Speed of Adjustment in U.S. Financial Markets

The perils of asset timing.

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It is accepted in investment management that the composition of the asset mix in a portfolio is a major determinant of portfolio return. Models of asset allocation fall into two major categories, *fixed-weight* and *flexible-weight*. In the fixed-weight model, portfolio allocations are specified and remain constant, so occasional rebalancing to maintain these weights is required.

In the flexible-weight model, asset weights are determined by a quantitative analysis, often involving changing economic or market conditions and relative asset valuations. Some quantitative investment managers offer asset allocation funds that manage the asset mix according to a flexible-weighting strategy. It is also common for investment strategists to suggest changes to a client's asset mix depending on changing investment fundamentals and relative valuations.

Flexible-weight asset allocation is divided into two major types, strategic and tactical; strategic is the more long-term version. It is often argued that both types depend on mean reversion of asset returns for their justification (see Campbell and Viceira [2002]).

A subcategory of flexible-weight asset allocation is *equity style timing*. Equity style timing is concerned with adjusting the portfolio weights of equity styles (e.g., value versus growth and small-cap versus large-cap) as economic or market conditions change. Examples of this approach are found in Fan [1995], Kao and Shumaker [1999], Asness et al. [2000], and Coggin and Fabozzi [2003].

Typically the shifts in a flexible-weight approach involve stocks, bonds, and possibly cash. For this approach

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to be successful, the returns on the assets in the portfolio must be *predictable.* That is, any statistical model that attempts to time the shifting of funds from one asset to another assumes the assets have returns that can be successfully forecasted.

We use U.S. financial market data from the post-World War II era to examine examples of asset shifts in the flexible-weight model between stocks and cash, stocks and bonds, or within equity styles. The research focuses on two critical aspects of the flexible-weight model: first, the predictability of the individual assets commonly included, and second, the speed of adjustment of one asset valuation to another as a rationale for flexible-weight asset allocation. We are concerned with the nature of the statistical evidence for the efficacy of flexible-weight asset allocation.

Arshanapalli, Coggin, and Nelson [2001] find that a 60/30/10 (stocks/bonds/cash) fixed-weight asset allocation compares favorably to flexible-weight asset allocations based on the recommendations of Wall Street investment strategists. This result casts some doubt on the overall value of the recommendations, especially if they are costly. Other studies have questioned the consistency over time of the small-large and value-growth stock premiums; Bauman and Miller [1997] challenge the value-growth premium, and Siegel [1998] challenges the small-large premium.

Jensen, Johnson, and Mercer [1998] argue that when changes in monetary conditions are included in the analysis, these challenges are muted. Campbell and Viceira [2005] use a vector autoregressive model approach to mean-variance asset allocation, and suggest that dividend yields, interest rates, and yield spreads have predictive power in portfolios of stocks, bonds, and bills. Hence changes in additional macroeconomic time series variables may well be associated with the relationships we discuss (although an investigation of this hypothesis is beyond the scope of our work here).

DATA AND METHODOLOGY

The time period is January 1946 through December 2003 (696 months). The data come from Dimensional Fund Advisors *ReturnsW* software.

Data

Our primary data are monthly index total returns (price change plus dividends or interest). From these monthly returns we construct end-of-month *price level indexes*, where June 30, 1926 = 1.00.[1]

To focus on the post-World War II era, we begin our sample with January 1946. The monthly price level indexes are the focus of our statistical analyses. The data are converted to natural logs for all statistical tests in this study.

The U.S. financial market data include monthly price level indexes for: the S&P 500, CRSP 1-5, CRSP 9-10, F/F large value and F/F large growth equity style indexes, one-month T-bills, and long-term government bonds. The S&P 500 is the Standard & Poor's 500 stock index; CRSP 1-5 is the Center for Research in Security Prices market capitalization deciles 1 through 5 (large-cap) stock index; CRSP 9-10 is the 9 through 10 deciles (small-cap) index; F/F large value is the Fama and French [1992] large value stock index; F/F large growth is the Fama and French large growth index; one-month T-bills is an index of T-bills with a maturity of one month; and long-term government bonds is an index of long-term government bonds (20+ year maturity).

Methodology

We include three types of tests: unit root, cointegration, and error correction.

Unit root tests. Coggin [1998] uses the variance ratio test of Lo and MacKinlay (1989) and the modified rescaled range test of Lo (1991), and shows that U.S. equity style price level indexes follow a random walk and do not exhibit long-range dependence. A random walk finding implies that future values of the indexes are not mean-reverting, and thus not predictable from past values alone.

A random walk is a special case of a unit root process where the first differences of a time series are uncorrelated. If a time series variable has a unit root, it is non-stationary. Depending on its form, non-stationarity complicates predictability.

We use the augmented Dickey-Fuller (ADF) [1979] and Said and Dickey [1984] regression test to examine the null hypothesis that a unit root in our monthly price level indexes allows higher-order autocorrelation in the indexes, with and without a structural break.[2]

It is now well established that a structural break in a time series (i.e., a break in the intercept, the slope, the variance, or any combination) can cause spurious rejection or acceptance of the unit root hypothesis, largely depending on the location of the break (see Busetti and

Taylor [2003] for a discussion). In economic and financial time series data, structural breaks include events such as wars, stock market crashes, oil embargoes, and major tax cuts and hikes.

As one would expect, structural breaks are problematic for statistical tests of relations among variables. Specifically, unit root and cointegration tests naturally suffer from relatively low statistical power, a problem exacerbated by structural breaks. Thus, when such breaks are suspected, unit root tests and cointegrating error correction models that allow such breaks should be used. Otherwise, erroneous conclusions are even more likely to be reached.

By including dummy variables for the level (intercept) and slope, Zivot and Andrews [1992] suggest a modification of Perron's [1989] ADF unit root test that allows a single break in the level, the slope, and both the level and slope of a deterministic trend for a time series at an *a priori* unknown time. We use the ADF methodology for their Model C, the most general case, which tests for a unit root while allowing a break in both the level and the slope.

Cointegration. Even if individual variables have a unit root, all is not lost. The concept of *cointegration* implies that there can be a linear combination of two (or more) non-stationary unit root time series variables that is stationary with mean, variance, and autocorrelation and that is independent of time.[3]

That is, if two variables are cointegrated, they cannot move independently of each other for long. This implies a predictable and long-run equilibrium relation between them over time. The quantitative measure of the equilibrium relationship is called the *speed of adjustment*.

If two unit root variables are not cointegrated, they are not jointly predictable using past values of each. Thus there is no equilibrium speed of adjustment between them, casting doubt on a flexible-weight asset allocation approach.

In their Nobel Prize-winning work, Engle and Granger [1987] propose a regression model to test for the cointegration of two unit root time series variables, y_t and x_t:

$$y_t = \alpha_0 + \alpha_1 x_t + \varepsilon_t \tag{1}$$

where ε_t is the regression error term and t = time.

This model is tested by a Dickey-Fuller ADF unit root test on the regression residuals, ε_t.[4] A rejection of the unit root null hypothesis for ε_t implies that the two time series are cointegrated of order 1. Because the Dickey-Fuller ADF cointegration test is based on the residuals estimated by a cointegrating regression, the cointegrating relation is not necessarily symmetric in finite samples (see Davidson and MacKinnon [1993, Chapter 20] for a discussion).

Thus we run the cointegrating regressions exchanging dependent and independent variables. The single-equation, residual-based, regression model of Engle and Granger has been shown to have more desirable properties than other approaches in the two-variable (one cointegrating vector) case (see Gonzalo and Lee [1998]).

Error correction. Engle and Granger [1987] suggest an error correction model (ECM) for two cointegrated time series variables, y_t and x_t:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta x_t + \alpha_2 \varepsilon_{t-1} + u_t \tag{2}$$

where $\Delta y_t = y_t - y_{t-1}$; $\Delta x_t = x_t - x_{t-1}$; ε_{t-1} from Equation (1) is an instrumental variable for $(y_{t-1} - \alpha x_{t-1})$; and u_t is the regression error term. In this model, the speed of adjustment (equilibrium error correction coefficient) is estimated by α_2. The speed of adjustment is the rate at which the two unit root time series return to a long-run equilibrium relation.

The original Engle-Granger [1987] regression model for cointegration does not include a structural break. Gregory and Hansen [1996] derive a model that allows a single structural break at an *a priori* unknown time, of which the original Engle-Granger model is a special case. They allow a break in the intercept, the slope, or both the intercept and the slope of the cointegrating regression. We use the ADF methodology for the Gregory and Hansen Model 4, the most general case, which tests the residuals from a cointegrating relation while allowing a structural break in both the intercept and slope at a single unknown time.

In order to deal with the problem of a structural break in the level and the slope (or both) in the Engle-Granger error correction model, Arranz and Escribano [2000] suggest a *robust extended error correction model* (RECM) for two cointegrated time series variables, y_t and x_t, using lags of ε_t:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta x_t + \alpha_2 \varepsilon_{t-1} + \alpha_3 \varepsilon_{t-2} + u_t \tag{3}$$

where ε_{t-1} and ε_{t-2} estimated from the cointegrating regression for y_t on x_t are instrumental variables for $(y_{t-1} - \alpha x_{t-1})$ and $(y_{t-2} - \alpha x_{t-2})$, respectively, and u_t is the regression error term. Arranz and Escribano show that this model

EXHIBIT 1
Summary Statistics: January 1946–December 2003

	S&P 500 Index	CRSP 1-5 Index	CRSP 9-10 Index	F/F Lrg Value Index	F/F Lrg Growth Index	One-Month T-bills	Long-Term Gov't Bonds
Annualized Return (%)	11.58	11.31	12.67	13.79	10.66	4.69	5.66
Total Return (%)	57,590	49,846	100,918	179,665	35,418	1,327	2,339
Growth of $1	$577	$500	$1,010	$1,798	$355	$14	$24
Annual Standard Deviation (%)	17.20	17.06	29.44	21.68	18.01	3.03	10.49
Annual Average Return (%)	12.92	12.63	16.28	15.79	12.14	4.73	6.14

EXHIBIT 2
Unit Root Tests

	ADF Unit Root Tests (5% Level)	
Price Level Indexes	Dickey-Fuller	Zivot-Andrews
S&P 500	Yes	Yes
One-Month T-Bills	Yes	Yes
F/F Large Value	Yes	Yes
F/F Large Growth	Yes	Yes
CRSP 1-5	Yes	Yes
CRSP 9-10	Yes	Yes
Long-Term Government Bonds	Yes	Yes

Yes indicates all tests accept the ADF null hypothesis of a unit root in the price level indexes at the 5% level.

is robust to the presence of one unknown structural break (or two) in the cointegrating relation. As in the Engle-Granger ECM model, the speed of adjustment (error correction coefficient) is estimated by α_2.

RESULTS

Exhibit 1 presents summary statistics for the data. Confirming the predictions of financial theory, stocks outperform bonds, with a higher standard deviation, and small stocks outperform large stocks, with a higher standard deviation. Partially confirming the prediction of behavioral finance, large value stocks outperform large growth stocks, but with a higher standard deviation.

Unit Root Tests

Exhibit 2 presents the results of unit root tests for the seven end-of-month price level indexes. This exhibit shows that each index confirms the unit root null hypothesis at the 5% level, using the Dickey-Fuller and Zivot-Andrews ADF tests.

The results in Exhibit 2 are not sensitive to the presence of a time trend in the time series regression model. Thus we will assume each index has a unit root. In time series language, we assume each index is integrated of order 1. The structural break dates estimated by the Zivot-Andrews tests vary between November 1968 and April 1994.[5]

Engle-Granger Cointegration Tests

Exhibit 3 presents the results of the Engle-Granger unit root cointegration tests. We have noted that the cointegrating relation is not necessarily symmetric in finite samples. Therefore we run each test exchanging dependent and independent variables. The primary relationships tested are: the S&P 500 versus one-month T-bills (corresponding to stocks versus cash), F/F large value versus F/F large growth (corresponding to value versus growth), CRSP 1-5 versus CRSP 9-10 (corresponding to large-cap versus small-cap), and S&P 500 versus long-term government bonds (corresponding to stocks versus bonds).

Exhibit 3 shows that for each cointegrating relation tested, we accept the (unit root) null hypothesis of no

EXHIBIT 3
Engle-Granger Unit Root Cointegration Tests

	Dickey-Fuller ADF Cointegration Test	
Cointegrating Relationships	10% Level	5% Level
S&P 500 vs. One-Month T-Bills	No	No
One-Month T-Bills vs. S&P 500	No	No
F/F Large Value vs. F/F Large Growth	No	No
F/F Large Growth vs. F/F Large Value	No	No
CRSP 1-5 vs. CRSP 9-10	No	No
CRSP 9-10 vs. CRSP 1-5	No	No
S&P 500 vs. Long-Term Government Bonds	No	No
Long-Term Government Bonds vs. S&P 500	No	No

No indicates the test accepts the ADF null hypothesis of a unit root in the residuals of the cointegrating regression indicating no cointegrating relationship. Critical values are taken from Davidson and MacKinnon [1993], Table 20.2.

EXHIBIT 4
Gregory-Hansen Unit Root Cointegration Tests

	Gregory-Hansen ADF Cointegration Test	
Cointegrating Relationships	10% Level	5% Level
S&P 500 vs. One-Month T-Bills	No	No
One-Month T-Bills vs. S&P 500	No	No
F/F Large Value vs. F/F Large Growth	Yes	No
F/F Large Growth vs. F/F Large Value	No	No
CRSP 1-5 vs. CRSP 9-10	No	No
CRSP 9-10 vs. CRSP 1-5	No	No
S&P 500 vs. Long-Term Government Bonds	Yes	Yes
Long-Term Government Bonds vs. S&P 500	No	No

No indicates the test accepts the ADF null of a unit root in the residuals of the cointegrating regression indicating no cointegrating relationship. Yes indicates the presence of a cointegrating relationship. Critical values are taken from Gregory and Hansen [1996], Table 1.

cointegrating relation. The results in Exhibit 3 are not sensitive to the presence of a time trend in the cointegrating regression model.

The finding of no cointegrated relation eliminates the justification for estimating the original Engle-Granger ECM and its speed of adjustment parameter. Thus, if we want to test an error correction model in our data, we must first use a cointegrating regression model that allows a structural break.

Gregory-Hansen Cointegration Tests

Exhibit 4 presents the results of the Gregory-Hansen unit root cointegration tests that allow a one-time break in both the level and the slope of the cointegrating regression at an *a priori* unknown time. We find marginal evidence of a cointegrating relation between the F/F large value and large growth price level indexes at the 10% significance level, with large value as the dependent variable. We also find stronger evidence of a cointegrating relation between the S&P 500 and long-term government bond price-level indexes at both the 10% and the 5% significance levels, with the S&P 500 as the dependent variable.

The structural break dates estimated by the Gregory-Hansen model are December 1974 for large value and large growth and June 1960 for stocks and long-term bonds.

EXHIBIT 5
Arranz-Escribano Robust Error Correction Model

Cointegating Relationship	Error Correction Term Significance	
	10% Level	5% Level
F/F Large Value vs. F/F Large Growth	No	No
F/F Large Growth vs. F/F Large Value	No	No
S&P 500 vs. Long-Term Government Bonds	No	No
Long-Term Government Bonds vs. S&P 500	Yes	Yes

Yes indicates significantly different from zero using autocorrelation and heteroscedasticity-consistent standard errors. The error correction term is from the OLS regression defined in Equation (3).

Arranz-Escribano Robust Error Correction Models

Exhibit 5 presents the results of the Arranz-Escribano robust error correction models. We have shown so far that of all the cointegrating relations we test in Exhibit 4 using the Gregory-Hansen methodology (which allows a structural break), only F/F large value versus F/F large growth and S&P 500 versus long-term government bonds present a cointegrating relation. Thus these are the only relations we deemed eligible to be tested further using the Arranz-Escribano RECM, which also allows a structural break.

Exhibit 5 shows that only the long-term government bonds versus S&P 500 cointegrating relationship has an error correction term significantly different from zero (the error correction term is equivalent to the speed of adjustment parameter).

Thus, of all the relations tested here allowing a structural break in the time series, only long-term government bonds and the S&P 500 have a cointegrating relation with a significant speed of adjustment term.

SUMMARY AND CONCLUSION

We have examined an important substantive question for professional investment management: Is flexible-weight asset allocation in U.S. financial markets supported by the statistical evidence? The tools include a battery of econometric tests recently developed to estimate the predictability and speed of adjustment of economic time series data subject to unit roots and structural breaks.

Given the difficulty in estimating precise statistical relations between and among unit root time series variables, we note that our findings are suggestive and not definitive. For example, in our data the Gregory-Hansen [1996] and Arranz-Escribano [2000] models give conflicting results for specification of the cointegrating regression of the S&P 500 and long-term government bonds. There may also be additional long-run "forcing variables" we have omitted that could facilitate a cointegrating relation (see Pesaran, Shin and Smith [2000]). Recent advances in fractional cointegration may also add clarity to research on this topic (see, e.g., Gil-Alana [2003]).

For these reasons, we are not yet ready to declare that flexible-weighting is without value. While it may appear doubtful as a general practice, some investment professionals might demonstrate economically valuable skill in this area.

Our findings suggest nonetheless that successful flexible-weight asset allocation in U.S. financial markets is likely to be difficult. By successful, we mean likely to add value over the appropriate fixed-weight allocation. Of all the relationships we test, only the long-term government bonds versus the S&P 500 relation (bonds versus stocks) has a significant speed of adjustment parameter suggesting a predictable and long-run equilibrium relationship. Our results further suggest that all the other relations we test can be described as two non-stationary (unit root) time series that do not have a long-run equilibrium relationship to which they return over time.

Simply put, our results suggest that an asset allocation strategy that depends on the return of combinations of individual asset values to a common equilibrium relation is likely to be problematic.

But why is fixed-weight asset allocation any better? After all, our results suggest that several key U.S. financial assets commonly found in the portfolios of individuals and institutions are best described as non-stationary and non-cointegrated, and thus non-predictable.

The answer, we suggest, is that even though these variables are unit root non-stationary and their values randomly fluctuate, *they randomly fluctuate around different levels.* In time series terminology, this is called random walk with drift.

Take large value stocks and large growth stocks as an example. In Exhibit 1 we see that the long-term average return (i.e., the long-term level) of large value stocks is 3.13 percentage points per year higher than the return of large growth stocks. The random fluctuations of these individual assets around their respective levels appear to be independent and thus cannot be predicted. Yet long-term investors might still benefit (add incremental return) by holding a portfolio that consistently overweights large value stocks if that strategy fits their risk/return profile, and assuming the long-term difference in levels persists.

While we have no formal evidence on this issue, we are aware that a number of institutional investors remain skeptical of attempts to allocate between assets in a portfolio using some quantitative decision rule. With the possible exception of long-term U.S. government bonds and stocks, our results suggest this skepticism may be well-founded.

ENDNOTES

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[1]All data begin with January 1926 except the Fama and French data, which start in July 1926. Hence we set the common starting point for the data at June 30, 1926.

[2]The original augmented Dickey-Fuller (ADF) regression model to test a time series variable, y_t, for a unit root is:

$$\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 t + \Sigma\gamma_j \Delta y_{t-j} + \varepsilon_t$$

where $\Delta y_t = y_t - y_{t-1}$, t = time, j = number of lags used to capture the autocorrelation in y_t, and ε_t is the regression error term. The ADF test used here is a t-test for the null hypothesis that $\alpha_1 = 0$ (y_t has a unit root) against the alternative hypothesis that $\alpha_1 < 0$. All unit root and cointegration tests in our study have a maximum j of 10.

[3]Non-linear cointegration is also possible, but the econometric methodology is not well developed at this time.

[4]In tests of Engle-Granger regression residuals for a unit root, the Dickey-Fuller ADF regression model has no intercept and no time trend.

[5]To check for the possibility of a second unit root, we carried out Dickey-Fuller ADF tests on the first differences of each price level index. Each test rejected the unit root null at the 5% level except for one-month T-bills.

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