect these correlations to be much smaller. The lack of perfect correlation arises for two reasons. One reason is that the funds do not attempt to mimic the Nikkei exactly; that is, they are simply actively managed Pacific funds. For example, consider the difference between Fund 4 (T. Rowe Price New Asia) and Fund 5 (T. Rowe Price Japan). Fund 4 covers all Asian markets and focuses on technology, whereas Fund 5 covers only Japan and represents a cross-section of industries. Not surprisingly, their correlations with the Nikkei are, respectively, 35 percent and 69 percent. Another reason for the lack of perfect correlation is that the funds' NAVs are dollar denominated; hence, the NAVs include the effect of changes in the yen/dollar exchange rate.

The returns to all five funds are positively correlated with exchange rate returns. Hence, the correlation with the Nikkei provides an idea of the "upper bound" on the quality of the available signal.

Second, Table 2 indicates stale pricing because these funds exhibit autocorrelations ranging from 7 percent to 30 percent, which suggests that the funds' securities do not all trade at 1:00 a.m., the prices are not updated on a systematic basis, or the funds hold some ADRs whose prices are incorporated in 4:00 p.m. prices.

Except for Fund 1 (the Warburg Pincus Japan Growth), the autocorrelations are not large, but part of the reason is that Japanese indexes exhibit a somewhat anomalous negative autocorrelation (see Ahn, Boudoukh, Richardson, and Whitelaw 2002 for a study of international index autocorrelations).

Third, stale pricing is indicated by the signals' considerable correlation (i.e., predictive power) for the funds' returns. The correlations with the signals range between 0.17 and 0.43 for the within-day S&P 500 return and between 0.24 and 0.43 for the U.S.-traded Nikkei futures. Because the S&P 500 and Nikkei futures do not contain the same information, these differences suggest the potential value of using multiple signals. These positions are tradable at zero transaction costs, so this degree of daily predictability implies large profit opportunities.

Signals. Given the results shown in Table 2, we can formalize some obvious trading opportunities. We consider here the following three possible signals:

- The difference between the closing Nikkei level in Japan and the implied Nikkei level at 4:00 p.m. (based on the nearest-to-maturity Nikkei futures contract) traded on the CME.[13] For simplicity, we have assumed that the investor trades arbitrarily close to 4:00 p.m.; in practice, an earlier time—say, 3:55 p.m.—may be more reasonable.
- The within-day change on the S&P 500. This variable is considered more of a check on how much more information is contained in the underlying Nikkei futures. Independently of the fact that the S&P 500 and the Nikkei are not close to being perfectly correlated, this measure also misses the eight and a half early-morning hours between 1:00 a.m. and 9:30 a.m. This time period can be important because substantial announcements are made during after-trading hours in Japan (see Craig et al.).
- A combination of these two signals.

Because of the restrictions on excessive trading (albeit sometimes leniently enforced), we consider strategies that *ex ante* lead to minimal amounts of trading. In other words, we focus on strategies that are expected to provide large daily excess returns but relatively infrequently.

Assuming prices follow a random walk but are not updated by mutual funds, expected returns for the strategy, $E(r)$, are given by

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

where r^{JPN} represents the return on the Japanese fund that trades at 4:00 p.m. (but actually represents the earlier 1:00 a.m. prices), *FUT* and *NIK* are the Nikkei futures and Nikkei price, respectively, and $r^{S\&P}$ is the return on the S&P 500 from open to close.

We define large excess returns in one of two ways—either 0.5 percent or 1.0 percent, depending on the frequency of trading desired. Of course, these thresholds translate to excess returns of 125 percent and 250 percent on an annualized basis. For example, if $E(r^{JPN}_{t_{1am}, t+1_{1am}}) > 0.5$ percent, the investor buys the fund. Each day the investor reevaluates the trade, selling the fund and going into a money market fund only if $E(r^{JPN}_{t_{1am}, t+1_{1am}}) < 0$.

Table 3 reports results for the five Pacific/Japan funds in our sample when each of the two signals and the combined signal was used. The Sharpe ratios were calculated for days when the trading rule placed the investor in the funds. These Sharpe ratios are remarkable, by any standard, for both excess-return threshold levels and for different signals. They are as high as 10 and almost always above 6—extraordinary levels for financial markets.[14] The Sharpe ratios of the funds themselves vary between –0.29 and 0.42 over this period. The reason for the success of the strategies is that they predict the sign of the next day's fund return 75 percent of the time, on average, whereas if markets are roughly a fair game from day to day, we would expect a number closer to 50 percent. Note that the Sharpe ratios tend to be higher for the higher threshold, 1 percent, primarily because these trades were based on a stronger signal and were even better at predicting whether the next day's return would be positive.

Generally, the strategy performed better when the signals were used together to predict the fund's return. Combining the S&P 500 and the Nikkei signals always added information. For some funds, it was especially important. For example, Fund 4 had less *ex ante* correlation with the Nikkei than the four other funds (see Table 2); therefore, the results improved when the S&P signal was added. At a threshold of 0.5 percent, the mean return and Sharpe ratio went from 36.44 percent and 4.81 to, respectively, 55.11 percent and 6.33 when we added the S&P signal.

Additionally, even though the investor was invested most of the time in the money market fund (which is shown in the next table), the cumulative returns tended to be greater for the trading strategy than for a corresponding buy-and-hold strategy. For example, with the combined signal and a threshold of 0.5 percent, the annualized mean return on the strategy for Fund 1 is 80.16 percent, versus 18.19 percent for the fund itself.

Interestingly, even though Fund 5 had a better buy-and-hold mean return than Fund 4, the trading strategy produced higher mean returns for 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, if the right signals are used, the strategy always works well because the investor invests only when the broad market moves. Because all of these funds have somewhat diversified portfolios, the result carries through for all funds.

■ *Trading costs.* In the previous process, we considered two expected-excess-return thresholds, 0.5 percent and 1.0 percent. We did so to minimize the amount of trading. **Table 4** documents, for two levels of fixed costs and three initial starting balances, the number of trades, the percentage of time the investor was in the fund, and buy-and-hold returns for the four-year sample period. For each threshold, we used both signals. Note that with this strategy, the investor was in the fund only a small fraction of the time, especially for the higher threshold. For example, using the 1.0 percent threshold, the percentage of days in the fund varies between 1.40 percent and 16.09 percent for the five funds. Furthermore, because the investor sometimes stayed in the fund on consecutive days (i.e., there was no sell signal), the actual amount of trading in and out of each fund was quite low. However, at the lower threshold level, the trading was significant. For the lower threshold, trade frequencies vary from 8 to 35 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 considered trades made through a third party, such as an online brokerage firm that sends orders in batches. To coincide with actual practice, we considered 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., $0.00 cost).

Several observations are of interest. First, even at the high trading cost and low initial capital level, the trading strategy returns for the five funds are much higher than the buy-and-hold returns at no cost. For example, at a cost of $29.95 and $10,000 of capital, the cumulative returns when the strategy was followed are 1,008.58 percent, 344.92 percent,

Table 3. Pacific/Japan Funds: Trading Results for Various Signals, January 1997–November 2000

					Strategy Signal								
		Fund			S&P 500			Nikkei			Combined		
Fund	Threshold (%)	Mean (%)	Sharpe Ratio	% Positive	Mean (%)	Sharpe Ratio	% Positive	Mean (%)	Sharpe Ratio	% Positive	Mean (%)	Sharpe Ratio	% Positive
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	100.00	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

NA = not available.

Note: "Mean" is the annualized mean return; "% Positive" is the percentage of days that yielded positive returns. Signals are the S&P 500 return from open to close, the return on the Nikkei 225 from close of the spot market in Japan to close of the futures market in Chicago, and the two signals combined.

Table 4. Pacific/Japan Funds: Trading Results with Trading Costs, January 1997–November 2000

				Threshold = 0.5%			Threshold = 1.0%		
Fund	Initial Balance ($ thousands)	Cost ($)	Fund Buy-and-Hold Return (%)	Strategy Return (%)	% of Time Invested	# of Buys	Strategy Return (%)	% of Time Invested	# of Buys
1		0.00	59.32	1,508.18	37.17	139	395.64	16.09	63
	10	14.95	59.08	1,258.80			348.34		
	10	29.95	58.84	1,008.58			300.89		
	100	14.95	59.30	1,483.24			390.91		
	100	29.95	59.27	1,458.22			386.16		
	1,000	14.95	59.32	1,505.69			395.17		
	1,000	29.95	59.32	1,503.18			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		
	1,000	14.95	38.40	576.90			169.65		
	1,000	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		
	1,000	14.95	–8.59	90.04			33.78		
	1,000	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		
	1,000	14.95	–19.89	692.35			240.67		
	1,000	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		
	1,000	14.95	31.71	486.85			104.81		
	1,000	29.95	31.70	485.99			104.70		

Note: For the strategy, we used the combined signals. Returns for each strategy and each fund are cumulative buy-and-hold returns over the full sample period.

61.59 percent, 356.62 percent, and 317.08 percent, respectively, for using the strategy with the five funds versus costless cumulative returns for the funds themselves of 59.32 percent, 38.40 percent, –8.59 percent, –19.89 percent, and 31.71 percent. Second, transaction costs matter only at a low level of capital ($10,000). That is, the returns for the four-year period fall by about 15 percent and 30 percent 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 using this strategy (see Note 7), these results suggest that trading restrictions will not prevent this practice. With relatively low amounts of capital, the strategy can be processed through third parties at little cost.

Risk. The strategies discussed here 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. 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 United States. One way this hedging can be

accomplished is by selling the futures at the close (to offset the exposure resulting from the long position in the fund) and then closing the position when the futures market opens again in the United States.[15] An alternative hedge instrument is the WEBS contract that trades on the Amex. This security is equivalent to an open-end index fund, but unlike funds, it does trade continuously during the U.S. trading day at market prices rather than NAV.

Although either the futures or the WEBS can hedge the exposure during the period when the Japanese market is open the next day, they also generate 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 low in this period.

Whether these hedges improve performance in practice is primarily an empirical question. Thus, **Table 5** and **Table 6** provide an analysis of the risk of the trading strategy with and without use of a hedge instrument (the CME Nikkei futures contract) at the U.S. close and closing the position at the U.S. open the following day.[16] As Table 5 shows, when the hedge was undertaken, the Sharpe ratios improved in all cases, sometimes by more than 25 percent. For example, for Fund 2, the Sharpe ratios for the 0.5 percent and 1.0 percent thresholds increased from 7.95 to 10.12 and from 10.46 to 13.98, respectively. Because these hedges are relatively easy to implement (and relatively low cost), these results promise substantial benefits.

Table 5. Pacific/Japan Funds: Effects of Hedging, January 1997–November 2000

		Fund			Strategy Mean (%)		Sharpe Ratio		%Positive	
Fund	Threshold (%)	Mean (%)	Sharpe Ratio	% Positive	Unhedged	Hedged	Unhedged	Hedged	Unhedged	Hedged
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

Note: For the strategy, we used the combined signals.

Table 6. Pacific/Japan Funds: Analysis of Unexpected Returns, January 1997–November 2000

		Fund			Unhedged Strategy			Hedged Strategy		
			Correlation			Correlation			Correlation	
Fund	Threshold (%)	Volatility (%)	With US$/¥	With Nikkei	Volatility (%)	With US$/¥	With Nikkei	Volatility (%)	With US$/¥	With 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

Note: For the strategy, we used the combined signals.

In Table 6, we compare the volatility and the exposure to the 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 was implemented only sporadically, on very strong signals. Second, the hedged strategy reduced the exposure (almost completely) to the overall Nikkei (the market)—for all five funds.[17]

International/Europe Funds. In addition to the Pacific/Japan funds, another natural choice for exploiting stale prices is the international funds that concentrate in equity markets in time zones that differ from the U.S. EST zone, such as Europe. Although European trading hours partially overlap U.S. trading hours, information that comes out during the later part of the day in the United States is potentially useful for trading Europe funds because it has not been incorporated in 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 United States and Japan.

As Figure 1 shows, the European stock markets have all closed by 12:00 p.m. (noon), although a number of markets close somewhat earlier. These closing prices are used to set fund NAVs and the purchase and sale prices that are in effect for fund transactions up to 4:00 p.m. Thus, at least a four-hour period, possibly more, exists during which investors can look to U.S. markets to "predict" contemporaneous moves in Europe, which then become built into the NAV of international/Europe funds the following day.

We focus here on those funds with significant assets under management for which the trading strategy is feasible, for a total of 12 funds (see Table 1) out of approximately 700 international no-load funds. To be comparable with the discussion of the Pacific/Japan funds, we used data for January 1, 1997, to November 30, 2000. **Table 7** documents the contemporaneous correlation of each fund return with the Eurotop stock index and with the dollar/euro exchange rate, fund autocorrelation, and fund cross-serial correlation with the relevant signals—in this case, S&P 500 returns in the United States for a day and for half-days.

First, note that contemporaneous correlations with the Eurotop are substantial—between 0.57 and 0.80. Second, these funds exhibit autocorrelations ranging from 0.07 to 0.30, with the majority being greater than 0.11. What these findings suggest is that the funds' securities do not all trade at the same time or the prices 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 with (i.e., predictive power for) the fund returns. In particular, the S&P 500 returns from both open to noon and noon to close exhibit considerable correlation with fund returns—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, would be an examination of the effects of using these two signals combined. As for the Pacific/Japan funds, because these

Table 7. International/Europe Funds: Correlation of Fund Returns, January 1997–November 2000

				Signals: S&P 500		
Fund	Eurotop	US$/€	Autocorrelation	Open to Close	Open to Noon	Noon to Close
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

positions are tradable at zero transaction costs, this amount of daily predictability implies large profit opportunities in these international funds.

Similar to the trading strategy for the Japan funds, we consider here strategies that either *ex ante* lead to minimal amounts of trading or are implemented through third-party vendors. We analyzed expected returns for strategies generated from signals in the U.S. stock market as given by

$$E(r^{Itl}_{t_{12pm},\,t+1_{12pm}}) = b_1 r^{S\&P}_{t_{9am},\,t_{12pm}} + b_2 r^{S\&P}_{t_{12pm},\,t_{4pm}}, \quad (2)$$

where r^{Itl} represents the return on the international fund that traded at 4:00 p.m. (but actually represents the earlier closing prices of international exchanges) and $r^{S\&P}$ is the return on the S&P 500 (broken down into periods during the day). As previously, large excess returns are defined as 0.5 percent or 1.0 percent. Nominal trading costs are \$14.95 or \$29.95 for three levels of initial capital—\$10,000, \$100,000, and \$1,000,000—and we consider the case of free exchanges. Also, each day, the investor reevaluated the trade and sold the fund only if $E(r^{Itl}) < 0$.

■ *Signals.* We investigated empirically the simulated trading results of strategies for the 12 funds described in Table 7 based on three signals—(1) open-to-close S&P 500 return, (2) noon-to-close S&P 500 return, and (3) combined open-to-noon and noon-to-close S&P 500 returns. **Table 8** reports annualized means, Sharpe ratios, and percentage of returns with the correct sign for the funds and the strategies. The Sharpe ratios for the strategy returns for both thresholds range from 5.52 to 12.16, compared with a range of –0.03 and 0.98 for the buy-and-hold fund strategy. In terms of the different trading signals, using S&P 500 information prior to noon in addition to the afternoon return provides a clear benefit. For the majority of funds and with the 0.5 percent threshold, the mean return was more than 1.5 times higher when using either of the signals that incorporated the earlier information (i.e., the full-day return or both the morning and afternoon returns) relative to using only the afternoon return. Surprisingly, even though the combined-signal strategy should, in theory, use the signal information more efficiently than either signal alone (by separating out the morning and afternoon S&P 500 signals) in practice, using the S&P 500 return over the entire day, open to close, worked just as well.

Table 8 also documents that the percentage of days for which we found a positive return when there was a trading signal was often above 80 percent for the 0.5 percent threshold and even higher for the 1.0 percent threshold. In contrast, we found the percentage of positive returns in the entire sample to be only slightly above 50 percent.

To understand the statistical significance of these and the Pacific/Japan fund results, we performed a simple binomial test. As a representative example, consider Fund 1 in the international/Europe group, Warburg Pincus International. The null hypothesis is that the trading results are caused by chance. Under this null, the "true" probability of seeing a positive return is 55 percent, the fraction of positive return days in the full sample. Under these conditions, the observed 82 percent value is almost six standard deviations from the mean, which is equivalent to a p-value of 0.00.

Alternatively, note that the Sharpe ratio itself corresponds to a t-test. Because both the mean and the standard deviation are annualized and we had 3.92 years of data, we can easily provide a test for the null that the mean return is zero for days when the strategy is invested in the fund. The relevant statistic is the Sharpe ratio times $\sqrt{3.92}$ (the number of years), which we found to be almost uniformly above 10 for all funds.

■ *Trading costs.* Results of the empirical analysis related to trading activity and costs for the international/Europe funds are in **Table 9**. Similar to the results for the Pacific/Japan funds, the cumulative return results are impressive for the 0.5 percent threshold. For every fund, the investor was in the fund less than 20 percent of the time, yet in almost every case, the strategy's return exceeded that of the fund, sometimes substantially so. Even when the threshold was increased to 1.0 percent, the strategy outperformed in the majority of cases.

With respect to trading through a third party, again, trading costs were relevant only for the case in which the investor had minimal amounts of capital. Therefore, Table 9 documents the most extreme case (i.e., \$29.95 and \$10,000) for each of the 12 international/Europe funds. For the 0.5 percent threshold, the cumulative returns fell by about 50 percent; for three funds, returns actually fell below the buy-and-hold strategy. Of course, even though the strategies' returns dropped substantially, the risk was still much less than the buy-and-hold strategy because the investor was in the fund on only a limited basis.

■ *Risk.* The strategy applied to the international/Europe funds is subject to risks similar to the risks for the strategy applied to the Pacific/Japan funds—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

Table 8. International/Europe Funds: Trading Results for Various Signals, January 1997–November 2000

		Fund			S&P 500 Open to Close			S&P 500 Noon to Close			S&P 500 Open to Noon and Noon to Close		
Fund	Threshold (%)	Mean (%)	Sharpe Ratio	% Positive	Mean (%)	Sharpe Ratio	% Positive	Mean (%)	Sharpe Ratio	% Positive	Mean (%)	Sharpe Ratio	% Positive
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	100.00	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	100.00	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	100.00	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	100.00	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	100.00	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	100.00	8.95	24.71	100.00	10.07	12.16	100.00

NA = not available.

Table 9. International/Europe Funds: Trading Results with Trading Costs, January 1997–November 2000

Fund	Initial Balance ($ thousands)	Cost ($)	Fund Buy-and-Hold Return (%)	Threshold = 0.5%			Threshold = 1.0%		
				Strategy Return (%)	% of Time Invested	# of Buys	Strategy Return (%)	% of Time Invested	# of 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		

markets the following day. These risks are more complex for the international/Europe strategy than for the Pacific/Japan strategy because the international/Europe portfolio holdings are spread across a wider 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. Instruments did not exist in the U.S. markets during our study period to carry out such hedges, but an investor could hedge volatility within the trading day in Europe. We found that when the hedge was undertaken, the Sharpe ratios improved in many of the cases (although by relatively small amounts) and the hedged returns were essentially uncorrelated with the European index.[18]

Case Study: Vanguard

In this section, we illustrate a trading strategy that is especially relevant for university academics because it pertains to trading Vanguard mutual funds, which are included in most university 403(b) plans. Among the Vanguard fund family, three funds are best suited to the trading strategies we have discussed: (1) the Vanguard International Growth, (2) the Vanguard International Pacific Equity Index , and (3) the Vanguard International European Equity Index. Table 1 describes characteristics of these funds in terms of trading. The first fund charges no fee to transfer in or out, whereas the other two funds charge 50 bps for transferring into the fund.[19] The advantage of the second and third funds is that they are index funds, with very high correlations with the aggregate markets in those two regions. When the investor was not in a fund, the money was in the Prime Money Market fund, which invests primarily in high-quality, short-term commercial paper.

The trading strategy used the same signals for the Pacific Index Fund as for the Pacific/Japan funds and used the same signals for the International Growth and European Index funds as for the international/Europe funds. In particular, for the Pacific-based fund, we used the full-day S&P 500 return and the closing Nikkei futures price relative to the closing price of the Nikkei in Japan. For the International Growth and Europe Index funds, we used S&P 500 for the open-to-noon and the noon-

to-close periods. We initiated the strategies in January 1997 and ended them in November 2000.

For the two funds with transaction costs, we subtracted those costs from the expected return calculations to obtain a comparison of all three funds net of transaction costs. The net expected returns for the three funds are denoted $E(R_1)$, $E(R_2)$, and $E(R_3)$. Given a threshold κ, a natural trading rule is to get into the fund with the highest net expected return if this return exceeds the threshold —that is if[20]

$$\max[E(R_1), E(R_2), E(R_3)] > \kappa. \quad (3)$$

In other words, we considered a single strategy of switching between the three funds and the money market fund in contrast to the previous strategies that moved in and out of a single fund.

Table 10, which shows the correlations between each fund's returns and the signals, provides (as for the Pacific/Japan and international/Europe funds) considerable evidence of predictability for these Vanguard fund returns. For example, the correlations between the Pacific Index Fund returns and the Nikkei futures signal and the S&P 500 signal are, respectively, 35 percent and 29 percent. Correlations for the International Growth and European Index funds are equally significant. Clearly, with large enough movements during U.S. trading hours, large excess profits are potentially available to an active investor.

Table 11 and **Table 12** document the results of our strategy for three expected-excess-return thresholds—0.25 percent, 0.50 percent, and 1.00 percent—and for a simple buy-and-hold strategy. As before, the results are striking. For example, Table 11 shows that the hedged and unhedged strategies have Sharpe ratios ranging from 4.54 to 8.02 for the days that the investor was in one of the three funds; in contrast, the Sharpe ratios of the buy-and-hold strategies for the individual funds range from –0.14 to 0.59 (see Table 10). Of course, the higher Sharpe ratios come from the fact that the investor was rarely in the international equity market and only when it tended to go up. For example, Table 12 indicates that for a threshold of 0.50 percent daily excess return (net of transaction costs), the investor

Table 10. Vanguard Funds: Summary Statistics for Fund Returns, January 1997–November 2000

				Correlation with Signals			
Vanguard Fund	Mean Return (%)	Sharpe Ratio	Fund Buy-and-Hold Return (%)	S&P 500 Open to Noon	S&P 500 Noon to Close	Nikkei Future Spot Rate	S&P 500 Open to Close
International Growth	10.01	0.30	39.40	0.30	0.35		
Pacific Index	1.75	–0.14	–4.03			0.35	0.29
European Index	15.36	0.59	69.89	0.18	0.37		

Table 11. Vanguard Funds: Trading Results, January 1997–November 2000

	Equal-Weighted Portfolio of Funds			Unhedged			Hedged		
Threshold (%)	Mean (%)	Sharpe Ratio	Buy-and-Hold Return (%)	Mean (%)	Sharpe Ratio	Buy-and-Hold Return (%)	Mean (%)	Sharpe Ratio	Buy-and-Hold Return (%)
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

Note: Mean is annualized mean return.

Table 12. Vanguard Funds: Descriptive Statistics for Trading Strategy, January 1997–November 2000

	% of Time Invested			# of Buys for Each Fund		
Threshold (%)	International Growth	Pacific Index	European Index	International Growth	Pacific Index	European Index
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

was in the International Growth 6.71 percent of the time, in the Pacific Index 9.82 percent of the time, and in the European Index 4.41 percent of the time. The aggregate number of trades over this four-year period for this 0.50 percent threshold was 99, which led (see Table 11) to a cumulative return of 216.87 percent and 222.63 percent on, respectively, the unhedged and hedged strategies of switching between the funds. Comparison with Table 10 shows that these cumulative returns contrast with buy-and-hold returns for the funds of 39.40 percent for the International Growth, only –4.03 percent for the Pacific Index, and 69.89 percent for the Europe Index. Most notably, even though the strategy earned seven times the return of an equal-weighted buy-and-hold portfolio (buy-and-hold return from Table 11 of 34.34 percent), the investor was actually in the risk-free money market account 77 percent of the time (see Table 12).

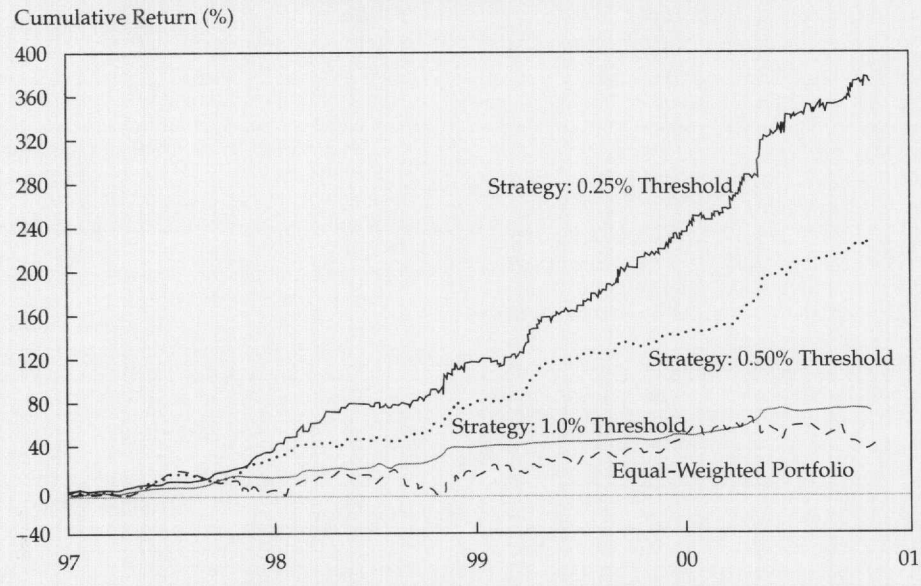
As a final indicator of the magnitude of these results, **Figure 2** shows a graph of the cumulative return on the strategy for the three thresholds versus the buy-and-hold equal-weighted portfolio of the three funds. Both the higher volatility and smaller cumulative return of the buy-and-hold strategy are apparent. Trading just 21 times over this 4-year period provided excess returns of 17 percent to 31 percent (depending on the hedging strategy) over the equal-weighted portfolio's realized returns with little or no risk.

Final Remarks

We have demonstrated that an institutional feature inherent in a multitude of mutual funds managing billions of assets generates fund NAVs that reflect stale prices. Because investors can trade in many cases at these NAVs with little or no transaction cost, an obvious trading opportunity exists. Simple, feasible strategies generate Sharpe ratios that are sometimes 100 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 United States. When implemented, these strategies provide gains that are matched by offsetting losses incurred by buy-and-hold investors in the funds.

Are mutual funds aware of these trading opportunities? Although we have no direct evidence concerning this question, the actions taken by certain funds to curtail short-term trading and our interaction with industry professionals suggest the funds do know about the problem. Specifically, some funds are now imposing back-end loads on positions held for periods shorter than a particular threshold. For example, Fidelity announced on March 1, 2000, that it would begin imposing a redemption fee of 1 percent on investments in international funds that are held for fewer 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 Note 7).

Figure 2. Cumulative Vanguard Fund Returns: Equal-Weighted Portfolio versus Hedged Strategy, January 1997–November 2000



Can this type of trading activity be prevented? One way to discourage short-term trading is the imposition of redemption fees. These fees dramatically reduce the returns to the strategies we have described, but they do not prevent the strategic timing of purchases. Another approach is to attempt to correct for stale prices in computing NAVs, but this approach is fraught with complications. Specifically, any correction would be subject to both model risk and estimation risk. And to the extent that the updating procedure became known or could be backed out from the data, traders might be able to exploit the inevitable errors. Nevertheless, subsequent to our sample period, numerous funds appear to have adopted this approach. A third way to prevent short-term trading would be to permit purchases only on the basis of the following day's NAV. In other words, money invested "today" would go into the fund "tomorrow" at tomorrow's closing price. 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 et al., Greene and Hodges, and Goetzmann et al.

Should mutual funds even worry about trying to prevent these types of strategies? Because the gains are offset by losses to other investors in the fund, the funds clearly have a fiduciary duty to take some preventive action. 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, 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 transaction costs or other expenses.

Given these issues, why haven't more funds taken stronger actions to restrict short-term trading? Perhaps the funds are not aware of the problem. A more cynical interpretation is that short-term trading increases average assets under management, which are 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, funds may have the perception that imposing redemption fees or delaying investments puts the fund at a competitive disadvantage relative to its peers in attracting money. Unfortunately, the profits and Sharpe ratios we have documented suggest that this activity will increase and, therefore, will eventually have to be curtailed.

Thanks to Mark Carhart, Gregory Kadlec, and seminar participants at New York University for helpful comments.

Notes

1. Some limitations exist on how quickly and how often investors can exchange between funds. These restrictions are discussed in the "Trading Mutual Funds" section.
2. Examples of cross-dependencies between international stock returns can be found in, among others, Eun and Shim (1989), Hamao, Masulis, and Ng (1990), Becker, Finnerty, and Gupta (1990), Becker, Finnerty, and Friedman (1993), and Lin, Engle, and Ito (1994).
3. Recent papers in finance (e.g., Chalmers, Edelen, and Kadlec 2001; Greene and Hodges 2000; Goetzmann, Ivkovic, and Rouwenhorst 2001) make a similar point. A comparison of our article with these papers is provided in the "Trading Mutual Funds" section.
4. A similar phenomenon occurs in illiquid domestic equity funds. Although markets for the securities in these funds are open until 4:00 p.m., some equities trade infrequently; therefore, stale prices are used to calculate end-of-day net asset values. 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 body of literature documents the effect of nontrading on portfolio return autocorrelations (e.g., Scholes and Williams 1979; Lo and MacKinlay 1988; Boudoukh, Richardson, and Whitelaw 1994).
5. In terms of taking advantage of a structural inefficiency in the market, our article is also similar in spirit to that of Scholes and Wolfson (1989), who examined taking advantage of dividend reinvestment plans.
6. In conversations with professionals in the money management business, as well as first-hand experience, we found that the fund families are reluctant to bar investors who violate their "excessive trading" rules (within reason). Whether the cause is that their information systems are not set up to identify offenders or simply that they are more lenient than their prospectuses imply is not known. Nevertheless, not only do their printed rules vary, so do their thresholds for identifying a clear violation. Conventional wisdom is that transactions greater than $1 million are looked at more closely than other transactions.
7. Currently, we know of at least 16 hedge fund companies covering 30 specific funds whose stated strategy is "mutual fund timing."
8. See discussions in French and Roll (1986), Barclay, Litzenberger, and Warner (1990), and Craig et al.
9. There are exceptions; for example, S&P 500 Index futures and Nikkei futures contracts trade around the clock on GLOBEX via the Chicago Mercantile Exchange.
10. There is an interesting difference between a quanto and WEBS-based hedge when hedging Nikkei-linked assets.

Changes in the Nikkei futures quantos traded on the CME reflect changes in the Nikkei level at a fixed exchange rate, whereas Japanese market WEBS reflect changes in the dollar value of the assets, thus incorporating both exchange rate and Nikkei level changes.

11. Pacific funds may also hold securities that trade elsewhere (e.g., American Depositary Receipts that trade on the NYSE). For these securities, funds use updated prices; however, these securities generally constitute a small fraction of any particular portfolio.
12. See Craig et al. for a detailed analysis of the extent to which the futures market in the United States predicts subsequent movements in Japan.
13. The implied level of the Nikkei can be inferred from pricing the Nikkei futures contract as a quanto. In particular, the Nikkei futures contract represents a non-U.S.-based derivative that pays off in dollars. From the results in Dravid, Richardson, and Sun (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.
14. See Brown, Goetzmann, and Ibbotson (1999) for an analysis of hedge fund performances.
15. Note that the optimal closing of the position would be at the close of the Japanese market. Thus, the investor essentially needs around-the-clock trading, which takes place on GLOBEX for futures contracts on both the S&P 500 and the Nikkei.
16. We took a position in the futures contract from its close to open. On days with consecutive large positive signals, this procedure reduced the potential value on the second day if the Nikkei-based information was released between the Japanese close and U.S. open.
17. We did not try to hedge the remaining exposure to exchange rates. In theory, one could use forward contracts to reduce the exposure for the relevant funds.
18. For brevity, the results are not reported, but they are available from the authors.
19. Starting in 2001, the two index funds dropped the fee for exchanges.
20. We ignored the option component embedded in the funds with transaction costs. That is, even if the expected return on a fund was less than, say, the money market rate, staying in the fund could still be worthwhile because exiting meant forgoing the option of getting in during the next period and saving the 50 bps charge.

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