NORTH-HOLLAND

International Review of Financial Analysis
10 (2001) 365–394

IRFA
INTERNATIONAL REVIEW OF
Financial Analysis

A contingent claim analysis of closed-end fund premia

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Abstract

We estimate contingent claims that replicate monthly net asset value (NAV) payoffs from closed-end funds. A claim's theoretical value is obtained by martingale pricing methods. The resulting net present value (NPVS) sequence is the theoretical premia sequence that is compared to the actual market premia sequence. The theoretical premia, like actual premia, are uncorrelated with NAV returns and are positively autocorrelated due to autocorrelation in the pricing information. However, there is poor correspondence between the theoretical and actual premia that seems due to the market's systematic errors in estimating a fund's management value. Risky arbitrage may be available to insiders. © 2001 Elsevier Science Inc. All rights reserved.

JEL classification: G11; G13; G14

Keywords: Risk-neutral pricing; Closed-end funds; Performance measurement; Arbitrage

1. Introduction

A difference between closed- and open-end funds is that management value is priced only in closed-end funds. This difference reflects the long-standing view that management

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PII: S1057-5219(01)00059-X

trading strategies can create or deplete the value that is reflected in the fund's premia (Boudreaux, 1973; Chay & Trzcinka, 1999; Malkiel, 1977). An alternative view is that a fund's net asset value (NAV) is an accurate measure of fundamental value (Klibanoff, Lamont, & Wizman, 1998, for example). If managed portfolios exist because they dynamically complete the available set of investments, then closed-end funds ought to sell at a premium to NAV. On the contrary, the premia are generally negative, which implies that the funds may be priceable with existing traded assets. In this research, we estimate the value of closed-end fund management via a NAV replicating claim that is contingent upon the values of traded style portfolios.

Research on closed-end fund premia has focused primarily on determining the causes of the observed premia via related factors.[1] Bodurtha, Kim, and Lee (1995) and Lee, Shleifer, and Thaler (LSR, 1991) explain the premia via investor sentiment arguments. Barclay, Clifford, Holderness, and Pontiff (1993), Brauer (1984), Brauer and Chang (1990), Brickley, Manaster, and Schallheim (1991), Malkiel (1995), and Pontiff (1994, 1995, 1996), investigate the premia due to market imperfections that include; portfolio liquidity, bid–ask spreads, incorrectly reported NAVs, tax effects, arbitrage costs, management expenses, management control, and open-ending restrictions. In searching for causality, previous research did not estimate the theoretical value of management's trading strategy for an individual fund. Because of a lack of an accepted valuation of closed-end funds, there is a continuing debate as to whether the management value hypothesis is true.

Here, we utilize derivative pricing methods to impute closed-end fund values using a similar procedure as Glosten and Jagannathan (GJ, 1994, 1988). GJ used splines applied to mutual funds, whereas, we utilize polynomials applied to closed-end funds and a risk-neutral probability measure. Application of the procedure permits a comparison of the theoretical valuations to the market prices of the closed-end funds.

2. Overview

If closed-end fund investors are exposed to the risk and return that arises from fund management's trading strategy and if the trading strategy is estimable in advance, the market can price the contingent claim that replicates the strategy's payoffs. The difference in the claim's price and the fund's NAV represents the net present value (NPV) of the trading strategy or its theoretical premium. Therefore, the theoretical premia should be equal to the observed premia across funds.

We estimate a contingent claim that closely replicates the monthly NAV payoffs from a closed-end fund. The market must estimate the replicating claim at the close of each month thereby presenting an extra source of risk that may be priced due to its nondiversifiability. To

[1] A closed-end fund premium is defined as the difference between the market price and the fund's net asset value expressed as a fraction of net asset value.

determine our results' sensitivity to potential estimation error, we estimate the contingent claim both in and out of sample. In-sample estimation uses all of a fund's available NAV data sequence, whereas the out-of-sample estimation begins with a 48-month moving window that is employed to estimate a NAV replicating claim for the 49th month. The remotest month is eliminated, the nearest month is added to the window, the replicating claim is reestimated, and so on. In general, similar conclusions follow from either approach but estimation statistics differ.

A quadratic regression function of the returns from five style portfolios is fit to the observed NAV returns on each individual fund. The claim's payoffs are a nonlinear function of the payoffs from a subset of a 1-month T-bill, a long government bond portfolio, a small-, a medium-, and a large-size portfolio. These five portfolios were chosen for their simplicity and so that they span the mean-variance portfolios generated by the five portfolios plus any fund's NAV portfolio.[2] The goodness of fit of a claim's payoffs is measured by the regression R^2, which averages .85 across funds in the LST data set and averages .77 in our second data set from Malkiel (1995). The spanning and relatively large R^2 imply that the replicating claim is quite close to the NAV in mean-variance space as well as in return space; although, an R^2 less than one may imply some "fundamental risk" (Shleifer & Summers, 1990) and claim estimation error.

Because our data interval is monthly, we are interested in the total value of a fund's trading strategy at the beginning of each month within the sample period. Using the NAV regression, the replicating claim's dollar payoff expression is determined. Under the assumption that index prices are log-normal diffusions within the month, the value expression for the claim is obtained by martingale pricing methods.[3] One of the nice features of the martingale price is that it is derived from no arbitrage conditions on the actual NAV payoffs and the payoffs from the dynamic replicating portfolio. If the theoretical price is not equal to the actual NAV, arbitrage profits are available. Because the replicating claim does not fit exactly, the arbitrage is risky.

The theoretical claim value is a function of the regression coefficients, the T-bill rate, and the conditional volatilities for the bond and the three equity-size portfolios. These volatilities are estimated as GARCH(1,1) processes. The theoretical premium or NPV is calculated by subtracting one from the theoretical claim value.

Even with these parsimonious models, the R^2 fit is surprisingly good. As in GJ, we assume that the portion of returns, not contained within the space spanned by the style portfolios, is not priced. As compensation for lack of fit, we impose an adjustment that shrinks the theoretical premia toward zero. That is, the absolute size of the theoretical premia is reduced for funds with NAVs that are not closely replicable thereby reducing a fund's theoretical absolute management value and its influence in the sample. In addition, we use

[2] There is a trade-off between overfitting the data and poor out-of-sample performance. We adopt the principles in Lo and MacKinlay (1990) and select a small and simple set of spanning portfolios.

[3] The most popular procedure for pricing derivatives and contingent claims uses martingale theory. The method is used throughout theoretical finance and in practice, even though the most widely used method requires the assumption that markets are complete.

the time series averages of each fund's premia in order to reduce the effect of each fund's nonpriced component.

The calculated NPV sequence (NPVS) is compared to the sequence of actual market premia on the fund. The hypothesis is that the observed market premia should closely correspond with the theoretical NPVS of the replicating claim. We find that the correspondence is consistent with market efficiency on some dimensions but lacking on others. The sequence of theoretical premia has many similarities to the sequence of actual premia. The theoretical values are uncorrelated with future NAV returns just as are the actual observed premia. In addition, the theoretical premia are highly autocorrelated as is true with actual premia (Pontiff, 1995; Thompson, 1978). A plausible explanation of the autocorrelation is that the pricing inputs, being the T-bill rate and the style volatilities, are autocorrelated. Whereas the actual premia are negatively correlated with future price returns, the theoretical premia have the desirable rationality property of being uncorrelated with the future price returns.

The market has difficulty determining which funds to discount and by how much. A market efficiency issue is whether the lack of correspondence is due to the market's systematic errors in estimating a fund's NAV replicating claim. Indeed, we find that the lack of correspondence appears to be due to biased and autocorrelated errors in the market's estimation of fund management value.

Prior closed-end fund literature discusses the potential for arbitrage between the fund's *price* and the fund's NAV as well as the potential for abnormal return from the premia signals. Much of the literature asserts that the lack of knowledge of a manager's trading strategy and the lack of timely knowledge of the NAV portfolio's composition precludes a costless arbitrage strategy.[4] Here, we provide a NAV replicating claim that facilitates arbitrage because the claim's composition is known; whereas in prior work, the NAV portfolio's composition is unknown. In addition, our attainable replicating claim provides the market with a means to arbitrage between a close replica of the NAV returns and the fund's NAV returns and not necessarily between the fund's NAV returns and the fund's price movements. If the fund's price and premia are unrelated to the NAV return in a noisy market, there will be no opportunity for short run arbitrage between the fund's price and its NAV. Our sequence of NPVS has the desirable quality of being the theoretical profits that would arise from a $1 arbitrage position between the NAV replicating claim and the fund's NAV portfolio thereby avoiding the problem of a noisy price.

If the theoretical price and NAV are different, then arbitrage between the replicating claim and the NAV is possible; we document the evidence for this type of arbitrage. If the NAV composition is known only to a fund's insiders, the arbitrage opportunity is available solely to them.

To investigate profitable investment opportunities to outsiders, we sequentially compare the theoretical and actual premia and construct a self-financing portfolio that is either long the

[4] See the discussion in Barclay et al (1993).

fund and short the claim, if the theoretical premium exceeds the actual premium, or vice versa. The portfolio is held for 1 month and then reevaluated. Also, we examine the benefits from the self-financing portfolio that is long a fund and short its NAV replicating claim, irrespective of the premia. In order to avoid the well-known difficulties of interpreting returns on risky self-financing portfolios, we do not evaluate the portfolios in isolation of the market index. We determine if an optimal self-financing portfolio overlay onto the equity index improves the index. We find a small improvement from a fund overlay but one must know the amount of the optimal overlay to obtain the improvements. A portfolio that uses an arbitrarily fixed amount of an overlay shows an insignificant benefit above simply holding the index portfolio, for most funds.

Section 3 presents summary data on the funds. Section 4 presents the estimation results of the NAV replicating claims, the estimation of the theoretical premia, and the comparison with actual premia. Rational markets and the potential for profitable investment strategies between the fund and the replicating claim are examined in Section 5.

3. The premia data and some properties

Two sets of data are analyzed. The first set (Set A) is originally from LST and later corrected in Chen, Miller, and Kan (1993).[5] The second set (Set B) was derived from Malkiel (1995). In Set A, we selected the same set of equity funds that was used in the LST monthly study and in Set B, we selected all of Malkiel's funds that were listed in Barrons.[6] The data period is from July 31, 1965 to December 31, 1991 for Set A funds and from October 31, 1980 to December 31, 1996 for Set B funds; but, individual funds may not have data covering an entire period. All other data are from the CRSP data files.

Table 1A and B provide some premia summary statistics that are germane to our subsequent analysis.[7] A premium is defined as the difference between price per share and NAV per share, divided by the NAV per share. The number of monthly observations varies from 2 to 317 across the 21 Set A funds and from 33 to 194 months across the 27 Set B funds. Funds marked with an a are omitted in subsequent analyses because of insufficient observations or because of an inability to model their payoffs with a simple set of spanning portfolios. To facilitate comparisons with subsequent tables, the average fund statistics at the bottom of the panel exclude these marked funds.

Fund average premia are negative and volatile but average premia vary substantially across funds. Premia have a large first-order autocorrelation for every fund. On average, funds' premia are uncorrelated with future 1-month NAV returns but this varies from +.36 to − .14 across the Set A funds and from .30 to − .27 across the Set B funds. Premia are negatively related to future fund price returns with only two exceptions.

[5] The original data was supplied to us by Charles Lee and the corrected file was provided by Raymond Kan.

[6] The beginning date of 10/31/80 was the approximate start of the Barrons' closed-end fund publication date. We have 27 funds versus 30 funds in the Malkiel set.

[7] A more detailed discussion of the Set A raw data series can be found in the LST study.

Table 1
Summary statistical properties of the closed-end funds' actual premia

Funds	Number of observations	Fund premia statistical properties: Mean	S.D.	Autocorrelation lag 1	Correlation with NAV return	Correlation with fund return	ARIMA model $(p,d,q)(P,D,Q)$	Coefficients estimates
(A) Overall data period: July 31, 1965 to December 31, 1990								
1. ASA[a]	284	−0.9447	0.5997	.9419	−.0411	−.1213	(0,1,0)	
2. Abacus Fund	35	−0.1422	0.0365	.7321	−.0101	−.2461	(1,0,0)	.757
3. Adams Express	311	−0.1111	0.0714	.8611	.0025	−.2163	(0,1,1)	.390
4. Advance Investors	30	−0.2100	0.0590	.6278	.0685	−.3004	(0,1,1)	.443
5. American International	38	−0.1305	0.0380	.7735	.3553	.2254	(0,1,0)	
6. Carriers and General	147	−0.1681	0.0470	.7382	−.0536	−.3441	(1,0,0)	.768
7. Central Securities	225	−0.2249	0.0960	.9328	.0778	−.0750	(0,1,1)	.461
8. Dominik Fund	102	−0.1645	0.0918	.9191	−.0527	−.2229	(0,1,1)	.279
9. Eurofund International[a]	63	−0.1563	0.1078	.7832	.1310	−.2068	(1,1,0)	−.417
10. General American Investors	313	−0.1055	0.0965	.9249	−.0555	−.1869	(0,1,1)	.371
11. MA Hanna[a]	2	−0.2731	0.0028					
12. International Holdings	110	−0.1930	0.0808	.8755	−.1353	−.3137	(0,1,0)(0,0,1)	−.359
13. Japan Fund[a]	248	−0.1109	0.1642	.9217	.1401	−.0708	(0,1,1)(0,0,2)	.297, −.159, −.178
14. Lehman Corp.	308	−0.0962	0.1188	.9590	−.0085	−.1205	(0,1,0)(1,0,0)	.263
15. Madison Resources	213	−0.0757	0.2244	.9789	−.0867	−.1669	(1,1,0)	−.175
16. Niagara Shares	315	−0.0706	0.1018	.9192	−.0659	−.2256	(0,1,1)(0,0,1)	.388, −.141
17. Petroleum and Resources Corp.	311	−0.0432	0.0637	.8145	−.0345	−.2344	(1,0,1)	.887, .206
18. Surveyor Fund	58	−0.0906	0.1261	.9424	−.0638	−.1751	(0,1,0)	
19. Tricontinental	317	−0.1426	0.0832	.9276	.0624	−.0995	(0,1,1)(1,0,1)	.303, .970, .869
20. United Corp.	133	−0.1832	0.0862	.8633	.0602	−.2257	(0,1,1)	.395

21. US and Foreign	203	– 0.1752	0.0919	.9276	– .0395	– .1891	(0,1,2)	.207, .178
Average fund[a] (*p* value)	186.4	– 0.1369 (.00)	0.0890	.8657	.0012	– .1833		
(B) Overall data period: October 31, 1980 to December 31, 1996								
1. Adams Express	192	– 0.0939	0.0552	.8685	.0547	– .1573	(0,1,1)	.267
2. Baker Fentress[a]	194	– 0.1984	0.0440	.7903	.0316	– .1287	(0,1,1)(1,0,1)	.523, .986, .908
3. Bergstrom Capital[a]	95	0.0024	0.1177	.9297	– .1981	– .2637	(1,1,1)	– .856, – .635
4. Blue Chip Value Fund	113	– 0.0784	0.0703	.8832	.0694	– .1543	(0,1,1)	.276
5. Central Fund of Canada[a]	112	– 0.0310	0.0737	.7908	– .0140	– .1032	(1,1,0)	– .283
6. Central Securities[a]	180	– 0.1361	0.0838	.9104	– .0268	– .0992	(0,1,1)(1,0,0)	.458, .245
7. Counsel Tamdem Securities[a]	108	– 0.1545	0.0516	.7127	– .0691	– .3036	(0,1,1)	.436
8. Engex	89	– 0.2389	0.0491	.5096	– .1980	– .4392	(2,0,0)	.387, .358, – .06
9. First Financial[a]	120	– 0.0943	0.0699	.7877	.0434	– .1263	(0,1,1)	.539
10. Gabelli	117	– 0.0379	0.0700	.8703	– .0906	– .2690	(0,1,1)	.324
11. General American Investors	192	– 0.0815	0.0803	.9173	– .0310	– .1611	(1,1,0)	– .355
12. Inefficient Markets	72	– 0.1496	0.0517	.8178	– .0736	– .3146	(1,0,0)	.931
13. Jundt Growth[a]	45	– 0.0584	0.0277	.3839	.0188	– .3958	(0,0,1)	– .408
14. Liberty All Star Equity	117	– 0.0791	0.0885	.9356	.0289	– .1243	(0,1,0)	
15. Morgren Small Cap[a]	110	– 0.0912	0.0667	.7296	.1306	– .0603	(0,1,1)	.555
16. New Age Media[a]	35	– 0.1557	0.0769	.8710	– .1856	– .5265	(2,0,0)	.55, .442
17. Petroleum and Resources Corp.[a]	186	– 0.0525	0.0546	.8052	.1042	– .1353	(0,1,1)(1,0,1)	.351, .984, .904
18. Quest for Value[a]	105	– 0.1776	0.0881	.7689	.3020	.1983	(0,1,1)	.518
19. Royce Value Trust	107	– 0.0870	0.0488	.8056	.1285	– .1579	(0,1,0)	
20. Royce Microcap OTC Trust[a]	33	– 0.1145	0.0546	.8410	– .2741	– .5446	(0,1,0)	

(continued on next page)

Table 1 (*continued*)

Funds	Number of observations	Fund premia statistical properties						
		Mean	S.D.	Autocorrelation lag 1	Correlation with NAV return	Correlation with fund return	ARIMA model $(p,d,q)(P,D,Q)$	Coefficients estimates
21. Salomon Brothers Fund	70	− 0.1375	0.0322	.7310	− .0413	− .2631	(0,1,1)	.427
22. Source Capital	186	− 0.0028	0.0814	.9329	− .0261	− .2017	(0,1,1)	.271
23. Tricontinental[a]	188	− 0.1130	0.0745	.8990	− .0371	− .1365	(0,1,1)	.44
24. Zweig[a]	111	0.0425	0.0805	.8888	.0755	− .0548	(0,1,1)	.270
25. Zweig Total Return Fund	98	0.0566	0.0595	.8987	− .1241	− .2685	(0,1,0)	
26. Global Health Sciences[a]	50	− 0.1366	0.0727	.8874	− .1327	− .3549	(1,1,0)	− .377
27. South-East Thrift and Bank[a]	53	− 0.0878	0.0514	.7252	− .1087	− .2616	(0,1,0)	
Average fund[a] (p value)	123	− 0.0846 (.00)	0.0624	.8337	− .0276	− .2283		

(A) displays the properties of 21 closed-end funds' premia calculated from data in Chen et al. (1993) while (B) displays the properties of 27 closed-end funds' premia obtained from Barron's. Premia are defined as the difference between price per share and NAV per share expressed as a fraction of NAV per share. Each fund's statistic is calculated over its available number of premia observations. NAV returns and fund price returns are calculated as monthly effective numbers in the original data set. Box–Jenkins multiplicative seasonal ARIMA$(p,d,q)(P,D,Q)$ models are fit to the premia and are of the general form

$$\phi(B)\Phi(B^s)(1-B)^d(1-B^s)^D Z_t = \theta(B)\Theta(B^s)u_t,$$

where $\phi(B)$ is the autoregressive polynomial of order p, B is the backshift operator, $\Phi(B^s)$ is the seasonal autoregressive polynomial of order p, $\theta(B)$ is the moving average polynomial of order q, $\Theta(B^s)$ is the seasonal moving average polynomial of order Q, d is the degree of differencing in the premia series, Z_t, D is the degree of differencing in the seasonal component, s, and u_t is the error term. Missing embedded observations are interpolated.

[a] The fund is omitted in the calculation of the average fund and p value statistic because the fund is omitted in subsequent analyses due to insufficient data or for reasons cited in the text.

Only 3 of the 21 Set A funds and 4 of the 27 Set B funds have stationary premia series being AR models. In the first differences and ignoring seasonality, 10 of the remaining 18 Set A funds are MA, 5 are random series, and 2 are AR models. In addition, five of the nonstationary fund series have seasonal components of varying forms. Also in the first differences, 14 of the remaining 23 Set B funds are MA, 5 are random series, and 3 are AR models. The statistical evidence of nonstationarity in premia is controversial because of the implications that the premia have no affinity for a finite mean. Our purpose here is to simply present the statistics demonstrating that there are individual fund peculiarities.

There seems to be little commonality in the behavior of the premia series across funds except for the well-known lack of correlation with future NAV returns, the negative correlation with future price returns, and their positive first-order autocorrelation. What is apparent from this data is that individual funds are not identical in terms of their premia behavior. The time series models indicate a stationary premium mean in some funds but not in others.

The aforementioned characteristics are present in both sets of funds despite their differences in dates and fund composition. Therefore, analyzing individual funds is preferred to analyzing portfolios of funds and this is consistent with the notion that funds are individually managed and have differing management value.[8] Based on this, we construct a model of the theoretical premia based upon the payoffs from each fund's NAV portfolio; other studies have concentrated on fund portfolios. Section 4 specifies, estimates, and tests the models.

4. Theoretical value specification

Our general approach is to specify and estimate a style function relating NAV returns from a closed-end fund to the contemporaneous returns from traded assets in the bill, bond, and equity markets. The monthly contingent payoff function (replicating claim) is derived from the return function, the NPV of the payoff function is obtained using martingale methods, and these theoretical NPVS are compared to the actual premia.

To estimate the style function, two approaches are employed. First, all available data for each fund were utilized for estimation and termed the in-sample procedure. In the second and out-of-sample procedure, each fund begins with a 48-month moving window that is employed to estimate the NAV replicating claim and its NPV for the 49th month. The remotest month is eliminated and the nearest month is added to the window and the replicating claim is reestimated, for the new 48-month window. The process is repeated until the data has been exhausted. The requirement of a 48-month window necessitates the dropping of Set A Funds 2, 4, and 5 as well as Set B Funds 13, 16, 20, 26, and 27 that have insufficient observations. The estimation details are as follows.

[8] Because of our prime interest in pricing individual funds, we refrain from reporting significance tests for average or aggregate statistics except where they are deemed to have some summary importance.

4.1. Estimating the "style" of the returns from a fund's asset portfolio

The NAV returns [Eq. (1)], from the closed-end fund portfolio j in the interval $[1,T_j]$, are defined as

$$\mathrm{RNAV}_{jt} = \frac{\mathrm{NAV}_{jt} + d_{jt}}{\mathrm{NAV}_{jt-1}} - 1, \qquad t = 1, 2, \ldots, T_j, \tag{1}$$

where NAV_{jt} is the NAV at the close of period t, d_{jt} are the period t distributions, and T_j is the number of observations for fund j.[9]

Using the NAV returns, we estimate a contingent claim that closely replicates the monthly NAV returns for each fund.[10] A quadratic function of the returns from five style portfolios is fit to the observed NAV returns on each individual fund using OLS. The NAV returns are a function of the return vector, $\boldsymbol{r}_t$=$[r_{Ft},r_{Bt},r_{St},r_{Mt},r_{Lt}]$, with elements given by the returns on a 1-month T-bill, a long government bond portfolio, a small-, a medium-, and a large-size portfolio, respectively.

$$\begin{aligned} \mathrm{RNAV}_{jt} &= \text{replicating NAV return}_{jt} + \text{error}_{jt} \\ &= a_j + B_j r_t + C_j r_t^2 + e_{jt}, \qquad t = 1, 2, \ldots T_j, \end{aligned} \tag{2}$$

where B_j is the (1×5) vector of coefficients for the (5×1) vector of style portfolio returns, $\boldsymbol{r}_t$, C_j is the (1×5) vector of coefficients for the (5×1) vector of squared returns, $\boldsymbol{r}_t^2$, and $e_{jt} \sim (0, \sigma^2_{e_{jt}})$ is the error that is orthogonal to each of the regressors. The misspecification error arises because the trading strategy is unobservable and we must specify the contingent traded assets and the functional form, either of which may contain errors.

In spirit, the model is similar to GJ who approximate general returns with a series of options. Our approach has the advantage of modeling returns with a parsimonious, nonlinear function of style portfolios' returns. Because returns are stationary, the estimation is very simple.

The regressions were rerun excluding the insignificant (.20 level) regressors. The results are shown in Table 2A and B, corresponding to the two sets of fund data, together with some related tests' results. Panel 1's cell entries are the in-sample results from a single total sample regression on each fund, whereas the results in panel 2 are averages of the moving regression results for each fund and for brevity only the average across funds is presented.[11]

We wish to screen out those funds for which we are unable to sufficiently replicate their NAV returns. Our desire to closely replicate the fund's payoffs necessitates a substantial cut in the number of funds. We screen based on the regression $R^2 > .6$ and on the sufficiency of the

[9] The NAV returns are as calculated in LST.

[10] Here, we are estimating a contingent claim rather than a fund's mimicking style portfolio. The latter would impose a zero intercept, zero quadratic coefficients, and a sum of one for the remaining coefficients in regression (2). See Huberman and Kandel (1987).

[11] A large Type I error was selected to reduce the Type II error probability of eliminating a priced style portfolio. The details of the in-sample results are presented in panel 1 because they will have a smaller replicating claim estimation error, compared to the out-of-sample results.

style portfolios. We measure the ability of the five style portfolios to span the unconditional mean-variance space generated by the five portfolios plus one closed-end fund. The p value associated with the F statistic is shown in column 2 of the tables.[12]

In Set A funds, spanning is rejected only for Fund 13 at the 1% level: this fund is therefore omitted from further tests. Fund 6 is a potential candidate for omission with a p value of .079; however, its large R^2 in column 3 suggests that the replicating claim's fit is quite close in return space. On the contrary, Funds 1 and 9 have relatively low R^2's and are omitted from the sample. In Set B, funds 2, 3, 5, 6, 7, 9, 13, 15, 16, 17, 18, 20, 23, 24, 26, and 27 are omitted because of spanning rejection or relatively low R^2 values.[13]

It seems that it is more difficult to model a fund's trading strategy in the more recent data set, perhaps due to foreign holdings and derivatives. Although our spanning and R^2 screens are based solely on the ability to replicate a fund's NAV returns, the screens have omitted Set A funds 1 (ASA), 9 (Eurofund), and 13 (Japan Fund) that hold foreign assets. Set B Funds 5 (Central Fund of Canada), 16 (New Age Media), 17 (Petroleum and Resources Corp.), 18 (Quest for Value), 23 (Tricontinental), and 26 (Global Health Sciences) contain foreign assets. As expected, these foreign asset funds would require a different replicating claim.[14] The remaining Set A funds have R^2's that average .85 and range from .62 to .96 and the Set B funds average .77 and range from .63 to .86. The R^2's and spanning statistics imply that the replicating claims are quite close to the NAVs in return space as well as in mean-variance space, particularly in the Set A funds.

Column 4 shows the mean residual standard deviation (S.D.) that is left unexplained by each fund's regression sequence. This variation is relatively small but it could contribute to measurement error in the theoretical value of a fund's NAV replicating portfolio. One may employ the error S.D. to bound the theoretical price. For example, the Set A average fund's residual return S.D. of 0.0174 implies a 95% confidence interval of ± 0.0341 per month. A "riskless" payoff of 0.0341 has a present value of 0.0339 when calculated at the average riskless return of 0.005 per month. Therefore, omitting a riskless payoff of ± 0.0341 will result in a theoretical premia error of ∓ 0.0339. Compared with say the average fund premia of -0.1369, the ∓ 0.0339 error is quite small if one considers that NAV residual returns as large as the 95% limit are rare and are not riskless.

Alternatively, if the error is risky and moves one to one with a traded asset omitted in the pricing regression, the theoretical value of the error will be zero. In this case, the only impact on value will be through the changes in the coefficients of the included traded assets. Finally, if the error is diversifiable, the market may not price it. Therefore, there are good reasons to conclude that the model error may be relatively small particularly when averaged over time as

[12] The statistic is calculated as a test of the restrictions of zero intercept and coefficients summing to one in an OLS of $RNAV_{jt}$ on the style returns, r_t (Huberman & Kandel, 1987) or identically as a mean-variance performance test (Jobson & Korkie, 1989). Bekaert and Urias (1996) show that this spanning test is also equivalent to a test of the mean-variance bounds on the marginal rate of substitution.

[13] The same criteria is used in panel 2 but the omitted funds are not identical to those of panel 1.

[14] The other omitted Set B funds have either an unknown and omitted style portfolio or simply generate a lot of noise.

Table 2
Goodness-of-fit measures for the closed-end fund NAV replicating claims

Funds	Spanning F statistic p value	R^2	Residual S.D.	Actual NAV return properties			Replicating NAV return properties	
				Mean	S.D.	Correlation with price return	S.D.	Correlation with price return
(A) Overall data period: July 31, 1965 to December 31, 1990								
Panel 1: Entire sample estimation of the NAV replicating claim								
1. ASA[a]	.3030	.0365	0.0965	0.0157	0.0978	.6415	0.0187	.1430
2. Abacus Fund	.2330	.8944	0.0113	0.0106	0.0362	.5656	0.0342	.5701
3. Adams Express	.5454	.9328	0.0106	0.0098	0.0400	.6319	0.0387	.6036
4. Advance Investors	.3737	.9127	0.0163	− 0.0018	0.0521	.7127	0.0498	.8116
5. American International	.1475	.9631	0.0075	0.0118	0.0330	.6523	0.0324	.6134
6. Carriers and General	.0789	.9068	0.0123	0.0038	0.0390	.6000	0.0371	.6138
7. Central Securities	.7996	.7598	0.0272	0.0100	0.0543	.6967	0.0473	.6621
8. Dominik Fund	.9564	.8249	0.0195	0.0041	0.0444	.5844	0.0404	.5755
9. Eurofund International[a]	.8844	.2450	0.0263	0.0057	0.0339	.5411	0.0268	.3157
10. General American Investors	.3698	.8758	0.0185	0.0115	0.0519	.7477	0.0486	.7398
12. International Holdings	.9855	.8639	0.0182	0.0048	0.0473	.6836	0.0440	.6277
13. Japan Fund[a]	.0012	.1491	0.0591	0.0177	0.0633	.6331	0.0244	.3500
14. Lehman Corp.	.9737	.9288	0.0127	0.0094	0.0467	.7264	0.0450	.7299
15. Madison Resources	.9699	.8256	0.0204	0.0096	0.0478	.6611	0.0434	.6528
16. Niagara Shares	.4253	.8360	0.0195	0.0097	0.0474	.6506	0.0433	.6466
17. Petroleum and Resources Corp.	.2934	.6188	0.0305	0.0107	0.0494	.7690	0.0389	.5909
18. Surveyor Fund	.9084	.8487	0.0208	0.0016	0.0500	.6621	0.0461	.6039
19. Tricontinental	.9933	.9263	0.0127	0.0091	0.0463	.7188	0.0445	.7344
20. United Corp.	.7262	.6242	0.0232	0.0078	0.0364	.5004	0.0288	.5265
21. US and Foreign	.2957	.8972	0.0148	0.0066	0.0454	.7042	0.0430	.7339
Average fund[a]	.593	.8494	0.0174	0.0076	0.0452	.6628	0.0415	.6492

Panel 2: Moving 48-month sample estimation of the NAV replicating claim								
Average fund[a]	.661	.8737	0.0171	0.0064	0.0464	.6729	0.0465	.6208
(B) Overall data period: October 31, 1980 to December 31, 1996								
Panel 1: Entire sample estimation of the NAV replicating claim								
1. Adams Express	.9997	.8069	0.0163	0.0120	0.0364	.6674	0.0328	.5279
2. Baker Fentress[a]	.1417	.2205	0.0644	0.0030	0.0716	.8910	0.0336	.4080
3. Bergstrom Capital[a]	.0309	.5604	0.0293	0.0157	0.0427	.6513	0.0320	.5139
4. Blue Chip Value Fund	.2617	.7669	0.0234	0.0084	0.0472	.6828	0.0414	.6149
5. Central Fund of Canada[a]	.5389	.0000	0.0445	0.0005	0.0430	.0190	0.0002	.2184
6. Central Securities[a]	.5209	.1517	0.1155	0.0170	0.1222	.9478	0.0476	.3055
7. Counsel Tamdem Securities[a]	.0455	.6910	0.0330	0.0078	0.0575	.8121	0.0478	.6213
8. Engex	.6983	.6272	0.0597	0.0065	0.0920	.8555	0.0728	.7522
9. First Financial[a]	.1150	.3648	0.0650	0.0173	0.0801	.8468	0.0484	.5550
10. Gabelli	.3089	.7205	0.0180	0.0108	0.0329	.6920	0.0279	.6876
11. General American Investors	.5775	.7398	0.0261	0.0120	0.0499	.7977	0.0430	.6962
12. Inefficient Markets	.4464	.6717	0.0242	0.0070	0.0398	.7804	0.0326	.6546
13. Jundt Growth[a]	.5701	.4846	0.0311	0.0060	0.0410	.7629	0.0286	.5004
14. Liberty All Star Equity	.2024	.8585	0.0162	0.0110	0.0427	.7569	0.0396	.7030
15. Morgren Small Cap[a]	.6619	.2155	0.1056	0.0138	0.1146	.8655	0.0532	.5180
16. New Age Media[a]	.3853	.4402	0.0388	0.0123	0.0457	.7254	0.0303	.5756
17. Petroleum and Resources Corp.[a]	.1765	.5009	0.0338	0.0074	0.0471	.7533	0.0333	.4938
18. Quest for Value[a]	.5917	.0000	0.3024	0.0504	0.3024	.9700	0.0000	.0000
19. Royce Value Trust	.7876	.8412	0.0146	0.0089	0.0359	.7641	0.0329	.7400
20. Royce Microcap OTC Trust[a]	.4398	.4981	0.0160	0.0119	0.0204	.5929	0.0144	.4113
21. Salomon Brothers Fund	.9264	.8315	0.0141	0.0117	0.0326	.7408	0.0298	.6778

(continued on next page)

Table 2 (*continued*)

Funds	Spanning F statistic p value	R^2	Residual S.D.	Actual NAV return properties: Mean	Actual NAV return properties: S.D.	Actual NAV return properties: Correlation with price return	Replicating NAV return properties: S.D.	Replicating NAV return properties: Correlation with price return
(A) Overall data period: July 31, 1965 to December 31, 1990								
22. Source Capital	.4122	.7880	0.0134	0.0110	0.0286	.6651	0.0254	.6337
23. Tricontinental[a]	.9972	.2906	0.0580	0.0125	0.0685	.8782	0.0369	.3739
24. Zweig[a]	.3713	.0716	0.0758	0.0117	0.0763	.8536	0.0204	.3371
25. Zweig Total Return Fund	.8252	.7901	0.0065	0.0074	0.0136	.3935	0.0121	.3925
26. Global Health Sciences[a]	.1085	.3641	0.0444	0.0122	0.0568	.8094	0.0343	.5928
27. South-East Thrift and Bank[a]	.1362	.1140	0.0783	0.0153	0.0796	.8980	0.0269	.2633
Average fund[a]	.5358	.7675	0.0211	0.0095	0.0408	.7117	0.0355	.6437
Panel 2: Moving 48-month sample estimation of the NAV replicating claim								
Average fund	.5699	0.7627	0.0178	.0125	0.0302	.5988	0.0273	.4986

This provides evidence on the fit of the contingent claim that is used to replicate the dollar payoffs from each fund's NAV. Fund NAV return means, S.D.'s, and correlations with the fund's price returns are compared with the replicating claim's respective S.D.'s and correlations. A replicating claim's returns are a quadratic function of the returns on at most five style portfolios' returns. To estimate a claim's coefficients a_j, B_j, and C_j as well as to determine fit, the regression

$$\mathrm{RNAV}_{jt} = \text{replicating NAV return}_{jt} + \text{residual}_{jt},$$

$$\mathrm{RNAV}_{jt} = a_j + B_j r_t + C_j r_t^2 + e_{jt}, \qquad t = 1, 2, \ldots, T_j$$

is run, where RNAV_{jt} is the month t return on fund j's NAV portfolio, $\boldsymbol{r}_t$ is the vector of returns on the style portfolios, r_t^2 is the vector of squared returns on the style portfolios. In panel 1 of (A), the replicating claim is estimated using all available data on the funds, whereas in panel 2 of (A), the replicating claim is estimated using a moving window of 48 months and excludes Funds 2, 4, and 5, which have insufficient data for the moving window. In panel 1 of (B), the replicating claim is estimated using all available data on funds, whereas in panel 2 of (B), the replicating claim is estimated using a moving window of 48 months on funds with sufficient data. The spanning F statistic is the value under the null hypothesis that the five style portfolios span the mean-variance space generated by the portfolios plus a fund.

[a] These funds were excluded in the average fund calculations and are omitted in subsequent tables because of lack of fit of the replicating portfolio reflected in small R^2 or significant spanning statistics.

in GJ's Propositions I and II. Nevertheless, an allowance for model error that shrinks the impact of funds that are not closely replicated is described in Section 4.2.

The remaining columns contain the NAV means and S.D.s and the correlations of the NAV return with the fund's price return. For each fund, the NAV replicating claim and actual NAV mean returns are identical by construction and the NAV S.D.'s are similar due to the high R^2's. The replicating NAV return versus actual NAV return correlations with a fund's price returns are also quite similar reflecting the closeness of the replicating claim's fit; the respective average correlations are .649 versus .663 in Set A and .644 versus .712 in Set B from Panels 1.

Overall, the Set A funds have NAV returns that are more closely replicated than Set B funds. Having developed the NAV return replicating claims, we can define the dollar payoffs from the claims and their theoretical values for both sets of funds.

4.2. Specifying the NAV payoff function and the replicating claim's value

The NAV replicating claim's payoff at time t, from a \$1 NAV investment at time $t-1$, may be written as a function of the dollar payoffs (gross returns) and the squared dollar payoffs from the five style portfolios. From Eq. (2), the NAV replicating payoff for fund j is

$$\begin{aligned} R_{jt} &= 1 + \text{replicating NAV return}_{jt} \\ &= 1 + a_j + (C_j - B_j)\boldsymbol{\iota} + (B_j - 2C_j)R_t + C_j R_t^2, \qquad t = 1, 2, \ldots, T_j \end{aligned} \tag{3}$$

where R_t=[R_{Ft},R_{Bt},R_{St},R_{Mt},R_{Lt}] is the (5×1) vector of dollar payoffs, $R_t{}^2$ is the (5×1) vector of squared dollar payoffs from a \$1 investment in each of the five style portfolios, and $\boldsymbol{\iota}$ is the (5×1) vector of ones.

Assuming that the long bond and the three equity-style portfolio prices follow log-normal diffusions from $t-1$ to t, one can price the payoffs of Eq. (3) by taking the expectation under the risk-neutral probability measure. The discounted claim prices are a martingale and the value of the payoff, R_{jt}, at the close of month $t-1$, is

$$V_{jt-1} = \left((1 + a_j) + (C_j - B_j)\boldsymbol{\iota}\right)\exp(-r_{Ft}) + (B_j - 2C_j)\boldsymbol{\iota} + C_j\exp(\sigma_t^2 + r_{Ft}), \tag{4}$$

where r_{Ft} is the continuously compounded riskless rate for month t, $\exp(\sigma^2 + r_{Ft})$ denotes the (5×1) vector with elements $e^{(\sigma_{kt}^2 + r_{Ft})}$, and σ_{kt}^2 is the conditional variance of style portfolio $k \in \{F,B,S,M,L\}$, with zero conditional variance on the 1-month T-bill, $\sigma_{Ft}^2 = 0$. Eq. (4) follows directly from the application of Girsanov's theorem using the Radon–Nikodym derivative.[15]

The value V_{jt-1} is the price, at time $t-1$, of the portfolio of the T-bill, bond, and equity indexes that replicates the NAV payoff at time t via a dynamic trading strategy from $t-1$ to t. The value contributed by the quadratic portion of Eq. (4) is given by the sum of terms that include the coefficients, C_j. Similarly, one can attribute the contribution of each style portfolio to the value by adding up the terms of B_j and C_j that involve a particular style portfolio. A

[15] The principles of the methodology are in Duffie (1988), for example. More detail on the style pricing approach is in Korkie and Turtle (2001).

Table 3
Summary properties of the closed-end funds' theoretical premia

Funds	Fund theoretical premia statistical properties						Fund theoretical value contributions						
							By functional form		By style portfolio				
	Mean	S.D.	Autocorrelation lag 1	Correlation with actual premia	Correlation with NAV return	Correlation with fund return	Linear	Nonlinear	T-bill	Bond	Small	Medium	Large
(A) Overall data period: July 31, 1965 to December 31, 1990													
Panel 1: Entire sample estimation of the NAV replicating claim													
2. Abacus Fund	0.0013*	0.0000	.8272	− .2042	− .0466	.0099	1.0013	0.0000	0.0000	0.0000	0.0000	0.0009	0.0025
3. Adams Express	− 0.1001*	0.0003	.8882	.1417	.1341	.0313	1.0008	− 0.1008	0.0000	0.0003	− 0.1127	0.5283	− 0.5116
4. Advance Investors	− 0.0029*	0.0004	.8081	− .4372	.3877	.2032	0.9971	0.0000	0.0000	− 0.0016	0.0000	0.0000	0.0049
5. American International	− 0.8604*	0.0031	.5838	.4098	.2894	.2219	0.8459	− 0.7064	− 0.1486	0.0010	− 0.8143	2.6880	− 2.7355
6. Carriers and General	− 0.0007*	0.0027	.7459	− .0300	− .1590	− .1411	0.9730	0.0262	− 0.0186	0.0005	0.0003	0.0000	0.0036
7. Central Securities	0.3837*	0.0003	.8532	.3927	− .0719	− .0718	1.0007	0.3830	0.0000	− 0.0008	0.3830	0.0032	0.0032
8. Dominik Fund	2.3181*	0.0005	.8571	− .4844	− .0991	.0681	1.0003	2.3178	0.0000	0.0000	− 0.0008	− 1.3431	3.6658
10. General American Investors	0.0013*	0.0001	.9370	.1144	− .0722	− .0245	1.0013	0.0000	0.0000	0.0000	− 0.0004	0.0029	0.0034
12. International Holdings	− 0.3275*	0.0009	.9138	− .1441	.1405	.1579	1.0013	− 0.3288	0.0000	0.0000	− 0.5897	2.4934	− 2.2280
14. Lehman Corp.	− 0.2827*	0.0011	.7863	− .0192	− .0178	.0238	0.9926	− 0.2753	− 0.0078	0.0000	0.1161	− 0.3967	0.0044
15. Madison Resources	0.6046*	0.0002	.9464	.3106	.0756	.0265	1.0023	0.6023	0.0000	0.0000	0.0000	0.6051	0.0023
16. NiagaraShares	0.6526*	0.0018	.8121	− .0498	.0989	.0847	1.0105	0.6421	0.0084	− 0.0008	0.0000	0.0017	0.6551
17. Petroleum and Resources Corp.	− 0.0569*	0.0003	.9362	.1987	.1043	.0792	1.0022	− 0.0592	0.0000	− 0.0010	0.0002	0.0000	− 0.0541
18. Surveyor Fund	0.5363*	0.0002	.8882	.3329	− .3778	− .1987	1.0030	0.5333	0.0000	0.0007	0.5333	0.0025	0.0017

19. Tricontinental	– 0.0666*	0.0001	.9372	– .1424	– .0812	– .0469	0.9997	– 0.0663	0.0000	0.0000	– 0.0004	– 0.0647	0.0045
20. United Corp.	0.3998*	0.0006	.8687	– .2446	.1985	.1796	1.0036	0.3962	0.0000	0.0000	– 0.7354	2.6419	– 1.5079
21. US and Foreign	0.6292*	0.0002	.8560	.0244	– .1500	– .1526	0.9993	0.6299	0.0000	0.0000	– 0.2322	0.0015	0.8661
Average fund (*p* value)	0.2252 (.23)	0.0007	.8497	.0100	.0208	.0265	0.9903	0.2349	– 0.0098	– 0.0001	– 0.0855	0.4215	– 0.1070
Panel 2: Moving 48-month sample estimation of the NAV replicating claim													
Average fund (*p* value)	0.5708 (.00)	1.4037	.7864	.0039	– .0179	– .0223	0.9917	0.3204	– 0.0098	– 0.0228	0.0531	0.0715	0.2142
(B) Overall data period: October 31, 1980 to December 31, 1996													
Panel 1: Entire sample estimation of the NAV replicating claim													
1. Adams Express	0.0000	0.0003	.9493	.4865	.0519	– .0035	1.0000	0.0000	0.0000	0.0004	0.0004	0.0013	0.0029
4. Blue Chip Value Fund	– 0.0025*	0.0001	.9252	– .6664	– .0270	.0231	0.9967	0.0000	0.0000	0.0000	0.0007	0.0000	0.0041
8. Engex	– 0.6272*	0.0000	1.0000	.0000	.0000	.0000	0.9933	– 3.1200	0.0000	0.0019	0.0030	5.7874	– 8.9056
10. Gabelli	0.0008*	0.0024	.7995	.0378	.0368	.1323	0.9729	0.0282	– 0.0189	0.0000	0.0000	0.0028	0.0000
11. General American Investors	0.0535*	0.0025	.8741	– .0559	.1115	.0767	1.0132	0.0590	0.0182	0.0000	0.0738	0.0031	0.0022
12. Inefficient Markets	– 0.0013*	0.0003	.9410	– .2076	.1141	.1486	0.9981	0.0000	0.0000	– 0.0007	0.0013	0.0020	0.0000
14. Liberty All Star Equity	– 0.0003*	0.0000	.9243	.7459	– .0115	– .0027	0.9997	0.0000	0.0000	0.0000	0.0002	0.0017	0.0024
19. Royce Value Trust	0.0005*	0.0004	.9121	.4246	.1715	.1005	1.0006	0.0000	0.0000	0.0000	0.0011	0.0018	0.0000
21. Salomon Brothers	– 0.8315*	0.0000	1.0000	.0000	.0000	.0000	0.9991	– 1.9287	0.0000	– 1.9293	0.0000	0.0014	0.0026
22. Source Capital	0.4226*	0.0007	.9576	.7053	– .0317	– .0685	1.0022	0.5342	0.0000	0.0010	0.0005	0.0018	0.5349

(continued on next page)

Table 3 (*continued*)

	Fund theoretical premia statistical properties						Fund theoretical value contributions						
							By functional form		By style portfolio				
Funds	Mean	S.D.	Autocorrelation lag 1	Correlation with actual premia	Correlation with NAV return	Correlation with fund return	Linear	Nonlinear	T-bill	Bond	Small	Medium	Large
25. Zweig Total Return Fund	− 0.7901*	0.0000	1.0000	.0000	.0000	.0000	0.9985	− 1.2105	0.0000	0.0011	0.0000	− 1.2097	0.0004
Average fund (p value)	− 0.1614 (.11)	0.0006	.9348	.1337	.0378	.0370	0.9977	− 0.5125	− 0.0001	− 0.1751	0.0074	0.4176	− 0.7596
Panel 2: Moving 48-month sample estimation of the NAV replicating claim													
Average fund (p value)	0.7067 (.016)	1.6424	.8100	.0286	.0518	.0644	0.9984	− 0.5802	− 0.0038	0.5626	0.7166	− 2.0283	0.1699

This displays the properties of a fund's theoretical premia value. Each fund's initial theoretical NAV is obtained from the valuation equation given by

$$V_{jt-1} = \frac{(1+a_j)+(C_j-B_j)\iota}{(1+r_{Ft})} + B_j\iota + C_j(\exp(\sigma_t^2 + r_{Ft}) - 2\iota),$$

where a_j, B_j, and C_j are coefficients' vectors described in Table 2, r_{Ft} is the 1-month T-bill return, ι is a conformable vector of ones, and $\exp(\sigma^2 + r_{Ft})$ denotes the conformable vector with elements $e^{(\sigma_{kt}+r_{Ft})}$ with σ_{kt}^2 being the conditional variance of style portfolio k. Theoretical values are shrunk more towards one if their R_j^2 fit is small via

$$V^*_{jt-1} = R_j^2 \max(V_{jt-1}, 0) + (1 - R_j^2),$$

and their theoretical premia or NPV_{jt-1} calculated by

$$\text{NPV}_{jt-1} = V^*_{jt-1} - 1, \qquad t = 1, 2, \ldots, T.$$

Value contributions by various aggregations, including linear and nonlinear terms and style portfolio exposures, in the preshrinkage valuation equation are presented. Total theoretical values before shrinkage are equal to the theoretical linear plus nonlinear value contributions. (The cash theoretical value contribution is omitted from the style portfolio columns.) In panel 1 of (A), the replicating claim is estimated using all available data on the funds, whereas in panel 2 of (A), the replicating claim is estimated using a moving window of 48 months and excludes Funds 2, 4, and 5, which have insufficient data for the moving window. In panel 1 of (B), the replicating claim is estimated using all available data on funds, whereas in panel 2 of (B), the replicating claim is estimated using a moving window of 48 months.

* Significance at the .01 level.

buy-and-hold NAV portfolio of any subset of the indexes has a value of one, an NPV of zero, and therefore will not show any contribution from fund management.[16]

It is difficult from an empirical point of view to know which specific traded assets are omitted in pricing each fund. However, if the model explains most of the variation in a given fund's NAV returns, one can be confident that the fund's estimated theoretical value is reliable. Because the claim is not an exact replica of some fund's NAV, an adjustment is imposed that shrinks the theoretical value towards one and the theoretical premium towards zero for larger model specification error.[17] Funds with returns that are precisely described by the regressors in Eq. (2) are considered to have an accurate theoretical valuation from Eq. (4) that is left essentially unchanged. Therefore, the adjusted theoretical value is calculated as

$$V^{*}_{jt-1} = R^2_j \max(V_{jt-1}, 0) + (1 - R^2_j) \qquad (5)$$

where V_{jt-1} is the unadjusted theoretical value from Eq. (4) and, due to the freedom to not replicate, we use an unadjusted theoretical fund value of at least zero.[18]

Finally, the estimated value added by fund management per dollar of NAV is the NPV,

$$\mathrm{NPV}_{jt-1} = V^{*}_{jt-1} - 1, \qquad t = 1, 2, \ldots, T, \qquad (6)$$

which is called the theoretical fund premium and which may be compared to a fund's observed premium at time $t-1$.

4.3. Comparative theoretical versus actual premia

The conditional return variances are estimated for the bond and the three equity-size portfolios, as GARCH(1,1) processes.[19] Using the conditional variances for each month, the monthly T-bill returns, and the estimated coefficients, the theoretical NAVs are determined according to Eqs. (4) and (5) and the theoretical fund premia calculated from Eq. (6). Table 3A and B show the properties of each fund's theoretical premia including an attribution of the theoretical value and the importance of linear versus nonlinear terms in the replicating claim's value.

Results in columns 8 and 9 show that the linear and the nonlinear terms in the pricing equations are important for the average fund and almost every individual fund has important exposure to the squared returns on the style portfolios. For example, Set A Fund 8 has a

[16] Insignificant coefficients were omitted in a second pass of the regression (2) and assigned zero values in the valuation (4).

[17] The average shrinkage over all Set A funds and months is from a theoretical premium of 0.225 to an adjusted theoretical premia of 0.174.

[18] A Bayesian or Bayes–Stein interpretation may be given to the shrinkage where 1.0 is the prior theoretical claim value. Negative values, V_{jt-1}, do not occur in the original LST data set but are present in the Kan updated set.

[19] For the Set A time period, GARCH(1,1) coefficients for the bond and small- and large-size portfolios are .15, .03, and .04 for the lagged squared disturbance term and .81, .83, and .83, for the lagged variance term. The unconditional variance is equal to the conditional variances for the medium-size portfolio. For the Set B time period, GARCH(1,1) coefficients for the bond and small-, medium-, and large-size portfolios are .056, .041, .049, and .053 for the lagged squared disturbance term and .921, .695, .941, and .928, for the lagged variance term.

theoretical value per dollar of assets of 1.000 from the linear component and 2.318 from the nonlinear component of the pricing equation, in the average month and before shrinkage. Columns 10 through 14 show that the average Set A fund has negative value contributions from the T-bill, and the small- and large-equity-style portfolios: the medium-equity-style portfolio has a positive value contribution. Generally, the average contributions are influenced by a few funds; this is particularly so in the Set B funds. Individual funds vary substantially in the value contributions from, and therefore the exposures to the five style portfolios, in both sets.

The statistical properties of the theoretical and actual premia can be compared via Tables 1 and 3.[20] On average, theoretical premia are positive (0.225) for Set A and negative (− 0.161) for Set B compared to respective actual premia of − 0.137 and − 0.085. The across fund average is insignificantly different (10% level) from zero and from the average actual premia for Set B but significantly different from the actual premia average for Set A (5% level). Every fund (except one fund) has a significant mean theoretical premium that varies across funds from large positive to large negative; whereas, actual premia are negative for all funds but one.

The theoretical premia volatility is smaller on average (0.0007 for Table 3A and 0.0006 for Table 3B) than the actual premia volatility (0.089 for Table 1A and 0.062 for Table 1B) because of the fixed estimate of the replicating claim that produces constant coefficients within the sample period. Using the moving window estimation substantially increases the average theoretical premia volatility to 1.404 (Set A) and 1.642 (Set B), as shown in panel 2 of Tables 3A and B. This larger volatility is due to the changing replicating claim. The in-sample estimation uses information that is not available at the close of each month. Nevertheless, the entire in-sample estimation has premia volatility that more closely resembles the actual premia volatility. This may imply that the market does not revise its pricing function very often.

The correlation between actual and theoretical premia is largest (.410) for Fund 5 and averages .010 across Set A funds. Correlation is largest (.746) for Fund 14 and averages .134 across Set B funds.

Thus, our first look at the actual and theoretical premia for each fund shows that the theoretical and actual premia for a fund are not very similar and the two premia are not highly positively correlated. As we summarize next, some other properties are quite similar.

The theoretical premia are highly autocorrelated (.850 and .935 for the average Sets A and B funds, respectively) as is true with actual premia (.866 for Set A and .834 for Set B).[21] The cause of this temporal dependence is that the pricing inputs, being the T-bill rate and the style volatilities, are highly autocorrelated. Both theoretical and actual premia are uncorrelated with future NAV returns (.021 and .001, respectively, for Set A and .038 and − .028, respectively, for Set B) for the average fund with most individual fund correlations being within the ± .20 range.

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[20] The Table 1 values are calculated from the entire data set whereas, for panel 2 in Table 3, the theoretical values are calculated from the rolling window of 48 months.

[21] See Pontiff (1995) and Thompson (1978).

Despite these average results, individual funds in Set A display quite different correlations between their theoretical premia and their future NAV returns. For all individual funds, actual premia are negatively correlated with future fund price returns; whereas, theoretical premia are fund specific and average approximately zero correlation with fund return (.027 for Set A and .037 for Set B).

4.4. Rationality properties of the premia errors

Table 3 has shown the similarities in the theoretical and actual fund premia; but, there were important differences as well. Given this lack of correspondence, one may ask if there are arbitrage opportunities caused by irrational fund pricing. To investigate the irrationality issue first, Table 4A and B contain an analysis of the pricing errors, defined as the monthly difference in the actual and theoretical premia for each fund. Because the theoretical premia are estimated in sample, pricing errors in panel 1 should more closely reflect irrational market behavior versus statistical estimation errors.

The mean error for each fund is significant (− 0.311 for Set A and 0.077 for Set B average funds) indicating a large bias in the theoretical prediction of the premia. The average fund's error volatility is a 0.089 S.D. and the mean absolute error (M.A.E.) is 0.074 for Set A and 0.062 and 0.052, respectively, for Set B. Ljung–Box statistics are significant for every fund indicating that the errors are predictable for each fund due in part to their large first-order autocorrelation (.889 for Set A and .868 for Set B on average) and most funds' errors are identified as nonstationary series.

Perhaps more striking is that the evidence of irrational pricing sustains for the funds with NAV returns that are very closely replicable; for example, Fund 5 in Set A and Fund 14 in Set B that have respective R^2's of .96 and .86. These funds have theoretical prices and premia that are substantially different from their actual values as shown by their Table 4 error properties.

We also estimated the NAV replicating claims using the 48-month moving window, rather than the entire sample for each fund, with the average fund results shown in panel 2. The estimation of the value of management produced a NAV replicating claim that fit the prior NAV returns about the same, on average, as using the entire sample of data. Despite the large volatility of the theoretical premia due to the changing replicating claim, most other properties are approximately the same as the total sample case. However, the average theoretical premia are different, in part, due to the removal of 48 data months and differing sample funds. Our previous conclusions, based on estimations using the entire sample and respecting the correspondence between a particular fund's actual and theoretical premia, are unaltered. The lack of correspondence appears to be due to systematic errors, which are more volatile in the moving window case, in the market's estimation of a fund's value and premia.

Gruber (1996) observes that funds' prices have systematic and unsystematic risks that differ from their asset portfolio risks. Our analysis suggests that one cause of this observation is the market's inability to estimate the NAV replicating claim that allows it to price the management's value. Overall, Table 4 shows that the pricing errors are related to information available prior to and at the time that the funds are priced in the market. Therefore and by definition, the funds' prices are irrational and arbitrage is available to insiders who know the

Table 4

Summary statistical properties of the estimated pricing errors on closed-end funds

Fund	Number of observations	Fund pricing error statistical properties: Mean	S.D.	M.A.E.	Autocorrelation lag 1	Ljung–Box	ARIMA Model (p,d,q)(P,D,Q)	Coefficients' estimates
(A) Overall data period: July 31, 1965 to December 31, 1990								
Panel 1: Entire sample estimation of the NAV replicating claim								
2. Abacus Fund	37	– 0.1419*	0.0365	0.0304	.7572	53.14*	(1,0,0)	.757
3. Adams Express	317	– 0.0166*	0.0719	0.0570	.8704	2191*	(0,1,1)	.390
4. Advance Investors	32	– 0.2121*	0.0612	0.0514	.6828	64.42*	(0,1,1)	.443
5. American International	40	0.6996*	0.0370	0.0273	.9500	65.71*	(0,1,0)log	
6. Carriers and General	153	– 0.1682*	0.0475	0.0370	.7697	225.5*	(1,0,0)	.770
7. Central Securities	231	– 0.5185*	0.0959	0.0775	.9352	2861*	(0,1,1)	.461
8. Dominik Fund	102	– 2.0770*	0.0925	0.0782	.9192	741.3*	(0,1,1)	.278
10. General American Investors	317	– 0.1068*	0.0962	0.0803	.9259	3112*	(0,1,1)	.371
12. International Holdings	118	0.0858*	0.0816	0.0612	.8911	673.5 *	(0,1,0)(0,0,1)	– .359
14. Lehman Corp.	315	0.1663*	0.1177	0.0921	.9592	3452*	(0,1,0)(1,0,0)	.259
15. Madison Resources	215	– 0.5728*	0.2249	0.1917	.9816	3004*	(1,1,0)	– .175
16. Niagara Shares	317	– 0.6152*	0.1026	0.0850	.9208	2772*	(0,1,1)	.383
17. Petroleum and Resources Corp.	317	– 0.0080*	0.0640	0.0526	.8228	1011*	(1,0,1)	.887, 0.206
18. Surveyor Fund	60	– 0.5466*	0.1250	0.1103	.9600	403.6*	(0,1,0)	
19. Tricontinental	317	– 0.0809*	0.0833	0.0685	.9357	2590*	(0,1,1)(1,0,1)	.303, 0.970, 0.869
20. United Corp.	144	– 0.4385*	0.0863	0.0679	.8756	1057*	(0,1,1)	.395
21. US and Foreign	144	– 0.7420*	0.0951	0.0846	.9504	1893*	(0,1,2)	.208, 0.177
Average fund	186.8	– 0.3114	0.0894	0.0737	.8887	1539.4		
Panel 2: Moving 48-month sample estimation of the NAV replicating claim								
Average fund	165	– 0.6139	1.3519	0.9380	.8172	420.0		

(B) Overall data period: October 31, 1980 to December 31, 1996

Panel 1: Entire sample estimation of the NAV replicating claim								
1. Adams Express	194	– 0.0943*	0.0551	0.0446	.8767	704.7*	(0,1,1)	.268
4. Blue Chip Value Fund	115	– 0.0778*	0.0716	0.0615	.8967	625.3*	(0,1,1)	.276
8. Engex	109	0.3940*	0.0483	0.0384	.6093	230.4*	(2,0,0)	.387, .358
10. Gabelli	123	– 0.0383*	0.0689	0.0561	.8784	694.7*	(0,1,1)	.333
11. General American Investors	194	– 0.1357*	0.0805	0.0688	.9250	1510*	(1,1,0)	– .348
12. Inefficient Markets	81	– 0.1471*	0.0504	0.0369	.9310	222.3*	(1,0,0)	.931
14. Liberty All Star Equity	121	– 0.0781*	0.0876	0.0761	.9416	1228*	(0,1,0)	
19. Royce Value Trust	120	– 0.0895*	0.0481	0.0392	.8627	292.9*	(0,1,0)	
21. Salomon Brothers	79	0.6954*	0.0323	0.0271	.7786	216.1*	(0,1,1)	.427
22. Source Capital	194	– 0.4250*	0.0815	0.0662	.9511	1540*	(0,1,1)	.272
25. Zweig Total Return Fund	98	0.8467*	0.0598	0.0511	.9014	534.2*	(0,1,0)	
Average fund	129.8	0.0773	0.0622	0.0515	.8684	709.0		
Panel 2: Moving 48-month sample estimation of the NAV replicating claim								
Average fund	86.2	– 0.7900	1.6765	1.3463	.8316	347.8		

Closed-end fund pricing error is defined as the actual premium less the theoretical premium for each month. The theoretical premium is calculated as the NPV of the contingent claim that replicates NAV payoffs on a fund. In panel 1 of (A), the replicating claim is estimated using all available data on a fund, whereas in panel 2 of (A), the replicating claim is estimated using a moving window of 48 lagging months and excludes Funds 2, 4, and 5, which have insufficient data for the moving window. In panel 1 of (B), the replicating claim is estimated using all available data on the funds, whereas in panel 2 of (B), the replicating claim is estimated using a moving window of 48 lagging months. Box–Jenkins multiplicative seasonal ARIMA(p,d,q)(P,D,Q) models, fit to the pricing errors, are of the general form

$$\phi(B)\Phi(B^s)(1-B)^d(1-B^s)^D Z_t = \theta(B)\Theta(B^s)u_t,$$

where $\phi(B)$ is the autoregressive polynomial of order p, B is the backshift operator, $\Phi(B^s)$ is the seasonal autoregressive polynomial of order P, $\theta(B)$ is the moving average polynomial of order q, $\Theta(B^s)$ is the seasonal moving average polynomial of order Q, d is the degree of differencing in the error series, Z_t, D is the degree of differencing in the seasonal component, s, and u_t is the error term. Missing embedded observations are interpolated in the models.

* Significance at the .01 level.

Table 5
Analyses of arbitrage opportunities provided by the irrational pricing of closed-end funds

Fund	Active arbitrage portfolio of fund and claim		Passive arbitrage portfolio of fund-claim		Equity index		Active arbitrage portfolio overlays onto the equity index			
							Optimal overlay + index		Equal values overlay + index	
	Mean return	S.D.	Mean return	S.D.	Mean return	S.D.	Mean return	Arbitrage weight	Mean Return	*Z* probability for performance
(A) Overall data period: July 31, 1965 to December 31, 1990										
Panel 1: Entire sample estimation of the NAV replicating claim										
2. Abacus Fund	0.0075	0.0364	0.0075	0.0364	0.0095	0.0359	0.0180	1.1340	0.0170	0.2082
3. Adams Express	0.0065	0.0423	0.0014	0.0428	0.0097	0.0443	0.0208	1.7076	0.0162	0.1345[#]
4. Advance Investors	0.0043	0.0575	0.0043	0.0575	0.0036	0.0581			0.0080	0.4238
5. American International	– 0.0046	0.0294	0.0046	0.0294	0.0115	0.0357	0.0162	– 1.0270	0.0070	0.0171[#]
6. Carriers and General	0.0011	0.0405	0.0011	0.0405	0.0049	0.0426	0.0071	1.9973	0.0060	0.4696
7. Central Securities	0.0020	0.0481	0.0020	0.0481	0.0105	0.0453	0.0114	0.4763	0.0125	0.2830
8. Dominik Fund	0.0021	0.0440	0.0021	0.0440	0.0046	0.0401	0.0090	2.0952	0.0067	0.4374
10. General American Investors	0.0042	0.0418	0.0014	0.0420	0.0095	0.0443	0.0145	1.2145	0.0136	0.4081
12. International Holdings	0.0048	0.0563	0.0052	0.0562	0.0053	0.0414			0.0101	0.4925
14. Lehman Corp.	0.0001	0.0374	0.0013	0.0374	0.0093	0.0442	0.0093	– 0.1053	0.0095	0.0583[#]
15. Madison Resources	0.0010	0.0517	0.0005	0.0517	0.0076	0.0440	0.0079	0.3585	0.0086	0.2114[#]
16. Niagara Shares	0.0007	0.0428	0.0007	0.0428	0.0096	0.0441	0.0098	0.3480	0.0102	0.2412[#]
17. Petroleum and Resources Corp.	0.0135	0.0494	0.0003	0.0512	0.0093	0.0442	0.0796	5.2242	0.0227	0.0049
18. Surveyor Fund	– 0.0014	0.0452	– 0.0014	0.0452	0.0028	0.0409			0.0014	0.3727[#]
19. Tricontinental	0.0036	0.0361	0.0024	0.0362	0.0093	0.0441	0.0144	1.4115	0.0129	0.2864
20. United Corp.	0.0040	0.0598	0.0040	0.0598	0.0049	0.0429	0.0779	18.2373	0.0089	0.4862
21. US and Foreign	0.0041	0.0408	0.0041	0.0408	0.0077	0.0443	0.0176	2.4329	0.0118	0.3538
Average fund	0.0031	0.0447	0.0024	0.0448	0.0076	0.0433	0.0224	2.5361	0.0108	0.2876
Panel 2: Moving 48-month sample estimation of the NAV replicating claim										
Average fund	0.0005	0.0472	– 0.0010	0.0472	0.0079	0.0437	0.0124	0.6349	0.0084	0.2783

(B) Overall data period: October 31, 1980 to December 31, 1996										
Panel 1: Entire sample estimation of the NAV replicating claim										
1. Adams Express	0.0041	0.0357	0.0013	0.0359	0.0077	0.0433	0.0203	3.0805	0.0118	0.2578
4. Blue Chip Value Fund	0.0027	0.0392	0.0009	0.0393	0.0113	0.0393	0.0128	0.5433	0.0140	0.4631
8. Engex	– 0.0005	0.0807	0.0005	0.0807	0.0103	0.0390	0.0112	– 0.0024	0.0107	0.0966[#]
10. Gabelli	0.0097	0.0379	0.0001	0.0392	0.0112	0.0420	0.0248	1.1695	0.0231	0.2253
11. General American Investors	0.0053	0.0409	0.0007	0.0412	0.0134	0.0389	0.0169	0.7327	0.0183	0.4977
12. Inefficient Markets	0.0032	0.0396	– 0.0004	0.0397	0.0130	0.0411	0.0115	0.2454	0.0139	0.2325[#]
14. Liberty All Star Equity	0.0038	0.0384	– 0.0002	0.0386	0.0107	0.0325	0.0138	0.5767	0.0154	0.4359[#]
19. Royce Value Trust	0.0024	0.0337	– 0.0013	0.0338	0.0099	0.0225	0.0120	0.3223	0.0136	0.2632[#]
21. Salomon Brothers	– 0.0029	0.0309	0.0029	0.0309	0.0116	0.0401	0.0129	– 0.3801	0.0090	0.0246[#]
22. Source Capital	0.0008	0.0304	0.0008	0.0304	0.0112	0.0409	0.0126	0.2515	0.0132	0.1963[#]
25. Zweig Total Return Fund	0.0012	0.0257	– 0.0012	0.0257	0.0124	0.0321	0.0126	0.1279	0.0136	0.1473[#]
Average fund	0.0027	0.0394	0.0004	0.0396	0.0115	0.0365	0.0147	0.6061	0.0143	0.2582
Panel 2: Moving 48-month sample estimation of the NAV replicating claim										
Average fund	0.0006	0.0332	0.0008	0.0332	0.0140	0.0311	0.0168	0.3627	0.0147	0.1301

An “active arbitrage portfolio” is defined as the monthly sequence of a long position in the closed-end fund and a short position in the NAV replicating claim if the theoretical premia exceeds the actual premia for a month or vice versa. A “passive arbitrage portfolio” is defined as a long position in the fund and a short position in the NAV replicating claim irrespective of the premia values in each month. Arbitrage means and S.D.’s are calculated on the difference of the fund and claim returns. The “equity index” is the CRSP value-weighted NYSE portfolio with distributions. The “optimal overlay” is that combination of the active arbitrage portfolio, with “weight” shown, and the equity index that maximizes the Sharpe performance. The “equal values overlay” is defined as the combination with equal dollar values in the equity index, the fund, and the short position in the claim, respectively. Tests for Sharpe performance larger than the equity index are provided by the one-tail “*Z* probability for Performance.” In panel 1 of (A), the replicating claim is estimated using all available data on the fund, whereas in panel 2 of (A), the replicating claim is estimated using a moving window of 48 lagging months and excludes Funds 2, 4, and 5, which have insufficient data for the moving window. In panel 1 of (B), the replicating claim is estimated using all available data on funds, whereas in panel 2 of (B), the replicating claim is estimated using a moving window of 48 lagging months. Missing values indicate cases where the average T-bill rate exceeded the vertex mean.

[#] Reduced Sharpe performance.

contents of the NAV. An important issue is whether the irrational pricing presents an opportunity for arbitrage, a topic discussed in Section 5.

5. Profitable trading strategies?

There are two types of arbitrage trading strategies to be considered: insider and outsider strategies. In the previous section, we have constructed a contingent claim that replicates the payoffs from a closed-end fund's portfolio. Because we found that the theoretical premia of the replicating claim is nonzero, then in the absence of trading costs, there exists an arbitrage opportunity obtained by trading the NAV portfolio against the NAV replicating claim.[22] However, the exact composition of the fund's portfolio is unknown to outsiders throughout the month. Therefore, arbitrage profits from trading the replicating claim and the NAV portfolio are unavailable to outsiders because of the unknown NAV compositions. An alternative possibility is arbitrage between the fund's price and the NAV replicating claim that may arise because of the difference between the actual price and the theoretical price of the replicating claim.[23]

To investigate the outsider arbitrage possibility, Table 5 contains two self-financing portfolios. An active arbitrage portfolio takes a long position in the fund and an offsetting short position in the replicating claim when the theoretical premium at month close exceeds the actual premium and vice versa. The position is revised at the close of each succeeding month of the fund's data series. Because most funds have a negative actual premia, this study as well as previous research examines a passive arbitrage portfolio that simply takes a long position in a fund and an offsetting short position in the replicating claim at the close of each month. These arbitrage portfolios are constructed for each fund.[24]

To avoid any problems of interpreting the self-financing arbitrage portfolio returns, the two arbitrage portfolios are each overlaid onto an equity index and the performance improvements to the index observed. For brevity, only overlays involving the active arbitrage portfolio are displayed in detail in Table 5A and B.

5.1. Overlay portfolio theory

Overlay portfolios require a specification of the dollar amount of the overlay per dollar of index investment. Two overlays are constructed; the first is an equal value overlay that has equal absolute dollar amounts in the equity index, the long position of the arbitrage portfolio, and the short position of the arbitrage portfolio. The second is the optimal overlay that

[22] See Naik and Uppal (1994) for a discussion and analysis of the costs involved.

[23] Prior literature investigates the arbitrage between the actual NAV returns and the fund price returns, rather than between the NAV replicating claim and the fund price returns or between the actual NAV returns and the NAV replicating claim.

[24] Throughout the paper, we use the term *arbitrage portfolio* to indicate a self-financing portfolio that may provide desirable investment opportunities, be they riskless or risky.

maximizes the Sharpe ratio. This optimal overlay is constructed by investing a fixed dollar amount in the equity index and an optimal dollar amount in the long position of the arbitrage portfolio and the same optimal amount in the short position of the arbitrage portfolio. The results from the two overlays help to determine the importance of knowing the proportions in the arbitrage overlay.

The mean return from an overlay is [Eq. (7)]

$$\mu_O = \mu_I + \omega\mu_A, \tag{7}$$

where μ_I is the index mean return, ω is the weight or ratio of the dollar amount long and short in the arbitrage portfolio to the dollar amount long in the index, and μ_A is the net mean return on the arbitrage portfolio.[25] The optimal arbitrage weight that maximizes the Sharpe ratio on the overlay is [Eq. (8)]

$$\omega^* = \frac{[\mu_A\sigma_I^2 - \sigma_{IA}(\mu_I - r_f)]}{[\sigma_A^2(\mu_I - r_f) - \mu_A\sigma_{IA}]}, \tag{8}$$

where σ_j^2 is the variance of return on asset j and σ_{IA} is the covariance between the returns on the index and the arbitrage portfolio. The performance of the overlay is measured by the change to the equity index Sharpe performance effected by the overlay. In the case of the equal values overlay, the test statistic is distributed standard normal Z.[26] The last four columns of Table 5A and B show the performance data from the active overlays. The tables are as usual divided into two panels representing the moving window sample results for the average fund and each fund's total sample results.

5.2. Overlay results

The active and passive arbitrage portfolio returns average 0.0031 and 0.0024, respectively, in Set A and 0.0027 and 0.0004, respectively, in Set B. These compare with the index average (over each fund's data period) of 0.0076 in Set A and 0.0115 in Set B. When the active arbitrage portfolio is overlaid onto the equity index, the resulting optimal overlay plus index has a mean return of 0.0224 in Set A and 0.0147 in Set B for the average fund and a small improvement (not shown) in the index's Sharpe measure for almost every fund in Sets A and B. To achieve the maximum performance, the optimal arbitrage weight was 2.53 in Set A and 0.606 in Set B for the average fund, when an optimal weight was calculable.[27] Although there was substantial weight variation from fund to fund, these optimal weights were long positions on the arbitrage portfolio as suggested by the arbitrage portfolio rule. These data suggest that

[25] Throughout, the return from a self-financing portfolio is defined as the difference in the returns on the long and short components. When used in conjunction with an overlay, this definition of return properly defines the overlay portfolio's returns.

[26] Jobson and Korkie (1981) spanning and intersection tests for optimal overlays are not employed here but are developed in Korkie and Turtle (2000).

[27] Weights are not calculated when the T-bill rate exceeds the vertex portfolio's mean because the resulting tangent portfolio is on the bottom of the hyperbola.

there is a potential advantage obtained by overlaying the equity index with an arbitrage portfolio of the fund and its NAV replicating claim, conditional upon choosing the optimal combination of the index and the arbitrage portfolio.

The preceding tests would not necessarily violate market efficiency because the optimal weight is unknown at the time of portfolio formation. An equal values overlay, versus the previous optimal overlay, does not search in sample for an optimum. So, an equal values overlay is useful for determining whether any economic advantages of the optimal overlay stem from knowing the maximizing weight.

When the active arbitrage portfolio is overlaid onto the equity index, the resulting equal values overlay plus the index has a mean return of 0.0108 in Set A and 0.0143 in Set B for the average fund, an increase over the index's means in both sets. However, only one fund (Fund 17) in Set A and no funds in Set B significantly increase the index's Sharpe measure. In addition, 5 of 17 Set A funds and 7 of 11 Set B funds decrease the index Sharpe ratio (two significantly in Set A and two in Set B, at the .10 level).

These results imply that the choice and advance knowledge of the overlay weight is critical to avoiding poor overlay performance. Therefore, overlaying the equity index with an active arbitrage portfolio of a fund and its NAV replicating claim may not produce significant improvements to simply holding the index. The panel 2 results are similar.[28]

6. Concluding comments

The analyses indicate that management value differs across closed-end funds and is reflected in our estimated, theoretical closed-end fund premia. The theoretical premia provide approximately zero arbitrage between the fund's net asset portfolio and a NAV replicating portfolio, replicated from five style portfolios. The existence of theoretical fund prices that differ from per share NAVs suggests that there is positive or negative value in fund management and that NAV is not an accurate indicator of fundamental value.

The theoretical premia have some similar properties to observed market premia such as the well-known autocorrelation in premia and the lack of premia correlation with future NAV returns; but, the actual and theoretical premia have different properties as well and they are uncorrelated.

Irrational pricing of the funds is due to the lack of correspondence between the observed fund premia and the theoretical premia. Systematic errors exist in the market premia compared with the theoretical premia. This implies available arbitrage profits from trading the NAV replicating portfolio and the fund's actual assets. Despite the profitability of this strategy, no profitable investment opportunities are obtainable by an alternative strategy of overlaying an equity index with an arbitrage portfolio that is long a fund and short its NAV replicating portfolio or vice versa. Arbitrage profits may exist only if there is advance knowledge of the optimal mix of the index and the arbitrage portfolio in the overlay. These

[28] Although not reported in the last four columns of Table 5, similar results and conclusions were obtained for the passive arbitrage portfolio overlay.

properties and results hold in the original LST data as well as in our new sample of funds from Malkiel that update the time period to the close of 1996.

It seems that an outsider cannot profit from the arbitrage overlays thereby preserving one dimension of market efficiency. However, insiders have an opportunity for arbitraging between the NAV replicating claim and the fund's net asset portfolio. Our large R^2's, long time series samples, and significant regression coefficients provide confidence that the quadratic function is a reasonably good description of the contingent claim generated by portfolio managers' trading. It remains a puzzle why a contingent claim, which closely replicates the NAV returns from a managed portfolio, has arbitrage free theoretical prices that differ systematically from the fund's market prices.

Acknowledgments

This paper was partially completed while Korkie was visiting Koç University and Washington State University. The research is supported in part by the SSHRC. The paper was first presented at the meetings of the *Northern Finance Association*, September 1998. We thank Charles Lee for providing the original data as well as Raymond Kan for providing his corrections to the same data file. Ranjini Sivakumar provided the expanded data set. The comments of Ken Beller, Steve Beveridge, Mark Huson, Dave Jobson, Aditya Kaul, Lawrence Kryzanowski, and Chu Zhang, at various stages of the paper are appreciated.

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