

Do Mutual Fund Managers Adjust NAV for Stale Prices?

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Abstract

This paper discusses how liquid assets can be used to infer fair prices of related illiquid assets. To illustrate this idea, I show how premiums on liquid exchange traded funds can be used for the fair valuation of mutual funds that are prone to stale prices. Mutual fund returns are predictable when the Net Asset Value is computed from data that does not reflect all available market information, which results in dilution of funds assets when market timers exploit the predictability. I show by using know predictors and ETF premiums that international mutual fund returns were predictable in the period from 2001 to 2010 and that the supplemental use of ETF premiums yields stronger predictability than other know predictors alone. I also provide evidence that mutual fund managers are more active in adjusting for fair pricing in the later part of the sample, but that there is still economically significant predictability in international mutual fund returns.

Keywords: Exchange traded funds, mutual funds, fair value pricing, market timing.

JEL Classifications: G12, G14, G15

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1 Introduction

In this paper, I show that returns of open-end international equity mutual funds were predictable in the period from 2001 to 2010 and illustrate, using a simple strategy, how they can be predicted using the information contained in exchange traded funds (ETF) premiums. I also provide evidence that mutual fund managers are more active in adjusting NAV in the later part of the sample, which makes it appear less affected by staleness. However, there still remains economically significant predictability in mutual fund returns.

1.1 Mutual Fund Returns Predictability

Under the efficient market hypothesis, it is believed that any risk-adjusted abnormal expected return on market-traded assets will be arbitrated away by market participants. However, market efficiency relies on prices adjusting as a result of trades between principals. When no such trading occurs, prices become stale and no longer reflect fair value. I show that if there is a need to determine the fair value of an asset for which the price is stale, the use of related liquid assets can yield a better inference than the sole reliance on wide market indices. I illustrate this concept in the context timing arbitrage of mutual funds. Chalmers, Edelen, and Kadlec (2001) note that when prices are set by an intermediary, economic distortions can arise. One such situation is the buying and selling of open ended mutual fund shares, in which case the fund manager sets the price of shares based on her estimation of net asset value (NAV) at the end of the day.

According to the Investment Act of 1940, mutual funds shares can only be sold, redeemed or repurchased at a price based on the current net asset value next computed after the order is made¹. The NAV must be computed on every business day at a specific time, usually at 4 p.m. ET when markets close. The NAV of a share is simply the total net assets of the fund, minus any liabilities and expenses, divided by the number of shares. Still according to the Investment Act, “The Portfolio securities with respect to which market quotations are readily available shall be valued at current market value, and other securities and assets shall be valued at fair value as determined in good faith by the board of directors of the registered company”². However, fair valuation is a tricky process when you cannot rely on market prices.

Exploitable opportunities occur when NAV returns are predictable. Previous studies have shown that NAV returns are predictable when the securities of the underlying asset class do not always have readily available market prices. For example, the last trade of some securities of a small cap fund can occur hours before markets close, foreign equity funds hold securities with trading ending many hours prior to 4 p.m. ET and bond funds holdings trade primarily

¹Investment Act of 1940, Rule 22c-1

²Investment Act of 1940, Rule 2a-4

over the counter with many sources of pricing information. When dealing with stale prices, the NAV does not reflect all available information if it computed using last transaction prices. To illustrate the problem, let's consider a mutual fund specialized in Japan equities. Japanese stocks trade on the Tokyo Stock Exchange until it closes at 3 p.m. local time (2 a.m. ET). Thus, when NAV is computed at 4 p.m. ET, the last transaction occurred more than 14 hours earlier. Any new information won't be reflected in the NAV unless the closing prices are correctly adjusted to reflect that new information. This poses a problem because if NAV is not properly computed, future returns are predictable, thus attracting investors specializing in "market timing arbitrage." This can lead to frequent purchase and redemption of fund shares, imposing costs to the funds (such as transaction fees and liquidity issues) that result in dilution to the detriment of long term shareholders.

Chalmers, Edelen, and Kadlec (2001) discuss this problem and show that while fund managers are allowed to adjust NAV to reflect new information, most do not (Zitzewitz (2003) presents similar results). Those studies use liquid US equity indices and market prices of futures as predictors of NAV returns. Goetzmann, Ivković, and Rouwenhorst (2001), Bhargava and Dubofsky (2001), Varela (2002), Zitzewitz (2003) and Boudoukh, Richardson, Subrahmanyam, and Whitelaw (2002) all find that simple trading strategies designed to exploit mispricing due to stale prices could lead to large abnormal returns. In the case of Zitzewitz (2003), he finds that investors can earn 35-70% per year in international funds and 10-25% in small-cap equity funds. He also provides evidence that agency problems might be the root cause of the market timing arbitrage problem. Looking at flow of funds, he finds that dilution in international funds was 1.14% in 2001 while Greene and Hodges (2002) find a lower 0.48% between 1998 and 2001.

Chen, Ferson, and Peters (2010) and Qian (2011) present methodology for performance evaluation of mutual funds in the presence of stale pricing. These papers view NAV stale pricing as a given that introduces bias in performance evaluation and correct for that bias. Instead of looking at the bias introduced by stale pricing, I focus on the ability of fund managers to adjust the NAV to account for stale pricing.

Awareness of the problem is not limited to the academic literature. In May of 2004, the SEC introduced a new rule forcing the disclosure in mutual fund prospectuses of the risks associated with frequent trading and market timing. The prospectuses must also disclose the measures taken (or lack of) to reduce frequent trading and market timing.

Current solutions in use to reduce market timing fall in two categories: solutions to prevent frequent trading and solutions for fair value adjustments of NAV. In order to prevent frequent trading, it is common practice to limit the number of round trips (buy and sell) by an investor in a given period and to impose high rear-load fees that disappear over time. While the implementation of the first solution is not straightforward (it is not always possible to track individual investors), the bigger issue with these restrictions is that they are imposed on all shareholders,

reducing the liquidity of investments in mutual funds.

As for fair value adjustment solutions, they fall into two categories: bottom-up and top-down approaches. In bottom-up approaches, such as the ones presented by Chalmers, Edelen, and Kadlec (2001) and Chua, Lai, and Wu (2008), individual securities are adjusted independently before computing NAV. In top-down approaches, such as the one presented by Goetzmann, Ivković, and Rouwenhorst (2001) and Jares and Lavin (2004), it is the fund's NAV that is directly adjusted. While my proposed adjustment methodology falls into the latter category, it could easily be adapted to individual securities. Ciccotello, Edelen, Greene, and Hodges (2002) and Zitzewitz (2003) both present an overview of the different methodologies.

In practice³, 80% of fund managers use proxies to determine if adjustment to closing exchange prices for foreign securities is necessary, with the S&P 500 and Russell 1000 being the most frequently used proxies. 78% use foreign currency exchange rates at 4 p.m. ET.

1.2 Exchange Traded Funds

Exchange traded funds (ETF) are similar to traditional index mutual funds in purpose. While open-end mutual funds shares can only be bought or sold at the end of the day at the net asset value, ETFs trade continuously during the day, like closed-end mutual funds, at a price that can be different from NAV. In order to maintain prices close to fair value, creation and redemption of shares is allowed in kind. The S&P 500 SPDR, the largest ETF, is a typical example. According to the prospectus, “The Trust issues and redeems SPDRs only in specified large lots of 50,000 SPDRs or multiples thereof referred to as *Creation Units*.” ... “Creation Units are redeemable in kind only and are not redeemable for cash⁴. Upon receipt of one or more Creation Units, the Trust delivers to the redeeming holder a portfolio of Index Securities (based on NAV of the Trust), together with a cash payment. Each redemption has to be accompanied by a Cash Redemption Payment that on any given Business Day is an amount identical to the Cash Component of a Portfolio Deposit.” The first ETF, the S&P 500 SPDR, began trading in 1993 and is discussed by Elton, Gruber, Comer, and Li (2002). It has about \$77 billion under management⁵ and there were over 900 other ETFs tracking equity, fixed-income, currency and commodity indices at year-end 2010 in the US alone⁶. Gastineau (2001) and Fuhr (2001) present introductions to the world of exchange traded funds while Kostovetsky (2003) provides a comparison of exchange traded funds and index mutual funds.

When the price is higher or lower than NAV, the ETF trades at a premium or discount.

³Data from “The Eighth Annual Fair Value Pricing Survey: Executive Summary and Key Trends and Findings”, Deloitte Financial Services, 2010.

⁴Some ETFs, such as leveraged ETFs, allow creation and redemption in cash.

⁵As of August 22, 2011.

⁶According to the 2010 Investment Company Fact Book, www.icifactbook.org.

Since ETF shares can be created or redeemed at any time by trading the underlying basket of stocks, large premiums or discounts should not be possible because of arbitrage, assuming that NAV reflects the true value of assets. When dealing with NAV estimated using stale prices, premiums and discounts might appear because actual prices of ETF include new information. Thus, in order to trade on the information reflected by ETF premiums, one would need an up-to-date (intraday) estimate of NAV, which is only available at the end of the day as it is for mutual funds. Fortunately, exchanges provide a similar measure called the Indicative Optimized Portfolio Value (IOPV) throughout the day that acts as a proxy for NAV.

1.3 Mutual fund returns and ETF premiums

To my knowledge, Jares and Lavin (2004) is the only paper that uses exchange traded funds in the context of mutual funds predictability. They use the returns on country ETFs as an explanatory variable alongside returns on the S&P 500. Zitzewitz (2003) also discussed the possibility of using ETF returns as predictors, but dismissed it because of the relative illiquidity of international ETFs at the time. Instead of relying solely on ETF returns, my methodology uses ETF premiums as additional predictors, a measure I consider more intuitive and closely related to the nature of the fair valuation problem.

Using the well-known Kalman filter in a dynamic linear framework, I show how ETF premiums can be used in conjunction with other known predictors such as S&P 500 returns to predict mutual fund returns. I also give evidence suggesting that fund managers are becoming more active at adjusting NAV for stale pricing, but that there is still economically significant predictability.

1.4 Outline of the Paper

Sections 2 and 3 describe the model and the filtering setup. Section 4 presents the data and methodology for estimating the model. Section 5 illustrates empirically predictability in mutual fund returns. Section 6 addresses fees and trading restrictions. Section 7 concludes.

2 Model

Let there be a mutual fund for which the true (fundamental) log value of assets v^{MF} follows a random walk

$$v_t^{MF} = v_{t-1}^{MF} + \varepsilon_t^{MF}, \quad (1)$$

where ε_t^{MF} is i.i.d. normal with mean zero and variance σ_{MF}^2 . The return ε_t^{MF} is linearly related to some publicly observable return r_t^I

$$\varepsilon_t^{MF} = \beta r_t^I + \varepsilon_t^{I'} \quad (2)$$

where $\varepsilon_t^{I'}$ is i.i.d. normal with mean zero and variance $\sigma_{I'}^2$.⁷

The publicly observable return is also observable at one point in time intra-period. Let $r_t^I \equiv r_t^{I-} + r_t^{I+}$, where r_t^{I-} is the return during the first sub-period and r_t^{I+} is the return during the second sub-period. Let μ and $(1 - \mu)$ denote the approximate weights of r_t^{I+} and r_t^{I-} on r_t^I , respectively. μ can be interpreted as the length of the second sub-period relative to one period.

At each time t , the fund manager observes n_t^{MF} , the log net asset value of the mutual fund. This NAV represents the total log value of the fund assets based on the latest transaction price. If all underlying assets trade continuously, then $n_t^{MF} = v_t^{MF}$. However, if prices are stale, we have

$$n_t^{MF} = (1 - \eta)v_t^{MF} + \eta v_{t-1}^{MF} + \varepsilon_t^{n,MF} \quad (3)$$

where η is the staleness parameter of the fund and $\varepsilon_t^{n,MF}$ is i.i.d. normal with mean zero and variance $\sigma_{n,MF}^2$. η can take values between 0 (no staleness) and 1 (fully stale). This net asset value is private information available only to the fund manager. The managers uses this information to set the price n_t^{MF*} that is effective for transaction orders received on day t before n_t^{MF*} becomes public.

Let there also exists an ETF with a similar objective as the mutual fund and for which both the true log value v^{ETF} and the log NAV n^{ETF} are publicly observable. The ETF premium is linearly related to the mutual fund premium, so we have

$$v_t^{ETF} - n_t^{ETF} = \gamma[v_t^{MF} - n_t^{MF}] + \varepsilon_t^{ETF} \quad (4)$$

where ε_t^{ETF} is i.i.d. normal with mean zero and variance σ_{ETF}^2 .

2.1 Relationship between v^{MF} , n^{MF} , r^{I-} and r^{I+}

By definition, full predictor returns r_t^I are linearly related to fundamental fund returns as

$$r_t^I = \frac{1}{\beta}[v_t^{MF} - v_{t-1}^{MF}] + \varepsilon_t^I, \quad (5)$$

where $\varepsilon_t^I = \frac{-1}{\beta}\varepsilon_t^{I'}$.

⁷The prime notation is used here to simplify the notation in the next section.

This relationship can further be decomposed in two sub-period predictor returns as

$$r_t^{I-} + r_t^{I+} = \frac{1}{\beta}[v_t^{MF} - n_t^{MF}] + \frac{1}{\beta}[n_t^{MF} - v_{t-1}^{MF}] + \varepsilon_t^I. \quad (6)$$

The exact relationship between v^{MF} , n^{MF} , r^{I-} and r^{I+} depends on the relative values of η and μ :

$$r_t^{I-} = \begin{cases} \frac{1}{\beta}[n_t^{MF} - v_{t-1}^{MF}] + \varepsilon_t^{I-} & \text{if } \mu = \eta \\ \frac{1}{\beta} \frac{1-\mu}{1-\eta}[n_t^{MF} - v_{t-1}^{MF}] + \varepsilon_t^{I-} & \text{if } \mu > \eta \\ \frac{1}{\beta}\{[n_t^{MF} - v_{t-1}^{MF}] + \frac{\eta-\mu}{\eta}[v_t^{MF} - n_t^{MF}]\} + \varepsilon_t^{I-} & \text{if } \mu < \eta \end{cases} \quad (7)$$

$$r_t^{I+} = \begin{cases} \frac{1}{\beta}[v_t^{MF} - n_t^{MF}] + \varepsilon_t^{I+} & \text{if } \mu = \eta \\ \frac{1}{\beta}\{\frac{\mu-\eta}{1-\eta}[n_t^{MF} - v_{t-1}^{MF}] + [v_t^{MF} - n_t^{MF}]\} + \varepsilon_t^{I+} & \text{if } \mu > \eta \\ \frac{1}{\beta} \frac{\mu}{\eta}[v_t^{MF} - n_t^{MF}] + \varepsilon_t^{I+} & \text{if } \mu < \eta \end{cases} \quad (8)$$

where $\varepsilon_t^{I-} + \varepsilon_t^{I+} = \varepsilon_t^I$ and ε_t^{I-} and ε_t^{I+} are i.i.d. normal with mean zero, variance $\sigma_{I-}^2 = (1-\mu)\sigma_I^2$ and $\sigma_{I+}^2 = \mu\sigma_I^2$ respectively, and mutually independent. Since μ and η are fixed parameters of the model, only one of the three situations is valid so the model is linear.

3 Filtering

The filtering problem of extracting valuable information from ETF premiums and other predictors is further complicated by the adjustment that might be done by mutual fund managers. I test three specifications that represent different assumptions regarding the action of managers.

I first start with a base specification that assumes fund managers make no adjustment before reporting NAV. Next, I introduce a richer specification in which they adjust NAV optimally using a predictor, but not ETF premiums. Finally, I test the base specification with the additional restriction that ETF premiums are not part of the arbitrageur's information set.

3.1 The mutual fund managers' problem

Each day, mutual fund managers need to set n_t^{MF*} – the price mutual fund shares trade at on date t – as close as possible to v_t^{MF} so that investors get a fair price, thus keeping out market timers. Their problem is $n_t^{MF*} = E[v_t^{MF} | \Phi_t^{MF}]$, where Φ_t^{MF} is the mutual fund managers' information set that includes n_t^{MF} and all the other information that fund managers look at. We are faced with a linear Gaussian model so fund managers can solve the problem optimally with Kalman filtering. If they do in fact solve the model optimally using all observables, econometricians would be unable to find evidence of predictability as managers have a strictly

greater information set.⁸ This contradicts empirical evidence, but does offer an interesting starting point to investigate actions of mutual fund managers.

3.1.1 Optimal filtering

The fund manager's information set, $\Phi_t^{MF} = \{n_t^{MF}, (v_t^{ETF} - n_t^{ETF}), r_t^{I-}, r_t^{I+}, \Phi_{t-1}^{MF}\}$, includes all publicly available information at time t plus private information about n_t^{MF} , the NAV value of fund. The filtering problem of the fund manager is to estimate v_t^{MF} , whose process is defined in (1). The observations are related linearly to that state variable as defined in (3), (4), (7) and (8) respectively.

Since $\varepsilon_t' = \{\varepsilon_t^{ETF}, \varepsilon_t^{I-}, \varepsilon_t^{I+}, \varepsilon_t^{n,MF}, \varepsilon_t^{MF}\}$ are assumed to be Gaussian innovations, this problem can be solved optimally with a Kalman filter. Details of the implementation using the standard Kalman filter are presented in Section A.1.

3.1.2 Suboptimal filtering

There is no reason to assume the fund managers are solving the filtering problem optimally. Since we cannot empirically differentiate optimal filtering from the absence of predictability, there is no point in testing for it explicitly. However, empirical evidence of predictability in Section 5 suggests that they do not solve optimally since manager have strictly better information than the econometricians. There is a multitude of ways fund managers can solve the problem suboptimally. For example, the manager could ignore some of the information such as the ETF premium or the predictor return. Another possibility is that instead of relying on the Kalman filter, they could use other more user-friendly approximations or rule-of-thumbs. Alternatively, managers might not pay attention at all and set the price to the observed NAV. I test for two different specifications of suboptimal filtering, which are:

1. $n_t^{MF*} = n_t^{MF}$, the fund manager does not adjust the NAV before setting the price.
2. The manager sets the price to the solution of the Kalman filter, without using the observation of $(v_t^{ETF} - n_t^{ETF})$, the ETF premium. This is a more efficient (in the context of this model) variation of the correction proposed by Goetzmann, Ivković, and Rouwenhorst (2001).

Details of the implementation of 2 using the standard Kalman filter are presented in Appendix A.1.

⁸ Φ_t^{MF} includes n_t^{MF} , which is unobservable to econometricians.

3.2 The arbitrageur's problem

As external observers, arbitrageurs (and econometricians) cannot solve the manager's problem since they only observe n_{t-1}^{MF*} , not n_t^{MF} . Thus the problem is to find the best $\hat{v}_t^{MF}$ and $\hat{n}_t^{MF*}$ using publicly available information, including ETF premiums and n_{t-1}^{MF*} , but not n_t^{MF} . If the resulting estimate $\hat{v}_t^{MF}$ is better than n_t^{MF*} , it means that mutual fund managers could get better estimates of the fair value of their funds by looking at extra information. Alternatively, it means that returns are predictable. Evaluating the quality of estimates directly with data is impossible since we do not observe v_t^{MF} . On the other hand, it is possible to test if there is economically significant predictability in adjusted returns ($n_t^{MF*} - n_{t-1}^{MF*}$), by building trading strategies and looking at their returns. These strategies aim to mimic what mutual fund arbitrageurs are doing, so I call this problem the arbitrageur's problem.

The arbitrageur's information set, $\Phi_t^A = \{n_{t-1}^{MF*}, (v_t^{ETF} - n_t^{ETF}), r_t^{I-}, r_t^{I+}, \Phi_{t-1}^A\}$,⁹ includes all publicly available information at time t plus private information about n_t^{MF} , the NAV value of fund. The filtering problem of the fund manager is to estimate v_t^{MF} , whose process is defined in (1), and n_t^{MF*} , which is the price that the manager will set for current day transactions. As for n_{t-1}^{MF*} , it is the solution to the manager's problem so the arbitrageur has to assume how the manager solves the problem. An estimate of n_t^{MF} can also be found as a by-product of the filtering problem. The other observations are related linearly to the state variables v_t^{MF} and n_t^{MF} as defined in (3), (4), (7) and (8) respectively. Empirically, I test for the two specifications of the manager's solution presented in Section 3.1.2, which are all linear functions of the state variables.¹⁰ To get the sense of the benefits gained from using ETF premiums, I also test the first manager's solution (no adjustment to NAV) without including ETF premiums in the arbitrageur's information set. The system is assumed to be linear with Gaussian innovations and is solved with a Kalman filter. Details of the implementation using the standard the Kalman filter are presented in Appendix A.2.

4 Methodology

4.1 Hypotheses

The main objective of this paper is to test the following two hypotheses:

- H1: ETF premiums improves the predictability of mutual fund returns prone to stale pricing over the use of traditional predictors.

⁹ n_{t-1}^{MF*} was not explicitly mentioned in Φ_t^{MF} as it is redundant information.

¹⁰The solution of the Kalman filter is linear, so the solution of one problem, such as in specifications 2, can be embedded as an observation in another Kalman filter as proposed by Carlson, Fisher, Gregoire, and Romero (2011).

H2: Over the period from 2000 to 2010, mutual fund managers have increased how they actively adjust NAV for stale pricing.

The main assumptions I rely on for testing are that the framework presented in Section 2 is a reasonable approximation of the real world and that the hypothesized adjustments to NAV are similar to the process presented in 3.1.2, which implicitly assumes that fund managers do not look at ETF premiums.

4.2 Data Sources

I have ETF data from January 1995 to December 2010, with data on international equity ETFs starting in 2000. Market prices for ETF shares are from the CRSP US Stock Database (security code 73). Over the sample period, there are 1116 ETFs, for which that last available listing was on AMEX (29), NYSE (2), NASDAQ (90) or NYSE ARCA (995)¹¹. Net asset value information is from the CRSP Survivor-Bias-Free US Mutual Fund Database. In total, there are 1077 ETF listed in the CRSP Mutual Fund Database in the sample period. ETFs from the two datasets are matched based on CUSIP for a total of 1075 matches. The 2011 Investment Company Fact Book¹² states that the total number of ETF in the US at 2010 year-end was 923, while 160 have been liquidated since 2000, for a total of 1083. It thus appears that my dataset is quite comprehensive. Mutual fund data is also from the CRSP Mutual Fund Database. The initial sample, which includes all open-ended funds with total net assets over \$5 millions and at least one year of observations (excluding the incubation period), consists of 27,003 mutual funds (unique share class). I adjust mutual fund NAVs for splits and dividends following the methodology from the “Survivor-Bias-Free US Mutual Fund Guide”. Daily index and futures data is from Datastream.

The empirical part of this research focuses on international equity funds because those funds are known to be prone to stale prices due to non-synchronous trading. The style filtering is done using the Lipper Objective Code available in the CRSP Mutual Fund Database.¹³ After filtering, 192 ETFs and 2,482 mutual funds remain. Details about the size of funds as of December 2010 are presented in Table 2 (numbers of funds is lower than stated above because dead funds are not presented in the table). Of the 2,482 mutual funds, 1,344 are retail funds, 807 are institutional

¹¹Over the sample period, many ETFs moved from AMEX and NYSE to NYSE Arca. As of December 2010, 2 where still actively trading on NYSE while 29 have been liquidated or delisted while still trading on AMEX.

¹²www.icifactbook.org

¹³For international funds, all international funds are included except those trading mostly securities from Canada, Mexico and other Latin-American countries since trading hours in those countries overlap with US exchanges. Included are funds with the following Lipper Objective Codes: 'CH', 'EM', 'EU', 'IF', 'IS', 'JA', 'PC' and 'XJ'. International small-cap funds with objective code 'IS' are excluded from estimation stage since the late appearance of first ETF in that style leaves us with only two years of valid observation.

funds, 156 are index funds and 645 are alive during the full period (2000-2010).¹⁴

4.3 Premiums

The premium or discount on an ETF is computed as the log difference between price and net asset value:

$$premium = \log(price) - \log(NAV).$$

The intuition behind the use of premiums as a source of information lies in the nature of the input used in its computation, namely net asset value and market price. While the market price fluctuates freely with trading, the net asset value is an estimate computed following a specific formula and using a wide array of data as input. Thus, the premium can be thought of as a measure of the misalignment between the NAV and what the market believes to be the true value. Summary statistics for observed premiums are presented in Table 3. Since ETF NAV is computed the same way as unadjusted mutual fund NAV, ETF premiums provide an estimate of NAV mispricing for related mutual funds.

4.4 Matching mutual funds with ETFs and predictors

In order to test for a relationship between ETF premiums and future mutual fund NAV returns, I first match each mutual fund with an ETF within the same style. The matching is re-evaluated monthly for each mutual fund. At each matching date, I generate a list of candidate ETFs for which there is at least one year of historical observations. I then pick the match for which the correlation between same-day mutual fund NAV returns and ETF NAV returns is the highest during the previous year (excluding current month observations). The premiums of the matched ETF are used for estimating the models (using past data excluding the current month) and the state variables (for the current month). The median correlation of mutual fund and ETF monthly matches is presented by year and style in Panel A of Table 4. The quality of the matches, as measured by correlation, increases over time, as is expected since the diversity of ETFs increases.

The same strategy is applied to the selection of the other predictor. Since the different specifications for managers action in Section 3.2 have different assumptions regarding the relationship between the predictor and the observed NAV return, I use a different procedure to pick the predictor used for each. Candidate predictors are equity indices (S&P 500, Russell 2000 and Nikkei 225, all USD-based) as well as US-listed index futures on the same indices, whenever

¹⁴The retail or institutional fund status is unknown for the some funds, so they do not sum up to the total number of funds. The number of index funds might be biased downward as the index fund status is only available for funds alive on or after June 2008.

both open and close data is available from Datastream. I also include same-style ETF price returns as candidate predictors.

Under the assumption there is no adjustment to NAV by the fund manager and prices are stale, mutual fund returns should be correlated with lagged predictor returns. In the other case, I assume the manager adjusts NAV returns using the predictor, so predictor returns should be correlated with contemporaneous adjusted NAV returns. For each mutual fund, on each month, I compute the correlation of NAV returns with candidate predictor returns and lagged candidate predictor returns using one year of observations prior to the current month. For each fund and month pair, I pick the predictor that is most appropriate for each model based on the observed historical correlations. The median correlation of mutual fund with predictor and lagged predictor matches are presented by year and style in Panels B and C of Table 4. As the time period progresses, the pool of candidate predictors increases with the appearance of new ETFs. Over the sample period the contemporaneous correlation is increasing, which is consistent with an increase in active adjustment by managers, but could also be explained by the presence of “better” predictors. However, the median correlation with the lagged predictors goes down over time, suggesting that there is less predictability in mutual funds returns, even with the bigger pool of candidates. This is consistent with fund managers becoming aware of the problem and adjusting NAV for stale pricing.

4.5 Estimation

For every monthly mutual fund observation, I estimate the two specifications presented in Section 3.2. In addition, I estimate the first specification with the additional assumption that arbitrageurs do not look at ETF premiums. Each specification is calibrated independently using matched ETF premiums and predictors. Estimation of parameters is done by maximum likelihood optimization using one year of historical daily data. Estimation of state variables for the previous year and the current month is done using the estimated optimal parameters. For each model and each monthly fund observations, I keep all the estimated state variables (previous year and current month) which are used for trading strategies presented in Section 5 and 6. The initial parameters for optimization are set to the previous month optimal parameters when available. For the remainder of the text, I will refer to the specifications as follow:

- No NAV adjustment: Assumes that the fund manager reports the NAV as observed; see specification 1 in Section 3.1.2.
- NAV adjustment: Assumes that the fund manager adjusts the NAV based on the predictor; see specification 2 in Section 3.1.2.
- No NAV adjustment, no ETF premiums: Same as no NAV adjustments, but further assumes that arbitrageurs don’t look at ETF premiums.

- Best: For each monthly fund observation, chooses either “No NAV adjustment” or “NAV adjustment” according to the estimated likelihood.

Figure 1 show the median estimated η by month for the specification with no NAV adjustment. The η for all styles are decreasing over time, indicating that staleness is decreasing. This is consistent with an increase in active adjustments to NAV by mutual fund managers. Table 5 presents the median estimated η by year and style for each specification. In the results for the best specification, there is a temporary decrease in 2008 and 2009, but no discernible trend which further supports the hypothesis that mutual fund managers are actively adjusting for stale pricing. Table 6 further decomposes the result for the specification with no NAV adjustment in different subsamples: funds alive during the full period, institutional funds, retail funds and index funds. The decline in apparent staleness is present in all subsamples, so it does not appear that the results are driven by just a small subset of funds. The next section looks at return predictability in mutual fund returns due to stale pricing.

5 Predictability

To evaluate the extent of mutual fund predictability, I devise a simple yet unrealistic trading strategy¹⁵ that an hypothetical arbitrageur could use. Every day, for every pair of matched ETF and mutual fund, I follow the following rule:

- If $E[v_t^{MF}] > E[n_t^{MF*}]$, sell the ETF short and buy the mutual fund.
- If $E[v_t^{MF}] \leq E[n_t^{MF*}]$, take no position.

where $E[v_t^{MF}]$ and $E[n_t^{MF*}]$ are the estimates for each monthly fund observation. If the matched ETF for a fund changes, then the ETF position remains the same but the ETF are switched, meaning if there is a short position on the old match, then that position is closed and a new short position is taken on the new match.

This result in a zero-cost strategy with risk being partly hedged, the quality of the hedge depending on the proximity of assets under managements between the ETF and the mutual fund. The goal being to illustrate the predictive power and the extent of the NAV mispricing, I do not control for fees and trading restrictions; this simple trading strategy could not be implemented as is. The effects of fees and trading restriction are discussed in Section 6. Equal-weighted portfolios with daily rebalancing are formed for each specification for the aggregate of funds and by style groups.

Table 7 presents annualized abnormal returns and Fama-French four factor alphas of the simple trading strategy using signals from the four specifications.

¹⁵Most mutual fund won't allow daily transactions or will limit them with the use of fees.

There is strong evidence of predictability in international funds returns. Results of Table 7 show positive abnormal returns and Fama-French four factor alphas for all years and specifications except for one observation. Furthermore, most of the results for the best specification are statistically significant at the 1% level. The additional information present in ETF premiums matters; returns and α for the specification with no NAV adjustment are all larger than those for the specification with no NAV adjustment and no ETF premiums, some by over twice as much. Looking at the results obtained for the best specification, while the first two year of the sample yield larger abnormal returns and α , afterwards there is no apparent trend. This is consistent with an increase in NAV adjustments around the year 2003, when the problem of stale pricing became more widely known and at least one year prior the rule changes by the SEC. Nonetheless, while it has decreased, there is still statistically significant predictability in international mutual funds in the later part of the sample. Breaking it down by style, Table 8 shows that the strategy based on the best specification yields mostly highly statistically significant positive abnormal returns and α . The few negative returns and α are all not statistically significant at the 10% level, except for one observation which is not significant at the 5% level.

6 Fees and Trading Restrictions

Besides adjusting for fair value pricing, mutual funds can circumvent market timers by imposing fees and trading restrictions. Rear-load fees, or redemption fees, usually get smaller with time and disappear after a set period. They can effectively penalize short-term investing without harming long-run investors, aside from reducing the liquidity of their investment. However, in an investment universe that includes highly liquid ETFs, this reduction in liquidity is a factor that put mutual funds at a disadvantage. Front-load fees aren't a significant deterrent to market timers because they are usually waved for large transactions. Table 9 presents a breakdown of the number of mutual funds in the sample that charge front-load and rear-load fees.

The most frequently used trading restriction is a limit on the number of round trips (buying then selling shares) an investor can make during a year. In this section, I investigate if the predicting power of exchange traded funds is still economically significant after controlling trading restrictions and redemption fees. Management fees and expenses are also taken into account as in the previous section, but transaction fees and borrowing fees are not.

6.1 Trading Restrictions

The most common trading restriction imposed by mutual funds is a limit on the number of round trips by an investor in one year, a round trip being defined as buying and then selling shares. While one can argue that a market timer could use different strategies to mask her

identity, it is nonetheless interesting to study the effectiveness of such a rule. To illustrate the effect of this restriction, I modify the simple trading strategy, borrowing inspiration from by the wildcard option methodology introduced by Chalmers, Edelen, and Kadlec (2001). Let $s_t = E[v_t^{MF}] - E[n_t^{MF*}]$ be a daily trading signal. For every fund, I identify the 2.5% and 97.5% quantiles from the historical empirical distribution of each signal. Cut-off values are re-estimated every month using the previous 12 months estimates for each model.¹⁶ Those estimated thresholds are used to limit transactions to days when the signals are the strongest and when the expected return is the largest. The new strategy is then

- If the signal is greater than the 97.5% threshold and you have no position, sell the ETF short and buy the mutual fund.
- If the signal is smaller than the 2.5% threshold and you have a position, close your position.
- Otherwise, do nothing.

Table 10 presents annualized abnormal returns and Fama-French four factor alphas of the more realistic trading strategy using signals from the four specifications.

Two important results can be extracted from using this restricted trading strategy. First, even though round-trip restrictions reduce abnormal returns, using the best specification as a signal still yields economically (but not statistically) significant abnormal returns in all years except 2009 and positive α in all but two years. This suggests that while managers are adjusting NAV for stale pricing, their shareholders still face the risk of dilution. However, the actual dilution is likely now lower than the 0.5% to 1.15% reported by Greene and Hodges (2002) and Zitzewitz (2003). Results are similar when breaking down by style as illustrated by Table 11.

Second, as further evidence that the additional information in ETF premiums matters, abnormal returns for the strategy relying on the specification with no NAV adjustment are still all larger than those for the specification with no NAV adjustment and no ETF premiums. This means that the few trading signals generated by the 2.5% and 97.5% threshold give better predictions when ETF premiums enter the filtering problem.

6.2 Fees

Some funds use rear-load fees to deter market timing. In most cases, those fees disappear with time. One might expect funds that do not use rear-load fees as a deterrent to use some more effective form of fair pricing adjustment. To study the differences between funds that impose rear-load fees and those that do not, I separate the sample in two, the funds imposing any level of rear-load fees in the first subsample and the funds with no rear-load fees in the second

¹⁶For every fund and every month, I use the estimates of v_t^{MF} and n_t^{MF*} generated from the calibrated models for that fund month pair.

subsample.¹⁷

Table 12 is a split of Panel C of Table 4, presenting the median correlation of returns for monthly mutual fund and lagged predictor matches for each subsample. The correlation of matches appears to be very similar in both subsamples with no major differences. Table 13 presents the median estimated η for the specification with no NAV adjustment, by year and style. The median annual η are very similar for both subsample with no noticeable differences. Table 14 presents annualized abnormal returns and Fama-French four factor alphas of the simple trading strategy on those two subsamples for the four specifications. While this is not an implementable strategy, it should indicate if one group differs from the other in terms of predictability due to fair value adjustment. As before, results are similar for both subsamples.

All the results presented in this subsection fail to show any notable difference between the funds with rear-load fees and without rear-load fees. This suggests that the decision to impose rear-load fees is independent from the effort of adjusting NAV for stale pricing.

7 Conclusion

In this paper, I show that returns of open-end international equity mutual funds where predictable in the period from 2001 to 2010 and illustrate, using a simple strategy, how they can be predicted using the information contained in exchange traded funds (ETF) premiums. I also provide evidence that mutual fund managers are more active in adjusting NAV in the later part of the sample, which makes it appear less affected by staleness. However, there still remains economically significant predictability in mutual fund returns.

This paper discusses how liquid assets can be used to infer fair prices of related illiquid assets. To illustrate this idea, I presented in Section 3.2 how premiums on liquid exchange traded funds can be used for the fair valuation of mutual funds that are prone to stale prices. I showed that mutual fund managers are more active in adjusting for fair pricing in the later part of the sample, as evidenced by a decrease in correlation with lagged predictors, a decrease in apparent staleness and a decrease in return predictability.

I showed by using known predictors and ETF premiums that international mutual fund returns where predictable in the period from 2001 to 2010 and that the supplemental use of ETF premiums yields stronger predictability than other known predictors alone. I further showed that there is still economically significant predictability in international mutual fund returns after controlling for fees and trading restrictions.

A way for fund managers to get rid of the predictability illustrated in this paper would be to implement the optimal filtering solution to their problem as described in Appendix A.1.

¹⁷The sum of both is not the full sample since fee structure information is not available for all funds.

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A Kalman Filter

Let there be a linear dynamic system where the true state at time t is evolved from the state at time $t - 1$ following

$$x_t = F_t x_{t-1} + B_t u_t + w_t, \quad w_t \sim \mathcal{N}(0, Q_t) \quad (9)$$

where F_t is the state transition matrix, Q_t is the covariance of the process noise, u_t is the control vector and B_t is the control-input model.

At time t , a noisy observation z_t of the true state is made

$$z_t = H_t x_t + \nu_t, \quad \nu_t \sim \mathcal{N}(0, R_t) \quad (10)$$

where H_t is the mapping from the state space to the observed space and R_t is the covariance of the observation noise.

The Kalman filter is a recursive estimator that can be represented as a prediction stage followed by an updating stage. First, a priori estimates of the state and of the covariance are generated from the system dynamics

$$\hat{x}_{t|t-1} = F_t \hat{x}_{t-1|t-1} + B_t u_t \quad (11)$$

$$P_{t|t-1} = F_t P_{t-1|t-1} F_t^\top + Q_t \quad (12)$$

Then, the estimate is updated with the observations

$$\tilde{y}_t = z_t - H_t \hat{x}_{t|t-1} \quad (13)$$

$$S_t = H_t P_{t|t-1} H_t^\top + R_t \quad (14)$$

$$K_t = P_{t|t-1} H_t^\top S_t^{-1} \quad (15)$$

$$\hat{x}_{t|t} = \hat{x}_{t|t-1} + K_t \tilde{y}_t \quad (16)$$

$$P_{t|t} = (I - K_t H_t) P_{t|t-1} \quad (17)$$

A.1 The mutual fund managers' problem

This section presents the details about the Kalman filter used to solve the problem presented in Section 3.1.

The state dynamics are

$$\underbrace{\begin{bmatrix} v_t^{MF} \\ v_{t-1}^{MF} \end{bmatrix}}_{x_t^M} = \underbrace{\begin{bmatrix} 1 & 0 \\ 1 & 0 \end{bmatrix}}_{F^M} \underbrace{\begin{bmatrix} v_{t-1}^{MF} \\ v_{t-2}^{MF} \end{bmatrix}}_{x_{t-1}^M} + w_t^M, \quad w_t^M \sim \mathcal{N}(0, Q^M), \quad (18)$$

$$w_t^M = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \varepsilon_t^{MF}, \quad Q^M = \begin{bmatrix} \sigma_{MF}^2 & 0 \\ 0 & 0 \end{bmatrix}. \quad (19)$$

The observation equations can then be written in terms of x_t^M :

$$\underbrace{\begin{bmatrix} n_t^{MF} \\ r_t^{I-} - b_3^{I-} n_t^{MF} \\ r_t^{I+} - b_3^{I+} n_t^{MF} \\ v_t^{ETF} - n_t^{ETF} + \gamma n_t^{MF} \end{bmatrix}}_{z_t^M} = \underbrace{\begin{bmatrix} (1-\eta) & \eta \\ b_1^{I-} & b_2^{I-} \\ b_1^{I+} & b_2^{I+} \\ \gamma & 0 \end{bmatrix}}_{H^M} x_t^M + \nu_t^M, \quad \nu_t^M \sim \mathcal{N}(0, R^M), \quad (20)$$

$$\nu_t^M = \begin{bmatrix} \varepsilon_t^{n,MF} \\ \varepsilon_t^{I-} \\ \varepsilon_t^{I+} \\ \varepsilon_t^{ETF} \end{bmatrix}, \quad R^M = \begin{bmatrix} \sigma_{n,MF}^2 & 0 & 0 & 0 \\ 0 & (1-\mu)\sigma_I^2 & 0 & 0 \\ 0 & 0 & \mu\sigma_I^2 & 0 \\ 0 & 0 & 0 & \sigma_{ETF}^2 \end{bmatrix} \quad (21)$$

where the values for the $b_j^{I+/-}$ depend on β , μ and η following (7) and (8) and are presented in Table 1.

	$\mu = \eta$	$\mu > \eta$	$\mu < \eta$
b_1^{I-}	0	0	$\frac{1}{\beta} \frac{\eta - \mu}{\eta}$
b_2^{I-}	$-\frac{1}{\beta}$	$-\frac{1}{\beta} \frac{1-\mu}{1-\eta}$	$-\frac{1}{\beta}$
b_3^{I-}	$\frac{1}{\beta}$	$\frac{1}{\beta} \frac{1-\mu}{1-\eta}$	$\frac{1}{\beta} \frac{\mu}{\eta}$
b_1^{I+}	$\frac{1}{\beta}$	$\frac{1}{\beta}$	$\frac{1}{\beta} \frac{\mu}{\eta}$
b_2^{I+}	0	$-\frac{1}{\beta} \frac{\mu - \eta}{1-\eta}$	0
b_3^{I+}	$-\frac{1}{\beta}$	$-\frac{1}{\beta} \frac{1-\mu}{1-\eta}$	$-\frac{1}{\beta} \frac{\mu}{\eta}$

Table 1 Values for $b_j^{I+/-}$

A.1.1 Specification 2

In the suboptimal solution, it is assumed fund managers do not look at ETF premiums. The solution differs from the optimal solution in the following way:

$$z_t^{M2} = \begin{bmatrix} n_t^{MF} \\ r_t^{I-} - b_3^{I-} n_t^{MF} \\ r_t^{I+} - b_3^{I+} n_t^{MF} \end{bmatrix}, \quad H^{M2} = \begin{bmatrix} (1-\eta) & \eta \\ b_1^{I-} & b_2^{I-} \\ b_1^{I+} & b_2^{I+} \end{bmatrix}, \quad (22)$$

$$\nu_t^{M2} = \begin{bmatrix} \varepsilon_t^{n,MF} \\ \varepsilon_t^{I-} \\ \varepsilon_t^{I+} \end{bmatrix}, \quad R^{M2} = \begin{bmatrix} \sigma_{n,MF}^2 & 0 & 0 \\ 0 & (1-\mu)\sigma_I^2 & 0 \\ 0 & 0 & \mu\sigma_I^2 \end{bmatrix}. \quad (23)$$

A.2 Arbitragers' problem

This section presents the details about the Kalman filter used to solve the problems presented in Section 3.2. All following specifications are estimated by maximum likelihood optimization. The parameters to estimate are always: $\gamma, \mu, \eta, \beta, \sigma_{ETF}, \sigma_{n,MF}, \sigma_I$ and σ_{MF} .

A.2.1 Specification 1

To the state variable v_t^{MF} , I add one lag v_{t-1}^{MF} that appears in the observation equations, as well as n_t^{MF} , the true NAV at time (which is observed with a lag). Note that $n_t^{MF} = (1-\eta)v_t^{MF} + \eta v_{t-1}^{MF} + \varepsilon_t^{n,MF}$, which can be rewritten as $n_t^{MF} = v_{t-1}^{MF} + (1-\eta)\varepsilon_t^{MF} + \varepsilon_t^{n,MF}$. The state dynamics become

$$\underbrace{\begin{bmatrix} v_t^{MF} \\ v_{t-1}^{MF} \\ n_t^{MF} \end{bmatrix}}_{x_t^{A1}} = \underbrace{\begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}}_{F^{A1}} \underbrace{\begin{bmatrix} v_{t-1}^{MF} \\ v_{t-2}^{MF} \\ n_{t-1}^{MF} \end{bmatrix}}_{x_{t-1}^{A1}} + w_t^{A1}, \quad w_t^{A1} \sim \mathcal{N}(0, Q^{A1}), \quad (24)$$

$$w_t^{A1} = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ (1-\eta) & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^{MF} \\ \varepsilon_t^{n,MF} \end{bmatrix}, \quad Q^{A1} = \begin{bmatrix} \sigma_{MF}^2 & 0 & (1-\eta)\sigma_{MF}^2 \\ 0 & 0 & 0 \\ (1-\eta)\sigma_{MF}^2 & 0 & \sigma_{n,MF}^2 + (1-\eta)^2\sigma_{MF}^2 \end{bmatrix}, \quad (25)$$

assuming that ε_t^{MF} and $\varepsilon_t^{n,MF}$ are independant.

The observation equations can then be written in terms of x_t^{A1} :

$$\underbrace{\begin{bmatrix} v_t^{ETF} - n_t^{ETF} \\ n_{t-1}^{MF} - \eta v_{t-2}^{MF} \\ r_t^{I-} \\ r_t^{I+} \end{bmatrix}}_{z_t^{A1}} = \underbrace{\begin{bmatrix} \gamma & 0 & -\gamma \\ 0 & (1-\eta) & 0 \\ b_1^{I-} & b_2^{I-} & b_3^{I-} \\ b_1^{I+} & b_2^{I+} & b_3^{I+} \end{bmatrix}}_{H^{A1}} x_t^{A1} + \nu_t^{A1}, \quad \nu_t^{A1} \sim \mathcal{N}(0, R^{A1}), \quad (26)$$

$$\nu_t^{A1} = \begin{bmatrix} \varepsilon_t^{ETF} \\ \varepsilon_{t-1}^{n,MF} \\ \varepsilon_t^{I-} \\ \varepsilon_t^{I+} \end{bmatrix}, \quad R^{A1} = \begin{bmatrix} \sigma_{ETF}^2 & 0 & 0 & 0 \\ 0 & \sigma_{n,MF}^2 & 0 & 0 \\ 0 & 0 & (1-\mu)\sigma_I^2 & 0 \\ 0 & 0 & 0 & \mu\sigma_I^2 \end{bmatrix}. \quad (27)$$

Note that v_{t-2}^{MF} is not part of the state space, so it is subtracted in the second element of the observation. The value used for this subtraction comes from the previous period estimate x_{t-1}^{A1} .

A.2.2 Arbitragers' problem: embedded filter

This section presents the details about the Kalman filter used to solve the problem presented in Section 3.2 for which the manager is assume to solve his problem using a Kalman filter.

Let K^M , H^M and F^M denote matrices of the mutual fund manager's problem defined in Section A.1. Since I assume that the observed n_{t-1}^{MF*} for specifications 2 is the result of the mutual fund manager's problem solved with a Kalman filter, we have $v_{t-1}^{*MF} = n_{t-1}^{MF*}$ where v_t^{*MF} is the arbitrager's belief about the manager's belief of the true value.

A.2.3 Specification 2

The state dynamics are

$$\begin{aligned}
 \underbrace{\begin{bmatrix} v_t^{MF} \\ v_{t-1}^{MF} \\ n_t^{MF} \\ n_t^{MF*} \\ n_{t-1}^{MF*} \end{bmatrix}}_{x_t^{A2}} &= \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ b_t^{M2} & 0 & 0 & c_t^{M2} & 0 \\ 0 & 0 & b_{t-1}^{M2} & 0 & c_{t-1}^{M2} \end{bmatrix}}_{F_t^{A2}} \underbrace{\begin{bmatrix} v_{t-1}^{MF} \\ v_{t-2}^{MF} \\ n_{t-1}^{MF} \\ n_{t-1}^{MF*} \\ n_{t-2}^{MF*} \end{bmatrix}}_{x_{t-1}^{A2}} \\
 &+ \underbrace{\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ K_{t,(1,2)}^{M2} & K_{t,(1,3)}^{M2} & 0 & 0 \\ 0 & 0 & K_{t-1,(1,2)}^{M2} & K_{t-1,(1,3)}^{M2} \end{bmatrix}}_{B_t^{A2}} \underbrace{\begin{bmatrix} r_t^{I-} \\ r_t^{I+} \\ r_{t-1}^{I-} \\ r_{t-1}^{I+} \end{bmatrix}}_{u_t^{A2}} + w_t^{A2}, \quad w_t^{A2} \sim \mathcal{N}(0, Q^{A2}),
 \end{aligned} \tag{28}$$

where $c_t^{M2} = [1 - K_{t,(1,1)}^{M2} - K_{t,(1,2)}^{M2}(b_1^{I-} + b_2^{I-}) - K_{t,(1,3)}^{M2}(b_1^{I+} + b_2^{I+})]$ and $b_t^{M2} = K_{t,(1,1)}^{M2} - b_3^{I-} K_{t,(1,2)}^{M2} - b_3^{I+} K_{t,(1,3)}^{M2}$.

$$\begin{aligned}
 w_t^{A2} &= \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ (1-\eta) & 1 \\ b_t^{M2}(1-\eta) & b_t^{M2} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \varepsilon_t^{MF} \\ \varepsilon_t^{n,MF} \end{bmatrix}, \\
 Q^{A2} &= \begin{bmatrix} \sigma_{MF}^2 & 0 & (1-\eta)\sigma_{MF}^2 & b_t^{M2}(1-\eta)\sigma_{MF}^2 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ (1-\eta)\sigma_{MF}^2 & 0 & \sigma_{n,MF}^2 + (1-\eta)^2\sigma_{MF}^2 & b_t^{M2}(\sigma_{n,MF}^2 + (1-\eta)^2\sigma_{MF}^2) & 0 \\ b_t^{M2}(1-\eta)\sigma_{MF}^2 & 0 & b_t^{M2}(\sigma_{n,MF}^2 + (1-\eta)^2\sigma_{MF}^2) & (b_t^{M2})^2(\sigma_{n,MF}^2 + (1-\eta)^2\sigma_{MF}^2) & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix},
 \end{aligned} \tag{29}$$

The observation equations are:

$$\underbrace{\begin{bmatrix} v_t^{ETF} - n_t^{ETF} \\ n_{t-1}^{MF*} \\ r_t^{I-} \\ r_t^{I+} \end{bmatrix}}_{z_t^{A2}} = \underbrace{\begin{bmatrix} \gamma & 0 & -\gamma & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ b_1^{I-} & b_2^{I-} & b_3^{I-} & 0 & 0 \\ b_1^{I+} & b_2^{I+} & b_3^{I+} & 0 & 0 \end{bmatrix}}_{H^{A2}} x_t^{A2} + \nu_t^{A2}, \quad \nu_t^{A2} \sim \mathcal{N}(0, R^{A2}), \quad (30)$$

$$\nu_t^{A2} = \begin{bmatrix} \varepsilon_t^{ETF} \\ \varepsilon_{t-1}^{*n} \\ \varepsilon_t^{I-} \\ \varepsilon_t^{I+} \end{bmatrix}, \quad R^{A2} = \begin{bmatrix} \sigma_{ETF}^2 & 0 & 0 & 0 \\ 0 & \sigma_{*n}^2 & 0 & 0 \\ 0 & 0 & (1-\mu)\sigma_I^2 & 0 \\ 0 & 0 & 0 & \mu\sigma_I^2 \end{bmatrix}. \quad (31)$$

A.2.4 Information set without ETF premiums

Solving the problem with specification 1 while assuming that ETF premiums are not in the arbitrageur's information set is the same as in A.2 with modified observation equations where the ETF premiums are removed:

$$\underbrace{\begin{bmatrix} n_{t-1}^{MF} - \eta v_{t-2}^{MF} \\ r_t^{I-} \\ r_t^{I+} \end{bmatrix}}_{z_t^{A1'}} = \underbrace{\begin{bmatrix} 0 & (1-\eta) & 0 \\ b_1^{I-} & b_2^{I-} & b_3^{I-} \\ b_1^{I+} & b_2^{I+} & b_3^{I+} \end{bmatrix}}_{H^{A1'}} x_t^{A1'} + \nu_t^{A1'}, \quad \nu_t^{A1'} \sim \mathcal{N}(0, R^{A1'}), \quad (32)$$

$$\nu_t^{A1'} = \begin{bmatrix} \varepsilon_{t-1}^{n,MF} \\ \varepsilon_t^{I-} \\ \varepsilon_t^{I+} \end{bmatrix}, \quad R^{A1'} = \begin{bmatrix} \sigma_{n,MF}^2 & 0 & 0 \\ 0 & (1-\mu)\sigma_I^2 & 0 \\ 0 & 0 & \mu\sigma_I^2 \end{bmatrix}. \quad (33)$$

Figures and Tables

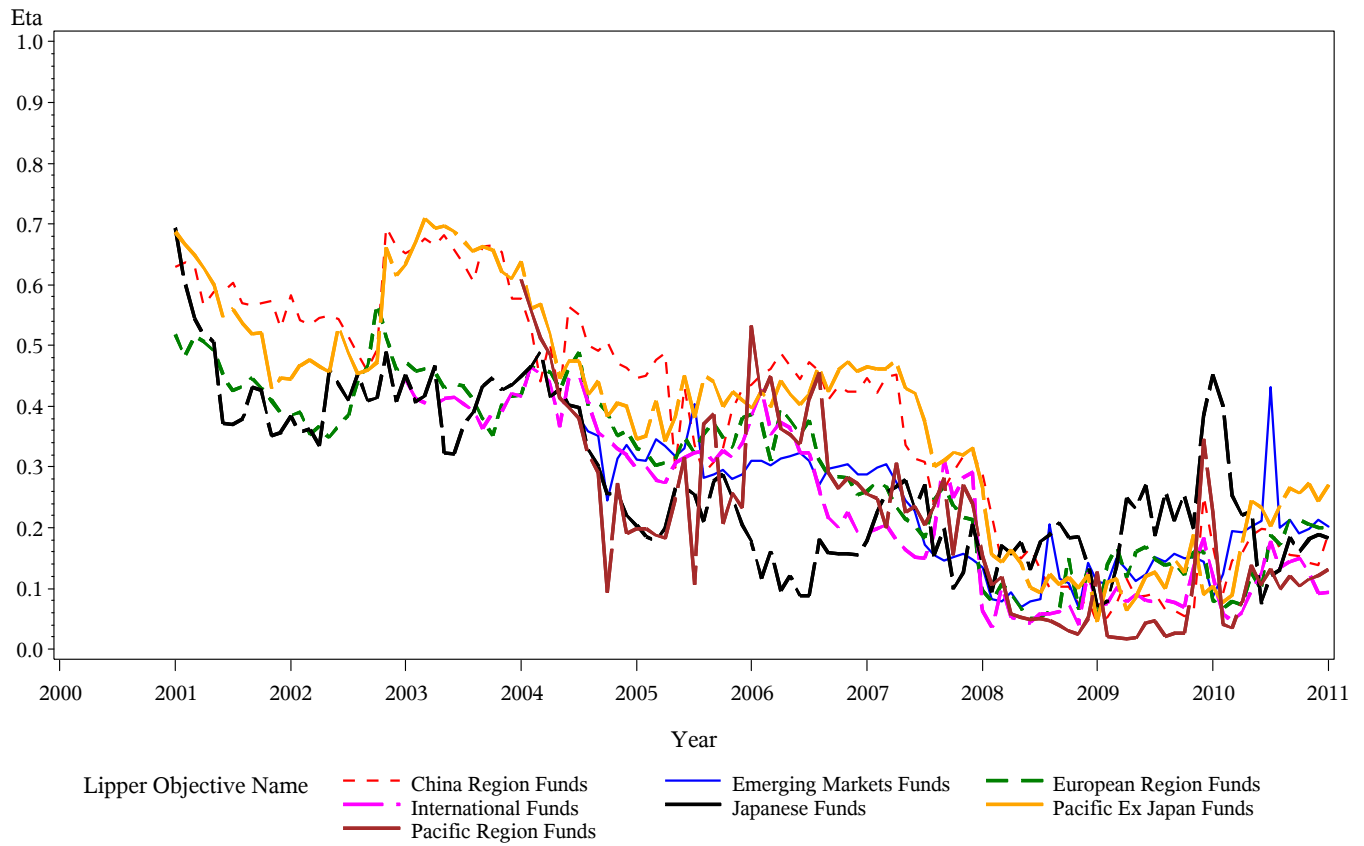


Figure 1 Median estimated η by month for the specification with no NAV adjustment, by style.

Table 2 Count and total net assets of international exchange traded funds and mutual funds by Lipper Objective according to the CRSP Survivor-Bias-Free US Mutual Fund Database as of December 31, 2010. Sample consists of ETFs and mutual funds with at least one year of returns prior to December 2010. Only mutual funds with at least \$5 millions are included. Total net assets are in \$ millions.

Style	ETFs		Mutual Funds	
	Funds	TNA	Funds	TNA
China Region Funds	21	15,819	52	9,618
Emerging Markets Funds	50	111,047	318	179,293
European Region Funds	26	9,667	64	11,999
International Funds	37	63,623	1,145	784,379
International Small-Cap Funds	3	1,348	93	41,803
Japanese Funds	10	5,318	21	838
Pacific Region Funds	5	1,675	33	9,780
Pacific Ex Japan Funds	13	18,438	30	19,000
Total	165	226,936	1,756	1,056,710

Table 3 Summary statistics for premiums computed using daily observations of international ETFs matched from the CRSP Stock Database and the CRSP Mutual Fund Database. Statistics are presented by Lipper Objective for international equity ETFs. The daily premium is defined as $premium = \log(price) - \log(NAV)$.

Style	Obs.	Mean	Std. Dev.	Min	Max
Emerging Markets Funds	29,984	0.0033	0.0160	-0.154	1.392
European Region Funds	47,411	0.0011	0.0101	-0.150	0.395
International Funds	30,044	0.0021	0.0110	-0.191	0.412
International Small-Cap Funds	2,650	0.0042	0.0130	-0.073	0.108
Japanese Funds	11,708	-0.0003	0.0150	-0.127	0.439
Pacific Region Funds	4,023	0.0012	0.0118	-0.095	0.165
Pacific Ex Japan Funds	18,300	0.0003	0.0161	-0.371	0.186

Table 4 Median correlation of returns for monthly mutual fund matches, by year and style. For each monthly mutual fund observation, a match is chosen as the one with the highest correlation in daily returns during the previous year (excluding the current month). Panel A presents ETF matches based on the correlation between same-day mutual fund returns and ETF NAV returns among ETF in the same style. Panel B presents predictors matches based on the correlation between same-day mutual fund returns and predictor returns. Panel C presents predictors matches based on the correlation between mutual fund returns and lagged predictor returns.

Panel A: Median correlation of returns for monthly mutual fund and ETF matches											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.78	0.80	0.85	0.80	0.80	0.77	0.79	0.81	0.87	0.93	0.89
Emerging Markets					0.92	0.91	0.94	0.97	0.98	0.99	0.98
European Region	0.81	0.85	0.92	0.96	0.87	0.82	0.88	0.94	0.97	0.98	0.98
International			0.62	0.60	0.82	0.84	0.89	0.91	0.95	0.98	0.98
International Small-Cap									0.67	0.89	0.87
Japanese	0.87	0.87	0.90	0.86	0.80	0.70	0.69	0.61	0.56	0.86	0.80
Pacific Region						0.86	0.86	0.89	0.94	0.97	0.93
Pacific Ex Japan	0.60	0.63	0.77	0.81	0.78	0.74	0.74	0.66	0.54	0.88	0.90
Panel B: Median correlation of returns for monthly mutual fund and predictor matches											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.41	0.49	0.53	0.51	0.63	0.68	0.71	0.78	0.88	0.95	0.92
Emerging Markets	0.43	0.54	0.54	0.50	0.67	0.69	0.83	0.88	0.93	0.96	0.96
European Region	0.32	0.77	0.81	0.82	0.77	0.78	0.85	0.91	0.94	0.97	0.96
International	0.53	0.53	0.59	0.57	0.70	0.70	0.89	0.93	0.95	0.97	0.96
International Small-Cap	0.40	0.47	0.54	0.55	0.57	0.50	0.59	0.71	0.87	0.92	0.92
Japanese	0.68	0.79	0.82	0.81	0.84	0.88	0.91	0.89	0.90	0.92	0.88
Pacific Region	0.69	0.75	0.77	0.80	0.78	0.69	0.81	0.86	0.90	0.95	0.91
Pacific Ex Japan	0.48	0.50	0.59	0.60	0.67	0.75	0.74	0.78	0.86	0.91	0.89
Panel C: Median correlation of returns for monthly mutual fund and lagged predictor matches											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.45	0.45	0.36	0.37	0.29	0.23	0.24	0.14	0.13	0.11	0.09
Emerging Markets	0.44	0.38	0.34	0.37	0.31	0.24	0.28	0.17	0.10	0.07	0.18
European Region	0.41	0.33	0.38	0.37	0.23	0.15	0.19	0.15	0.11	0.04	0.06
International	0.48	0.37	0.41	0.40	0.30	0.17	0.18	0.14	0.11	0.05	0.09
International Small-Cap	0.49	0.46	0.45	0.47	0.36	0.25	0.29	0.23	0.12	0.05	0.07
Japanese	0.38	0.35	0.33	0.27	0.23	0.11	0.08	0.07	0.13	0.05	0.07
Pacific Region	0.50	0.44	0.41	0.43	0.34	0.17	0.14	0.11	0.12	0.07	0.03
Pacific Ex Japan	0.50	0.46	0.38	0.42	0.31	0.23	0.28	0.20	0.11	0.08	0.10

Table 5 Median estimated η by style and year. Each entry represents the median estimated η from all the monthly fund observations in a given style during the year. Panel A presents results for the specification with no NAV adjustment, Panel B for the specification with no NAV adjustment and no ETF premiums, Panel C for the specification with NAV adjustment and Panel D for the best specification (highest likelihood).

Panel A: No NAV adjustment											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.64	0.60	0.55	0.65	0.51	0.44	0.44	0.36	0.04	0.04	0.16
Emerging Markets					0.34	0.33	0.25	0.17	0.02	0.06	0.20
European Region	0.52	0.43	0.40	0.41	0.46	0.32	0.33	0.23	0.01	0.14	0.15
International			0.45	0.41	0.42	0.34	0.28	0.13	0.01	0.02	0.02
Japanese	0.72	0.41	0.42	0.44	0.43	0.22	0.06	0.24	0.18	0.15	0.19
Pacific Ex Japan	0.68	0.55	0.48	0.67	0.47	0.44	0.47	0.38	0.05	0.03	0.27
Pacific Region				0.64	0.34	0.25	0.34	0.21	0.01	0.01	0.06
Panel B: No NAV adjustment, no ETF premiums											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.80	0.66	0.50	0.63	0.53	0.44	0.42	0.34	0.01	0.04	0.20
Emerging Markets					0.35	0.35	0.41	0.18	0.01	0.20	0.31
European Region	0.55	0.42	0.38	0.39	0.44	0.30	0.32	0.24	0.01	0.15	0.21
International			0.44	0.41	0.42	0.34	0.25	0.17	0.01	0.15	0.15
Japanese	0.81	0.40	0.40	0.40	0.39	0.22	0.16	0.20	0.19	0.14	0.20
Pacific Ex Japan	0.76	0.60	0.48	0.65	0.48	0.42	0.48	0.35	0.01	0.03	0.24
Pacific Region				0.61	0.38	0.34	0.32	0.21	0.01	0.05	0.09
Panel C: NAV adjustment											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.14	0.15	0.67	0.21	0.59	0.44	0.78	0.62	0.01	0.26	0.44
Emerging Markets					0.90	0.69	0.71	0.68	0.60	0.60	0.61
European Region	0.15	0.61	0.81	0.55	0.71	0.71	0.48	0.96	0.29	0.33	0.57
International			0.68	0.78	0.79	0.94	0.44	0.01	0.01	0.50	0.46
Japanese	0.01	0.01	0.02	0.07	0.29	0.34	0.28	0.31	0.35	0.01	0.09
Pacific Ex Japan	0.11	0.06	0.68	0.64	0.50	0.48	0.51	0.43	0.40	0.65	0.48
Pacific Region				0.70	0.46	0.43	0.44	0.72	0.63	0.84	0.47
Panel D: Best											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.64	0.60	0.54	0.21	0.51	0.46	0.50	0.38	0.04	0.04	0.42
Emerging Markets					0.47	0.59	0.38	0.19	0.02	0.10	0.59
European Region	0.52	0.60	0.43	0.42	0.47	0.46	0.38	0.23	0.01	0.14	0.51
International			0.35	0.41	0.48	0.51	0.30	0.08	0.01	0.03	0.45
Japanese	0.01	0.02	0.05	0.28	0.44	0.34	0.28	0.30	0.33	0.14	0.10
Pacific Ex Japan	0.23	0.58	0.51	0.64	0.48	0.43	0.48	0.40	0.05	0.04	0.28
Pacific Region				0.64	0.39	0.28	0.38	0.32	0.01	0.01	0.41

Table 6 Median estimated η by style and year for the specification with no NAV adjustment. Each entry represents the median estimated η from all the monthly fund observations in a given style during the year. Panel A presents results for funds that are alive during the full period, Panel B for funds open to retail investors, Panel C for funds open to institutional investors and Panel D for index funds.

Panel A: Full period											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.64	0.60	0.55	0.65	0.51	0.43	0.43	0.37	0.04	0.03	0.11
Emerging Markets					0.35	0.34	0.25	0.18	0.02	0.06	0.20
European Region	0.52	0.43	0.42	0.43	0.46	0.31	0.34	0.24	0.01	0.13	0.14
International			0.45	0.41	0.42	0.33	0.29	0.13	0.01	0.02	0.02
Japanese	0.68	0.38	0.39	0.40	0.38	0.03	0.03	0.24	0.13	0.14	0.18
Pacific Ex Japan	0.71	0.56	0.48	0.70	0.44	0.49	0.49	0.38	0.05	0.04	0.27
Pacific Region				0.54	0.34	0.31	0.34	0.21	0.01	0.01	0.06
Panel B: Retail											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.64	0.60	0.55	0.65	0.51	0.44	0.44	0.37	0.04	0.04	0.16
Emerging Markets					0.34	0.33	0.24	0.17	0.03	0.07	0.20
European Region	0.52	0.43	0.40	0.41	0.47	0.33	0.34	0.24	0.01	0.13	0.17
International			0.44	0.41	0.42	0.34	0.28	0.12	0.01	0.02	0.02
Japanese	0.72	0.40	0.40	0.40	0.43	0.22	0.05	0.24	0.18	0.16	0.19
Pacific Ex Japan	0.68	0.55	0.48	0.67	0.47	0.45	0.47	0.38	0.06	0.04	0.27
Pacific Region						0.60	0.34	0.18	0.01	0.01	0.06
Panel C: Institutional											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region					0.48	0.40	0.45	0.35	0.02	0.03	0.17
Emerging Markets					0.35	0.32	0.26	0.17	0.02	0.05	0.20
European Region	0.54	0.44	0.41	0.42	0.43	0.31	0.30	0.19	0.01	0.15	0.08
International			0.46	0.42	0.42	0.33	0.28	0.13	0.01	0.02	0.02
Japanese	0.72	0.45	0.44	0.46	0.41	0.23	0.16	0.20	0.16	0.05	0.19
Pacific Ex Japan	0.70	0.58	0.53	0.75	0.53	0.35	0.48	0.37	0.05	0.03	0.27
Pacific Region				0.64	0.34	0.25	0.34	0.29	0.01	0.01	0.05
Panel D: Index funds											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region									0.01	0.02	0.01
Emerging Markets					0.36	0.34	0.24	0.08	0.02	0.02	0.19
European Region	0.56	0.58	0.34	0.31	0.45	0.31	0.23	0.17	0.01	0.16	0.13
International			0.45	0.40	0.41	0.32	0.21	0.10	0.01	0.01	0.01
Japanese	0.72	0.45	0.41	0.37	0.03	0.03	0.10	0.24	0.21	0.14	0.21
Pacific Region				0.54	0.34	0.25	0.36	0.12	0.01	0.01	0.02

Table 7 Annualized equal-weighted returns and FF4 alphas obtained with a simple zero-investment strategy based on pairs of matched international ETFs and open-end mutual funds, for each specification. The daily trading rule is the following: when the estimated fundamental value of the mutual fund is higher than the expected NAV, buy a share in the mutual fund and short sell the ETF. Otherwise, take no position. These results assume no borrowing fees, trading fees or trading restrictions. T-stats are presented in parenthesis, with *, **, *** indicating significance at 10%, 5% and 1% level respectively.

Panel A: Returns										
Specification	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	61.50%	48.00%	9.10%	20.60%	20.50%	18.00%	19.60%	10.60%	8.10%	19.00%
	(5.88***)	(4.07***)	(0.95)	(3.24***)	(5.19***)	(5.08***)	(4.82***)	(1.69*)	(1.67*)	(5***)
No NAV adjustment	45.80%	44.80%	10.40%	19.60%	18.20%	17.20%	19.50%	7.20%	8.40%	14.80%
	(4.53***)	(3.71***)	(1.05)	(3***)	(4.55***)	(4.69***)	(4.73***)	(1.20)	(1.67*)	(3.87***)
NAV adjustment	50.30%	40.70%	12.10%	16.40%	19.90%	14.70%	13.10%	15.70%	14.40%	18.70%
	(5.52***)	(3.64***)	(1.47)	(3***)	(5.31***)	(4.61***)	(3.85***)	(2.09**)	(2.99***)	(4.95***)
No NAV adjustment, no ETF premiums	18.00%	22.40%	9.30%	16.50%	11.70%	13.70%	15.90%	1.90%	2.70%	11.30%
	(1.95*)	(1.93*)	(0.93)	(2.7***)	(3.36***)	(3.89***)	(3.92***)	(0.28)	(0.59)	(3.28***)
Panel B: Fama-French 4 factors α										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	59.40%	42.50%	9.80%	23.70%	21.10%	22.20%	19.00%	6.10%	10.50%	21.00%
	(6.15***)	(4.31***)	(0.99)	(4.17***)	(6.47***)	(7.04***)	(5.44***)	(1.28)	(3.07***)	(6.68***)
No NAV adjustment	42.80%	39.60%	11.30%	23.00%	18.60%	21.30%	19.70%	2.90%	10.60%	17.20%
	(4.5***)	(3.87***)	(1.10)	(3.92***)	(5.79***)	(6.54***)	(5.31***)	(0.62)	(3.07***)	(6.07***)
NAV adjustment	48.60%	34.50%	14.10%	19.00%	20.40%	18.50%	12.60%	9.60%	16.00%	20.60%
	(5.78***)	(3.69***)	(1.64)	(3.85***)	(6.43***)	(6.59***)	(4.21***)	(1.7*)	(4.14***)	(6.57***)
No NAV adjustment, no ETF premiums	14.90%	17.20%	10.00%	19.40%	12.20%	16.50%	16.00%	-2.90%	5.10%	12.80%
	(1.73*)	(1.8*)	(0.96)	(3.41***)	(4.14***)	(5.13***)	(4.15***)	(-0.59)	(1.46)	(4.48***)

Table 8 Annualized equal-weighted returns and FF4 alphas obtained with a simple zero-investment strategy based on pairs of matched international ETFs and open-end mutual funds for the best specification, by style. The daily trading rule is the following: when the estimated fundamental value of the mutual fund is higher than the expected NAV, buy a share in the mutual fund and short sell the ETF. Otherwise, take no position. These results assume no borrowing fees, trading fees or trading restrictions. T-stats are presented in parenthesis, with *, **, *** indicating significance at 10%, 5% and 1% level respectively.

Panel A: Returns										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	120.30%	124.20%	71.00%	47.00%	31.70%	40.40%	52.40%	26.80%	4.20%	15.60%
	(4.44***)	(5.79***)	(3.67***)	(4.14***)	(4.55***)	(3.37***)	(3.72***)	(2.08**)	(0.39)	(1.24)
Emerging Markets				18.50%	29.00%	39.60%	47.90%	49.60%	22.20%	26.70%
				(1.93*)	(3.53***)	(3.9***)	(4.22***)	(2.67***)	(2.51**)	(5.41***)
European Region	51.80%	47.60%	43.50%	19.40%	26.30%	16.10%	12.30%	13.20%	7.40%	28.10%
	(4.87***)	(3.64***)	(4.41***)	(3.33***)	(5.6***)	(4.31***)	(3.64***)	(2.32**)	(1.71*)	(5.69***)
International			-0.50%	19.70%	18.70%	13.30%	12.10%	2.20%	5.20%	17.10%
			(-0.05)	(2.74***)	(4.9***)	(4.41***)	(2.98***)	(0.37)	(1.06)	(4.48***)
Japanese	56.40%	35.30%	46.20%	25.40%	19.00%	6.30%	3.60%	0.40%	16.40%	-12.80%
	(3.99***)	(3.35***)	(5.12***)	(4.19***)	(4.41***)	(1.19)	(0.93)	(0.04)	(1.12)	(-1.19)
Pacific Ex Japan	74.50%	58.40%	73.70%	35.50%	7.00%	49.90%	70.50%	20.60%	-14.50%	29.80%
	(3.58***)	(2.81***)	(3.26***)	(2.54**)	(0.72)	(4.27***)	(5.76***)	(1.34)	(-1.35)	(4.9***)
Pacific Region				12.20%	0.20%	15.80%	22.00%	-7.20%	11.50%	15.70%
				(1.11)	(0.03)	(2.88***)	(4.77***)	(-1.03)	(1.95*)	(3.88***)
Panel B: Fama-French 4 factors α										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	111.90%	115.10%	87.90%	51.50%	31.50%	54.30%	58.90%	20.10%	13.00%	23.00%
	(4.3***)	(5.71***)	(5.34***)	(4.88***)	(4.81***)	(5.05***)	(4.39***)	(1.74*)	(1.32)	(1.94*)
Emerging Markets				26.50%	31.30%	48.20%	49.40%	37.00%	27.50%	29.10%
				(2.91***)	(4.38***)	(5.25***)	(5.87***)	(2.49**)	(4***)	(6.72***)
European Region	52.30%	42.40%	46.00%	22.80%	26.20%	19.20%	12.00%	10.50%	8.00%	30.00%
	(5.17***)	(3.85***)	(5.3***)	(4.44***)	(6.28***)	(5.32***)	(3.55***)	(2.08**)	(2.08**)	(6.52***)
International			-1.10%	22.70%	19.00%	16.50%	11.00%	-0.70%	7.00%	18.90%
			(-0.09)	(3.36***)	(5.63***)	(5.45***)	(2.75***)	(-0.14)	(1.78*)	(5.71***)
Japanese	49.40%	31.50%	50.60%	27.10%	19.80%	8.20%	3.50%	1.70%	16.10%	-9.00%
	(3.7***)	(3.43***)	(6.36***)	(4.62***)	(4.76***)	(1.48)	(0.88)	(0.15)	(1.09)	(-0.85)
Pacific Ex Japan	68.90%	52.40%	106.30%	43.50%	8.50%	59.50%	66.70%	16.70%	-13.20%	33.30%
	(3.36***)	(2.68***)	(4.63***)	(3.3***)	(0.95)	(5.29***)	(6.13***)	(1.12)	(-1.3)	(6.23***)
Pacific Region				15.40%	1.00%	18.50%	22.50%	-10.90%	11.90%	17.10%
				(1.43)	(0.14)	(3.57***)	(4.8***)	(-1.78*)	(2.13**)	(4.46***)

Table 9 Count and total net assets of international exchange traded funds and mutual funds by Lipper Objective according to the CRSP Survivor-Bias-Free US Mutual Fund Database as of December 31, 2010. Sample consists of ETFs and mutual funds with at least one year of returns prior to December 2010, with at least \$5 millions and with information on fee structure. Total net assets are in \$ millions. Funds with rear-loads fees are further broken down by maturity of the fees, in months.

	Front-Load Fees		Rear-Load Fees		R-L Fees > 1m		R-L Fees > 2m		R-L Fees > 6m		
Style	N	N	TNA	N	TNA	N	TNA	N	TNA	N	TNA
China Region	44	15	2,638	28	7,223	20	6,848	16	5,970	7	525
Emerging Markets	178	34	23,573	86	33,388	74	27,211	60	26,445	29	18,800
European Region	59	13	2,405	34	4,564	22	3,981	14	732	11	368
International	632	139	88,288	286	95,338	196	77,679	145	47,915	84	11,867
Japanese	18	3	24	10	515	9	511	6	494	1	9
Pacific Region	29	5	478	16	4,042	11	3,828	5	458	3	90
Pacific Ex Japan	29	6	970	20	9,081	16	7,008	12	6,877	4	302
Total	989	215	118,376	480	154,151	348	127,066	258	88,891	139	31,960

Table 10 Annualized equal-weighted returns and FF4 alphas obtained with a simple zero-investment strategy based on pairs of matched international ETFs and open-end mutual funds, for each specification. The daily trading rule is the following: when the difference between the estimated true value and the expected NAV is larger than the higher threshold, buy a share in the mutual fund and short sell the ETF (or keep that position). When the difference between the estimated true value and the expected NAV is smaller than the lower threshold, close the position (or keep no position). Otherwise, keep current position. Signal thresholds are evaluated monthly using daily filtered estimations from the previous year and are set to the 2.5% and 97.5% percentiles of the empirical distribution. These results assume no borrowing fees or trading fees. T-stats are presented in parenthesis, with *, **, *** indicating significance at 10%, 5% and 1% level respectively.

Panel A: Returns										
Specification	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	11.70%	4.70%	2.80%	3.80%	5.40%	4.70%	4.10%	1.60%	-0.80%	1.50%
	(1.38)	(0.49)	(0.37)	(1.09)	(1.71*)	(1.14)	(1.05)	(0.29)	(-0.21)	(0.35)
No NAV adjustment	12.20%	4.10%	3.00%	3.10%	5.20%	6.30%	4.40%	1.60%	-1.00%	1.80%
	(1.46)	(0.43)	(0.37)	(1.09)	(1.63)	(1.54)	(1.16)	(0.29)	(-0.29)	(0.61)
NAV adjustment	7.80%	4.90%	0.60%	2.40%	4.80%	2.50%	3.70%	1.90%	-1.20%	1.30%
	(0.94)	(0.51)	(0.15)	(0.62)	(1.51)	(0.60)	(0.92)	(0.28)	(-0.2)	(0.30)
No NAV adjustment, no ETF premiums	8.10%	1.60%	2.80%	3.10%	3.10%	5.60%	3.60%	1.40%	-2.30%	0.80%
	(1.11)	(0.17)	(0.35)	(0.96)	(0.94)	(1.39)	(0.89)	(0.23)	(-0.47)	(0.23)
Panel B: Fama-French 4 factors α										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	8.40%	-0.70%	2.70%	5.40%	6.00%	9.40%	4.10%	-2.80%	0.90%	4.30%
	(1.05)	(-0.09)	(0.35)	(1.62)	(2.21**)	(2.76***)	(1.11)	(-0.7)	(0.36)	(1.29)
No NAV adjustment	10.00%	-1.00%	3.00%	4.30%	5.70%	10.60%	4.50%	-2.90%	0.40%	3.30%
	(1.24)	(-0.14)	(0.35)	(1.57)	(2.15**)	(3.07***)	(1.26)	(-0.75)	(0.17)	(1.67*)
NAV adjustment	3.50%	0.20%	0.90%	4.40%	5.60%	7.20%	3.70%	-3.30%	2.70%	4.10%
	(0.46)	(0.03)	(0.24)	(1.25)	(2.06**)	(2.09**)	(1.00)	(-0.62)	(0.71)	(1.23)
No NAV adjustment, no ETF premiums	4.60%	-3.40%	2.80%	4.90%	3.70%	9.40%	3.50%	-3.40%	0.90%	2.50%
	(0.67)	(-0.44)	(0.33)	(1.65)	(1.40)	(2.76***)	(0.89)	(-0.81)	(0.26)	(0.95)

Table 11 Annualized equal-weighted returns and FF4 alphas obtained with a simple zero-investment strategy based on pairs of matched international ETFs and open-end mutual funds for the best specification, by style. The daily trading rule is the following: when the difference between the estimated true value and the expected NAV is larger than the higher threshold, buy a share in the mutual fund and short sell the ETF (or keep that position). When the difference between the estimated true value and the expected NAV is smaller than the lower threshold, close the position (or keep no position). Otherwise, keep current position. Signal thresholds are evaluated monthly using daily filtered estimations from the previous year and are set to the 2.5% and 97.5% percentiles of the empirical distribution. These results assume no borrowing fees or trading fees. T-stats are presented in parenthesis, with *, **, *** indicating significance at 10%, 5% and 1% level respectively.

Panel A: Returns										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	9.80%	22.30%	6.30%	0.80%	2.10%	9.40%	4.20%	9.70%	2.30%	-2.40%
	(0.53)	(1.32)	(0.38)	(0.15)	(0.33)	(0.83)	(0.36)	(1.03)	(0.16)	(-0.16)
Emerging Markets				3.10%	10.80%	9.50%	12.90%	8.40%	0.30%	0.10%
				(0.40)	(1.37)	(0.73)	(1.43)	(0.54)	(0.06)	(0.02)
European Region	7.90%	2.20%	1.50%	1.90%	6.50%	7.10%	0.90%	2.00%	1.50%	3.10%
	(1.01)	(0.19)	(0.23)	(0.41)	(1.93*)	(2.27**)	(0.36)	(0.38)	(0.34)	(0.53)
International			2.50%	4.20%	5.00%	2.60%	1.70%	-0.30%	-1.60%	1.10%
			(0.28)	(1.07)	(1.63)	(0.82)	(0.39)	(-0.05)	(-0.42)	(0.28)
Japanese	10.50%	5.20%	10.40%	3.00%	6.10%	-2.20%	1.70%	-9.00%	2.10%	-4.90%
	(0.74)	(0.50)	(1.18)	(1.09)	(1.71*)	(-0.44)	(0.49)	(-0.81)	(0.18)	(-0.42)
Pacific Ex Japan	17.60%	10.10%	2.80%	-0.30%	-8.10%	24.70%	22.20%	11.70%	-6.70%	3.90%
	(0.80)	(0.56)	(0.21)	(-0.06)	(-0.98)	(1.97*)	(1.87*)	(0.86)	(-0.53)	(0.58)
Pacific Region				-2.30%	-13.00%	8.10%	9.50%	-4.00%	6.20%	4.10%
				(-0.63)	(-1.49)	(1.34)	(2.38**)	(-0.57)	(0.95)	(0.88)
Panel B: Fama-French 4 factors α										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	5.50%	15.10%	17.20%	2.80%	2.30%	24.60%	11.70%	5.10%	11.50%	9.70%
	(0.32)	(1.01)	(1.34)	(0.56)	(0.40)	(2.4**)	(1.08)	(0.60)	(0.95)	(0.76)
Emerging Markets				7.70%	13.70%	25.70%	15.60%	-2.40%	1.70%	3.20%
				(1.04)	(1.98**)	(2.36**)	(2.09**)	(-0.2)	(0.51)	(0.71)
European Region	4.80%	-3.10%	3.10%	4.40%	6.60%	9.80%	0.60%	-0.50%	2.20%	5.90%
	(0.63)	(-0.35)	(0.53)	(1.03)	(2.19**)	(3.3***)	(0.22)	(-0.12)	(0.54)	(1.16)
International			1.10%	5.70%	5.10%	4.80%	0.90%	-3.30%	0.10%	3.30%
			(0.12)	(1.53)	(1.8*)	(1.59)	(0.20)	(-0.7)	(0.02)	(1.07)
Japanese	4.00%	1.20%	13.60%	2.50%	6.60%	-0.50%	2.30%	-8.10%	3.50%	-0.50%
	(0.30)	(0.14)	(1.76*)	(0.94)	(1.93*)	(-0.09)	(0.64)	(-0.71)	(0.28)	(-0.05)
Pacific Ex Japan	17.10%	4.50%	18.30%	1.80%	-6.10%	36.60%	22.50%	7.40%	-5.70%	8.00%
	(0.77)	(0.27)	(1.38)	(0.36)	(-0.77)	(3.23***)	(2.07**)	(0.57)	(-0.48)	(1.47)
Pacific Region				-1.80%	-10.00%	13.30%	9.50%	-6.70%	5.00%	5.60%
				(-0.49)	(-1.22)	(2.32**)	(2.36**)	(-1.03)	(0.82)	(1.27)

Table 12 Median correlation of returns for monthly mutual fund matches with lagged predictors, by year and style. For each monthly mutual fund observation, a match is chosen as the one with the highest correlation during the previous year (excluding the current month) between mutual fund returns and lagged predictor returns. Panel A presents funds without rear-load fees while Panel B presents funds with rear-load fees.

Panel A: No rear-load fees											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.48	0.53	0.38	0.36	0.31	0.21	0.23	0.16	0.14	0.11	0.11
Emerging Markets	0.44	0.38	0.34	0.37	0.31	0.24	0.28	0.18	0.10	0.06	0.19
European Region	0.40	0.33	0.37	0.36	0.24	0.15	0.19	0.16	0.10	0.04	0.07
International	0.49	0.37	0.41	0.40	0.30	0.18	0.18	0.14	0.10	0.04	0.09
International Small-Cap	0.49	0.46	0.45	0.48	0.38	0.26	0.31	0.24	0.12	0.05	0.08
Japanese	0.38	0.34	0.34	0.31	0.24	0.11	0.08	0.10	0.13	0.04	0.08
Pacific Region	0.50	0.44	0.40	0.44	0.35	0.17	0.13	0.11	0.11	0.07	0.03
Pacific Ex Japan	0.50	0.46	0.38	0.40	0.28	0.19	0.25	0.17	0.11	0.08	0.11
Panel B: With rear-load fees											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.41	0.41	0.35	0.38	0.28	0.24	0.24	0.14	0.13	0.10	0.09
Emerging Markets	0.44	0.37	0.34	0.35	0.31	0.25	0.28	0.16	0.10	0.06	0.18
European Region	0.41	0.32	0.38	0.38	0.22	0.17	0.19	0.15	0.10	0.04	0.06
International	0.48	0.37	0.40	0.40	0.29	0.16	0.17	0.14	0.11	0.05	0.09
International Small-Cap	0.50	0.47	0.44	0.47	0.35	0.26	0.29	0.24	0.12	0.04	0.07
Japanese	0.39	0.37	0.33	0.25	0.23	0.12	0.07	0.06	0.14	0.07	0.08
Pacific Region	0.52	0.45	0.41	0.42	0.29	0.14	0.14	0.11	0.12	0.07	0.03
Pacific Ex Japan	0.50	0.44	0.38	0.43	0.33	0.26	0.30	0.22	0.12	0.08	0.10

Table 13 Median estimated η by style and year. Each entry represents the median estimated η from all the monthly fund observations in a given style during the year, for the specification with no NAV adjustment. Panel A presents funds without rear-load fees while Panel B presents funds with rear-load fees.

Panel A: No rear-load fees											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.64	0.61	0.57	0.68	0.52	0.41	0.41	0.38	0.04	0.05	0.21
Emerging Markets					0.34	0.33	0.25	0.17	0.02	0.05	0.20
European Region	0.53	0.42	0.40	0.41	0.47	0.32	0.33	0.22	0.01	0.14	0.17
International			0.45	0.41	0.43	0.33	0.29	0.13	0.01	0.01	0.02
Japanese	0.73	0.41	0.44	0.48	0.43	0.23	0.20	0.24	0.19	0.16	0.19
Pacific Ex Japan	0.68	0.55	0.47	0.66	0.46	0.35	0.43	0.36	0.06	0.05	0.26
Pacific Region				0.54	0.34	0.32	0.34	0.20	0.01	0.01	0.02
Panel B: With rear-load fees											
Style	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China Region	0.63	0.59	0.54	0.63	0.50	0.45	0.46	0.37	0.03	0.04	0.17
Emerging Markets					0.35	0.34	0.23	0.17	0.03	0.07	0.20
European Region	0.51	0.43	0.40	0.41	0.46	0.33	0.34	0.25	0.01	0.15	0.12
International			0.45	0.41	0.43	0.34	0.28	0.12	0.01	0.02	0.02
Japanese	0.69	0.41	0.41	0.40	0.44	0.22	0.03	0.22	0.18	0.16	0.19
Pacific Ex Japan	0.68	0.55	0.49	0.69	0.48	0.48	0.49	0.38	0.05	0.03	0.27
Pacific Region				0.64	0.35	0.24	0.33	0.22	0.01	0.01	0.09

Table 14 Annualized equal-weighted returns and FF4 alphas obtained with a simple zero-investment strategy based on pairs of matched international ETFs and open-end mutual funds, for each specification. The daily trading rule is the following: when the estimated fundamental value of the mutual fund is higher than the expected NAV, buy a share in the mutual fund and short sell the ETF. Otherwise, take no position. These results assume no borrowing fees, trading fees or trading restrictions. Panel A and B (C and D) present returns (FF4 alphas) for funds without rear-load fees and with rear-load fees respectively. T-stats are presented in parenthesis, with *, **, *** indicating significance at 10%, 5% and 1% level respectively.

Panel A: No rear-load fees (Returns)										
Specification	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	60.90%	50.10%	8.20%	21.10%	21.10%	17.90%	19.60%	12.30%	10.10%	19.60%
	(5.86***)	(4.2***)	(0.83)	(3.2***)	(5.25***)	(4.98***)	(4.88***)	(1.9*)	(1.98**)	(5.18***)
No NAV adjustment	46.80%	45.00%	9.80%	19.70%	18.70%	17.20%	19.80%	8.10%	10.50%	15.30%
	(4.62***)	(3.71***)	(0.97)	(2.93***)	(4.59***)	(4.69***)	(4.83***)	(1.31)	(1.99**)	(4.03***)
NAV adjustment	50.60%	43.00%	11.20%	16.60%	20.40%	14.10%	12.90%	17.50%	15.50%	19.10%
	(5.62***)	(3.78***)	(1.33)	(2.96***)	(5.37***)	(4.4***)	(3.81***)	(2.3**)	(3.12***)	(5.09***)
No NAV adjustment, no ETF premiums	17.90%	21.00%	9.10%	16.90%	11.70%	13.80%	16.30%	2.20%	4.00%	11.80%
	(1.94*)	(1.82*)	(0.89)	(2.67***)	(3.3***)	(3.9***)	(4.02***)	(0.33)	(0.81)	(3.41***)
Panel B: With rear-load fees (Returns)										
Specification	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	63.00%	50.10%	12.80%	21.50%	20.60%	19.30%	21.50%	10.90%	6.70%	20.40%
	(5.7***)	(4.02***)	(1.41)	(3.51***)	(5.1***)	(5.24***)	(5.16***)	(1.8*)	(1.40)	(5.05***)
No NAV adjustment	48.30%	47.50%	13.70%	20.80%	18.40%	18.40%	21.10%	8.00%	6.90%	16.50%
	(4.52***)	(3.72***)	(1.47)	(3.32***)	(4.54***)	(4.83***)	(4.97***)	(1.37)	(1.39)	(4.06***)
NAV adjustment	49.30%	42.80%	15.90%	17.80%	20.10%	16.90%	15.50%	14.50%	13.40%	20.20%
	(5.18***)	(3.65***)	(2**)	(3.31***)	(5.22***)	(5.07***)	(4.3***)	(1.93*)	(2.8***)	(5***)
No NAV adjustment, no ETF premiums	19.70%	25.40%	10.90%	17.00%	11.90%	13.90%	16.90%	1.30%	1.80%	12.00%
	(2.01**)	(2.06**)	(1.18)	(2.92***)	(3.34***)	(3.81***)	(4.06***)	(0.19)	(0.38)	(3.26***)
Panel C: No rear-load fees (Fama-French 4 factors α)										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	58.50%	44.30%	8.70%	24.30%	21.70%	22.20%	19.00%	7.60%	12.30%	21.70%
	(6.11***)	(4.49***)	(0.85)	(4.07***)	(6.54***)	(6.92***)	(5.48***)	(1.57)	(3.49***)	(6.99***)
No NAV adjustment	43.80%	39.60%	10.40%	23.10%	19.10%	21.30%	19.80%	3.60%	12.60%	17.70%
	(4.59***)	(3.88***)	(0.98)	(3.78***)	(5.82***)	(6.48***)	(5.37***)	(0.76)	(3.54***)	(6.35***)
NAV adjustment	48.30%	36.50%	13.00%	19.30%	20.90%	18.10%	12.40%	11.40%	16.90%	21.10%
	(5.84***)	(3.87***)	(1.48)	(3.76***)	(6.51***)	(6.36***)	(4.17***)	(1.98**)	(4.25***)	(6.85***)
No NAV adjustment, no ETF premiums	14.80%	15.80%	9.60%	19.80%	12.20%	16.60%	16.20%	-2.40%	6.40%	13.40%
	(1.71*)	(1.66*)	(0.90)	(3.35***)	(4.08***)	(5.08***)	(4.22***)	(-0.48)	(1.74*)	(4.68***)
Panel D: With rear-load fees (Fama-French 4 factors α)										
Style	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Best	60.80%	44.10%	14.40%	24.80%	21.00%	23.60%	21.10%	6.50%	9.20%	22.80%
	(5.98***)	(4.23***)	(1.54)	(4.64***)	(6.39***)	(7.32***)	(5.97***)	(1.42)	(2.79***)	(6.89***)
No NAV adjustment	44.70%	41.70%	15.40%	24.40%	18.80%	22.60%	21.50%	3.70%	9.30%	19.20%
	(4.49***)	(3.86***)	(1.60)	(4.44***)	(5.84***)	(6.81***)	(5.67***)	(0.83)	(2.78***)	(6.47***)
NAV adjustment	47.30%	36.10%	18.70%	20.50%	20.60%	20.70%	15.20%	8.40%	15.20%	22.50%
	(5.45***)	(3.69***)	(2.31**)	(4.34***)	(6.36***)	(7.13***)	(4.85***)	(1.50)	(4.07***)	(6.72***)
No NAV adjustment, no ETF premiums	16.20%	19.70%	12.30%	19.90%	12.30%	16.80%	17.10%	-3.70%	4.20%	13.80%
	(1.77*)	(1.95*)	(1.28)	(3.76***)	(4.11***)	(5.13***)	(4.39***)	(-0.75)	(1.21)	(4.68***)