Is There Conditional Mean Reversion in Stock Returns?

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This research examines the behavior of ex post returns, expected returns, and residual returns for book-to-market equity/size portfolios for the period from June 1963 through December 1996 for stocks listed on the NYSE, AMEX, and Nasdaq. Utilizing the methodological approach employed by Fama and French (1992, 1993, 1995, 1996a), the results of this research indicate that expected returns generated by the Fama-French three-factor model have a similar mean-reverting structure to their corresponding ex post returns. Furthermore, the results indicate that there is no significant decrease in the mean-reverting tendency between residual returns and their corresponding ex-post returns. The tendency for mean reversion seems to be closely related to companies traded on the AMEX and Nasdaq markets, which, for the sample period examined in this study, share common attributes of smaller size and lower book-to-market equity ratios. These findings support the hypothesis that there exists conditional mean reversion in stock returns and that the Fama-French three factor model is unable to fully account for the mean reversion tendency.

Introduction

Recent research by Fama and French (1988a, 1988b), Poterba and Summers (1988), and Bekaert and Hodrick (1992) reports significant negative serial correlation in long-term stock returns. One explanation for this statistical phenomenon is that there exists a stationary component in stock prices. The existence of a stationary component in stock prices implies that stock returns should revert to their mean returns in the long run. In this sense, the term *mean reversion* can be used to describe the existence of a stationary component in stock prices.

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In the absence of an equilibrium model for expected stock returns, the link between mean reversion in stock returns and market efficiency is not clear. Nevertheless, there are several interesting implications of mean-reverting stock returns for market efficiency. For example, suppose that (ex-post) stock returns can be decomposed into two parts: (1) an (conditional) expected return component and (2) an unexpected return component. Under this scenario, if an expected return-generating model can be specified that can fully explain the mean reversion phenomenon such that the unexpected return component is serially uncorrelated, then mean-reverting stock returns are consistent with market efficiency. Fama and French (1988a, 1988b) suggest that the stationary component in stock prices is caused by time-varying expected returns and, hence, is not inconsistent with market efficiency. On the other hand, if the assumed expected return-generating model cannot fully account for the mean reversion phenomenon in stock returns, then this is evidence inconsistent with market efficiency. In addition to the empirical finding of the mean reversion phenomenon, there is considerable evidence of time-varying expected returns [e.g., Keim and Stambaugh (1986), Campbell (1987), French, Schwert, and Stambaugh (1987), Fama and French (1988a, 1988b), Fama (1990), and Balvers, Cosimano, and McDonald (1990)].

This research investigates whether time-varying expected returns can fully account for mean reversion in stock returns. To examine this issue, the three-factor predictive model proposed by Fama and French (1992, 1993, 1995, 1996) is used to extract expected returns from ex post returns. Within the context of the predictive Fama and French three factor model, this research examines this issue and extends the literature in several respects. First, while most prior studies have focused on the price behavior of the market portfolio and sub-portfolio levels for stocks listed only on the NYSE, this research extends the database to include smaller companies listed on the AMEX and the OTC, given the results of prior research that suggest that the mean reversion phenomenon may be related to the size of the company. Second, while prior research has examined the ability of the Fama-French model to explain mean reversion with the use of regression techniques, this research provides a direct measure of the presence of mean reversion through the use of a variance ratio test in examining of the autocorrelation structure present in total, explained, and residual returns, after controlling for the effects of the Fama-French pricing factors. Variance ratio tests are more powerful than regression analyses in addressing Type II errors (Poterba and Summers, 1988) in assessing autocorrelation in returns. Finally, unlike previous research that has concentrated on the autocorrelation in stock returns at long horizons with annual increments, this research also examines the autocorrelation structure in stock returns at horizons from two months to 10 years.

The results of this research indicate strong positive autocorrelation in stock returns for short return horizons, particularly for those in smaller-sized and smaller book-to-market ratio portfolios comprising primarily securities traded on the AMEX and Nasdaq markets. This short-run, positive autocorrelation structure is present for both total excess returns as well as for expected and residual returns, as measured by the Fama-French three-factor model. Second, for longer return horizons, there is the presence of negative autocorrelation, indicating the presence of mean reversion. The finding of mean reversion in both the total and the expected and residual returns indicates that while controlling for the Fama-French factors may help explain many of the reported pricing anomalies (Fama and French, 1996), these factors cannot fully explain the existence of mean reversion.

Defining Mean Reversion in Stock Returns

Fama and French (1988b) regress current returns on past returns to examine the serial correlation in NYSE stock returns for decile-sized portfolios, industry portfolios, and equally-weighted and value-weighted market portfolios. Their finding of an autocorrelation pattern in stock returns is consistent with the hypothesis that stock prices have a slowly-decaying stationary component. Poterba and Summers (1988) also examine mean reversion in stock prices using a variance-ratio test on monthly data. Their results show that ex-post returns exhibit positive autocorrelation over short horizons, but display strong negative autocorrelation over longer horizons. Poterba and Summers (1988) conclude that their results are consistent with the existence of a stationary component in stock prices.[1]

In a related paper, Summers (1986) hypothesizes that stock prices have two components–a random walk (permanent) component and a stationary (temporary) component.[2]. That is, suppose that there is a positive stationary shock[3] at time t so that P_t (the stock price at time t) increases and is larger than what it would be without the positive stationary shock. Thus, it is expected that $\ln P_t - \ln P_{t-Q} \approx R_{t-Q,t} \geq r$, where r is the constant drift term from the random walk component and is the grand mean of all stock returns. Assuming that Q is large enough so that P_{t+0} will not be affected by the stationary shock at time t and reverts to the level that is determined by the permanent component, it is expected that $\ln P_{t+Q} - \ln P_t \approx R_{t,t+Q} \leq r$. Thus, this

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[1]Jagadeesh (1991), Gangopadhyay (1996), and Gangopadhyay and Sen (1999) further report seasonal mean reversion; they observe that stock returns in January display mean-reverting behavior, while this is not the case for stock returns in other months. On the other hand, Richardson and Stock (1989), Kim et al. (1991), and McQueen (1992) make adjustments to statistical techniques of estimating autocorrelation in stock returns and report that the random walk hypothesis cannot be rejected.

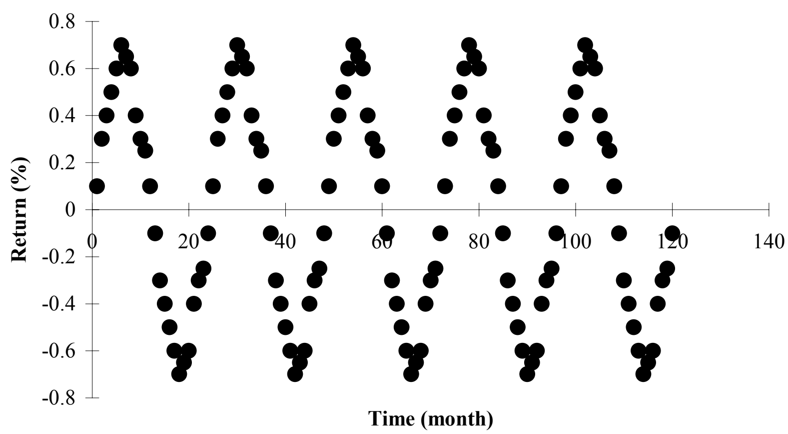
[2] Assuming that the permanent and stationary components are generated by two independent mechanisms, Fama and French (1988b) show that the existence of both components might produce a U-shaped pattern in the serial correlation of ex post returns.

[3] Note that the following argument can be similarly applied to the case in which a stationary shock is negative.

stationary shock tends to induce negative autocorrelation in stock returns at some Q.[4] That is, stock returns will fluctuate around the grand mean r. Therefore, the stationary component in stock prices induces mean reversion in (ex-post) stock returns. This stationary component in stock prices should cause stock prices to move around the levels solely determined by the random walk (permanent) component, however, but not around the grand mean of stock prices.

Mean reverting stock returns do not necessarily require ex-post stock returns to have negative serial correlation at all horizons. Therefore, even though positive autocorrelation in ex-post short-term stock returns is consistent with mean-reverting stock returns, this does not necessarily support the mean-reverting stock return hypothesis. To see this argument, suppose that we have a 10-year sample of monthly continuous returns on a stock (Figure 1).[5] As shown in Figure 1, stock returns are mean reverting. If one examines the serial correlation of these monthly returns, one would expect to see a positive autocorrelation. Now, if a series of ten annual returns is constructed from this sample of monthly returns (by summing every 12 adjacent monthly returns), a plot of these annual returns is shown in Figure 2 below. It can be seen from Figure 2 that the serial correlation of these annual returns is likely to be negative. Thus, mean-reverting stock returns do not necessarily require the serial correlation of stock returns to be negative at all horizons.

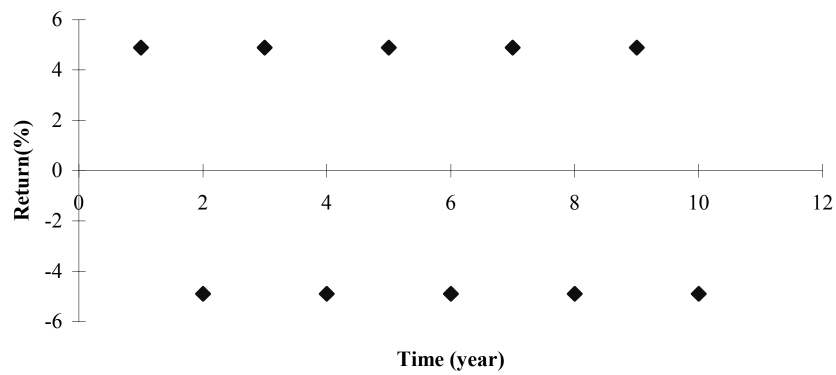
Figure 1–Mean Reverting Monthly Stock Returns with Positive Autocorrelation



[4] Note that, unlike the proof by Fama and French (1988b), the argument offered here does not make the assumption that the stationary and permanent components are generated by two independent (or at least uncorrelated) mechanisms. Therefore, it is possible that the serial correlation in stock returns at some horizon is negative even when the stationary and permanent components are dependent on each other in some manner.

[5] Note that Figure 1 shows a perfect case of mean reverting stock returns which is sufficient for purposes of this argument.

Figure 2–Mean-Reverting Stock Returns with Negative Autocorrelation in Stock Returns (%)



Testing for Mean Reversion under Time-Varying Expected Returns

The Hypothesis

Assume that P_t^* is the time t stock fundamental value such that r_t is the time-varying expected return for the period from time t - 1 to time t. Assume further that the observed market value P_t has the following relationship with the fundamental value P_t^*:

$$\ln P_t = \ln(P_t^*(1+x_t)) = \ln P_t^* + \ln(1+x_t) = \ln P_t^* + x_t \tag{2}$$

where x_t is the multiplicative factor resulting from the long swing of stock prices away from fundamental values due to pure speculative activities in the market. Note that x_t and P_t^* are assumed to be generated by two independent (or at least uncorrelated) mechanisms. Equation (2) enables us to denote stock returns in the following form:[6]

$$\begin{aligned} R_t &= \ln P_t - \ln P_{t-1} = \ln P_t^* - \ln P_{t-1}^* + x_t - x_{t-1} \\ &= E[R_t | \Omega_{t-1}] + e_t + x_t - x_{t-1} = r_t + e_t + u_t\ . \end{aligned} \tag{3}$$

[6] The analysis presented here can be viewed as an extension of Fama and French (1988b), and Poterba and Summers (1988) in that both of these papers hypothesize that $R_t = \ln P_t - \ln P_{t-1} = r + e_t + z_t - z_{t-1}$ where z_t is the (multiplicative) stationary component in time t's stock price.

Equation (3) decomposes stock returns into three parts: (1) r_t, which is the time-varying expected return and is assumed to follow a mean-reverting process, (2) e_t, which is the fundamentally-related residual term, and (3) $u_t (= x_t - x_{t-1})$, which results from the long swing of stock prices away from fundamental values and is assumed to follow a mean-reverting process, if any. Because r_t and e_t result from the fundamental value P_t^*, the term *fundamental component* will be used to denote $(r_t + e_t)$, and u_t is the *speculative component*, because it is caused by the long swing of stock prices away from fundamental values.[7]

The preceding discussion leads to the following time-varying expected return hypotheses:

$$H_0: \ R_t = r_t + e_t, \tag{4a}$$

$$H_a: \ R_t = r_t + e_t + u_t. \tag{4b}$$

These hypotheses will be examined to determine whether time-varying expected returns fully account for the stationary component in stock prices. Under the alternative hypothesis of the time-varying expected return model (equation 4b), the autocorrelation in stock returns, $\gamma(Q)$, can be defined as follows:

$$\begin{aligned}\gamma(Q) &= \frac{Cov(R_{t-Q,t}, R_{t,t+Q})}{Var(R_{t-Q,t})} \\ &= \frac{Cov(r_{t-Q,t} + e_{t-Q,t} + u_{t-Q,t}, r_{t,t+Q} + e_{t,t+Q} + u_{t,t+Q})}{Var(R_{t-Q,t})} \\ &= \frac{Cov(r_{t-Q,t}, r_{t,t+Q}) + Cov(r_{t,t+Q}, e_{t-Q,t}) + Cov(u_{t-Q,t}, u_{t,t+Q})}{Var(R_{t-Q,t})}.\end{aligned} \tag{5}$$

The last equality follows from the assumption that u_t and $(r_t + e_t)$ are generated by two independent mechanisms and the fact that under the time-varying expected return model, $Cov(r_{t-Q,t}, e_{t,t+Q}) = 0$ and $Cov(e_{t-Q,t}, e_{t,t+Q}) = 0$ by construction. The first two terms of the numerator of equation (5) are due to the fundamental component in stock prices, whereas $Cov(u_{t-Q,t}, u_{t,t+Q})$ results from the speculative stationary component in stock prices. Thus, when there is autocorrelation in stock returns, it could be the result of either the time-varying expected returns, or the speculative component, or both.

It is difficult to separate these two individual effects by looking only at the serial correlation of stock returns. If the time-varying expected return r_t can be purged from the ex post stock return, then the residual return will include only e_t and u_t, and the speculative stationary component in stock prices can be examined by looking at the

[7] Note that the fundamental component $r_t + e_t$ and the speculative component u_t, if any, are assumed to be generated by two independent (or at least uncorrelated) mechanisms.

time series behavior of these residual returns. From this perspective, the time-varying expected return hypotheses [equations (4a) and (4b)] can be modified as shown in (6a) and (6b):

$$H_0: \ R_{t-Q,t} - r_{t-Q,t} \text{ is serially uncorrelated,} \tag{6a}$$

$$H_a: \ R_{t-Q,t} - r_{t-Q,t} \text{ is negatively autocorrelated at some Q.} \tag{6b}$$

In this scenario, the test statistic under the alternative hypothesis [equation (6b)] can be simplified as follows:[8]

$$\begin{aligned} \lambda(Q) &= \frac{\mathrm{Cov}(e_{t-Q,t} + u_{t-Q,t}, e_{t,t+Q} + u_{t,t+Q})}{\mathrm{Var}(e_{t-Q,t} + u_{t-Q,t})} \\ &= \frac{\mathrm{Cov}(u_{t-Q,t}, u_{t,t+Q})}{\mathrm{Var}(e_{t-Q,t}) + \mathrm{Var}(u_{t-Q,t})} = \frac{\mathrm{Cov}(x_t - x_{t-Q}, x_{t+Q} - x_t)}{\mathrm{Var}(e_{t-Q,t}) + \mathrm{Var}(u_{t-Q,t})}. \end{aligned} \tag{7}$$

The second line of equation (7) follows from the assumption that e_t and u_t are generated by two independent mechanisms and under the time-varying expected return model, $\mathrm{Cov}(e_{t-Q,t}, e_{t,t+Q}) = 0$. The numerator of $\lambda(Q)$ also can be expressed as $-\sigma_x^2 + 2\mathrm{Cov}(x_t, x_{t-Q}) - \mathrm{Cov}(x_t, x_{t-2Q})$. Because x_t is assumed to follow a stationary process, $\mathrm{Cov}(x_t, x_{t+Q})$ decreases in absolute value and approaches zero as Q increases, and the numerator of $\lambda(Q)$ should approach $-\sigma_x^2$ as Q increases. Consequently, the autocorrelation in residual returns will be negative at some horizon. If the model used to extract expected returns from ex-post returns is the correct equilibrium model, then the finding of negative autocorrelation in residual returns is consistent with the existence of a speculative stationary price component.

Testing For Mean Reversion

Because there is no exact restriction on the length of the time interval for a time-varying expected return model, the validity of the procedure for purging time-varying expected returns from ex-post stock returns should not be affected by the length of the time interval for estimating time-varying expected returns. Therefore, for the test procedures used in this research, short-term time-varying expected returns will

[8] The following mathematical analysis of $\lambda(Q)$ is essentially the same as that of $\beta(Q)$ in Fama and French (1988b). The differences are that: (1) here it is assumed that x_t is induced by the speculative stationary component in stock prices, whereas Fama and French hypothesize that x_t (in their notation z_t) is caused by the stationary component in stock prices, and (2) $\lambda(Q)$ is the autocorrelation in residual returns, whereas in Fama and French, $\beta(Q)$ is the autocorrelation in total returns.

be purged from short-term (ex post) stock returns.[9] Once this is done, the variance ratio test developed by Lo and MacKinlay (1988) will be used to examine whether the autocorrelation in the residual term is significant at different return horizons. Furthermore, the research design also will examine whether time-varying expected returns follow a mean-reverting process.

The measurement of the expected and residual return components in total returns requires the use of a model. This research will employ the Fama-French three-factor model (1992, 1993, 1995, 1996) to examine the mean reversion in stock returns, where:

$$NR_{i,t} - RF_t = \alpha_i + b_i[RM_t - RF_t] + s_i SMB_t + h_i HML_t + e_{i,t} \qquad (8)$$

where $NR_{i,t}$ is portfolio i's time t return, RF_t is the time t one-period T-bill return rate for period t, RM_t is the time t market return, SMB_t is a proxy for the size risk factor, and HML_t is a proxy for the book-to-market equity ratio risk factor. Consistent with the Fama-French studies, all return measures to be used in these tests are market value-weighted, and the tests will utilize portfolio returns rather than individual stock returns as the dependent variable in the model.[10]

Methodological Approach for Testing
Portfolio Formation and Return Estimation

Data used in this research include the NYSE and AMEX stocks on the CRSP monthly tape from June 1963 through December 1996, Nasdaq stocks on the CRSP monthly tape from December 1972 through December 1996, the annual Compustat database from 1962 through 1996 (excluding the research file prior to 1977), and the one-month Treasury bill rate from the Ibbotson Associates' stock, bonds, bills, and inflation series on CRSP indices file from June 1963 through December 1996. This research follows a method identical to the one used in Fama and French (1993) to form 25 size-BE/ME portfolios and calculate risk premiums for the market, size, and book-to-market ratio variables.

Regression Estimation and Testing

This research employs Fama and MacBeth's (1973) cross sectional regression predictive approach in estimating future expected returns. At the end of month t,

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[9]The time interval between time t-1 and time t can be lengthened; however, it is important to note that as the return horizon is lengthened, the sample size becomes smaller, thus decreasing the power of the test. One way to increase the sample size is to use overlapping observations, as proposed by Hansen and Hodrick (1980). The residual terms from this overlapping approach, however, are autocorrelated by construction.

[10] The tests also are replicated using equally-weighted returns, but the results are similar and are not reported here.

$b_{i,t}$, $s_{i,t}$, and $h_{i,t}$ for portfolio i ($i = 1, \ldots, 25$) are estimated by running the following OLS time series regression:

$$AR_{i,j} = \alpha_{i,t} + b_{i,t}ARM_j + s_{i,t}ASMB_j + h_{i,t}AHML_j + e_{i,j} \tag{9}$$

where $j = t-59, \cdots, t$; $AR_{i,j}$ is portfolio i's annualized excess return (i.e., $NR_{i,j} - RF_j$) at the end of month j, which is computed by compounding portfolio i's 12 monthly excess returns preceding month $j+1$; ARM_j, $ASMB_j$, and $AHML_j$ are the annualized market portfolio risk premium, the annualized size risk premium, and the annualized book-to-market equity risk premium, respectively, at the end of month j and are computed by compounding the 12 corresponding monthly measures preceding month $j+1$. Therefore, equation (9) is estimated using annual overlapping observations within a five-year monthly moving window.[11] The use of annual observations to estimate risk sensitivities follows from the empirical finding of Handa, Kothari, and Wasley (1989) that betas have a more significant relationship with stock returns when they are estimated from annual returns.

For each portfolio i (i = 1, 2, ... , 25), monthly expected excess returns are then extracted by estimating the following OLS cross sectional regression:

$$NR_{i,t+1} - RF_{t+1} = \gamma_{0,t} + \gamma_{1,t}b_{i,t} + \gamma_{2,t}s_{i,t} + \gamma_{3,t}h_{i,t} + e_{i,t+1}\,. \tag{10}$$

The predicted value of the cross-sectional regression, $(\gamma_{0,t} + \gamma_{1,t}b_{i,t} + \gamma_{2,t}s_{i,t} + \gamma_{3,t}h_{i,t})$, is used as the estimated month $t+1$ expected excess returns for portfolio i and $e_{i,t+1}$ is taken as the month $t+1$ residual return of portfolio i. This process is repeated monthly beginning in June 1969 and ending with December 1996. In this manner, a series of monthly expected (excess) returns for each portfolio and a series of monthly residual returns for each portfolio are obtained for the overall sample period. A variance ratio test then is applied to examine the autocorrelation structure for various return horizons for the two time series.[12]

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[11]There are 60 sets of annual observations. As observed by Hansen and Hodrick (1980), overlapping observations utilize the data more effectively. Unlike Hansen and Hodrick, the general-method-of-moments approach will not be used to adjust the residual covariance matrix. The reason is that equation (9) is used primarily for estimation purposes but not for hypothesis testing. These tests also are replicated using non-overlapping monthly returns as a check for robustness. The results for these tests are similar to those reported in this study.

[12] Equation (10) is estimated using annualized dependent and independent variables. The residual is by construction, orthogonal to the set of independent variables. Short-term positive autocorrelation in the dependent variable can result in positive short-term autocorrelation in the residual. To clarify this possibility, suppose one estimates the following regression equation:

$$Y = a + bX + e$$

Empirical Results

Descriptive Statistics for Data in the Tests

Table 1 reports summary statistics for the 25 annually adjusted book-to-market equity ratio/size portfolios for the period from July 1963 to December 1996. As shown in Panel A of Table 1, the average monthly excess returns for the 25 portfolios have a systematic relationship with the size (ME) and book-to-market equity ratio (BE/ME) ranked portfolios. Except for the lowest BE/ME equity group (Panel A), for a given BE/ME group, returns decrease monotonically as ME increases. Except for the two largest ME portfolios (Panel A), for a given size category, average excess returns increase monotonically with the magnitude of the BE/ME ratio. Panel A also indicates that, within each BE/ME group, the standard deviation of a portfolio's excess returns decreases as the portfolio's ME rank increases. Within each ME grouping, there appears to be a U-shaped relationship between the standard deviation of a portfolio's excess returns and the portfolio's BE/ME rank.

Panel B of Table 1 reports information about the average number of securities for each of the 25 portfolios.[13] These 25 portfolios do not have the same number of securities because the portfolios are formed with the size and book-to-market equity ratio quintile breakpoints for the NYSE stocks. For the study period, Panel B of Table 1 indicates that, on average, about 82 percent (527.7/646.1) of all AMEX stocks and approximately 77 percent (1,675/2,171.9) of all Nasdaq stocks are included in the five portfolios with the lowest ME rank. Furthermore, on average, the five lowest ME-ranked portfolios account for 57 percent (1,877.8/3,272.5) of all NYSE/AMEX/Nasdaq stocks, with Nasdaq stocks accounting for about 68 percent (1,675/(273.8+527.7+1,675)) of this total[14]. Panel C of Table 1 reports that the (arithmetic) mean and standard deviation values of the monthly market risk premia

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$$\Rightarrow \mathrm{Cov}(e_t, e_{t-1}) = \mathrm{Cov}(Y_t, Y_{t-1}) + b^2\mathrm{Cov}(X_t, X_{t-1})$$
$$- b\mathrm{Cov}(X_t, Y_{t-1}) + \mathrm{Cov}(Y_t, X_{t-1})$$

If the last two terms in the above are assumed to be 0 (which may not be true), then the error term may show positive autocorrelation up to a year by construction.

As discussed in footnote 12, the regressions also were run separately using non-overlapping data. The results of these tests are similar to those presented in the paper. Even though the results are similar under alternative methodologies, the possibility for positive autocorrelation in the error form in the short-run exists. We gratefully acknowledge the comments of an anonymous reviewer for alerting us to this possibility.

[13] Although the results are not reported here, the distribution of securities in the six risk premium portfolios is similar to that of the securities in the 25 book-to-market equity/size portfolios.

[14] Because the values shown in Panel B of Table 1 are time series averages, separate totals in the NYSE, AMEX, and Nasdaq panels will not necessarily sum to their composite total given in the NYSE.AMEX/Nasdaq panel.

(MBS), the monthly size risk premia (SMB), and the monthly book-to-market equity ratio risk premia (HML) for the period from July 1963 to December 1996.[15]

Table 1–Dependent and Independent Variables in the Fama-French Three-factor Model

Panel A: Mean (Standard Deviation) of Excess Monthly Returns on 25 BE/ME and ME Portfolios

	BE/ME				
ME	1 (low)	2	3	4	5(high)
1 (small)	0.0032	0.0071	0.0075	0.0098	0.0104
	(0.076)	(0.064)	(0.059)	(0.055)	(0.059)
2	0.0054	0.0068	0.0078	0.0089	0.0101
	(0.069)	(0.058)	(0.053)	(0.049)	(0.055)
3	0.0049	0.0054	0.0065	0.0079	0.0101
	(0.063)	(0.054)	(0.048)	(0.046)	(0.055)
4	0.0049	0.0044	0.0057	0.0069	0.0092
	(0.055)	(0.051)	(0.047)	(0.044)	(0.051)
5 (large)	0.0045	0.0043	0.0042	0.0065	0.0059
	(0.047)	(0.044)	(0.042)	(0.042)	(0.046)

Panel B: Number of Stocks in a Portfolio

BE/ME	1 (low)	2	3	4	5 (high)	total	1 (low)	2	3	4	5 (high)	total
ME	NYSE/AMEX/Nasdaq (7/63-12/96)						NYSE (7/63-12/96)					
1 (small)	467.1	291.2	270.2	315.3	534.0	1877.8	23.5	33.6	41.5	61.0	114.2	273.8
2	136.1	103.0	97.2	88.5	74.3	499.1	39.3	57.1	63.9	58.9	56.4	275.6
3	102.6	79.1	75.2	59.5	41.7	358.1	60.8	61.2	59.3	52.8	40.2	274.3
4	82.2	63.1	57.2	51.1	32.3	285.9	68.2	60.0	54.8	52.8	36.0	271.8
5 (large)	85.3	56.6	47.6	40.8	21.3	251.6	86.4	62.8	53.1	46.6	24.0	272.9
total	873.3	593.0	547.4	555.2	703.6	3272.5	278.2	274.7	272.6	272.1	270.8	1368.4
	AMEX (7/73-12/96)						Nasdaq (7/63-12/96)					
1 (small)	73.3	76.3	81.4	105.4	191.3	527.7	540.8	276.3	229.6	245.0	383.3	1675.0
2	27.3	16.2	12.1	8.7	7.0	71.3	110.8	58.7	49.2	42.4	26.7	287.8
3	12.3	5.7	4.6	2.3	2.6	27.5	57.9	30.0	27.6	16.9	7.8	140.2
4	5.2	3.7	2.7	2.4	0.8	14.8	26.9	10.5	9.1	5.2	2.3	54.0
5 (large)	2.0	1.0	0.9	0.5	0.4	4.8	9.8	2.7	1.5	0.7	0.2	14.9
total	120.1	102.9	101.7	119.3	202.1	646.1	746.2	378.2	317.0	310.2	420.3	2171.9

Panel C: Risk Factor Premia

	Mean	Std.
MBS	0.0049	0.0427
SMB	0.0021	0.0270
HML	0.0037	0.0253

All return measures are market value-weighted. Monthly excess return is defined as the difference between portfolio monthly return and t-bill rate for the month. The 25 annually adjusted BE/ME and ME portfolios are formed according to the BE/ME and ME ranks of individual stocks at the end of June of each year, where the ME ranks of individual stocks are determined according to market equity measured at the end of June of year t and the BE/ME ratio ranks of individual stocks are determined according to book-to-market ratio measured at the end of the previous year t-1. A portfolio's mean monthly excess return is the time series (arithmetic) average of monthly excess returns of the portfolio for the sample period. The mean number of securities in a portfolio is the time series (arithmetic) average of monthly numbers of securities in the portfolio. MBS is the risk premium (or excess return) for the market portfolio that consists of all the stocks in the 25 annually adjusted book-to-market equity/size portfolios. SMB and HML are the size and book-to-market equity risk premiums, respectively.

[15] These results are qualitatively similar to those in Fama and French (1993, pp. 11 & 14).

Variance Ratio Test Results for the Presence of Autocorrelation in Total Excess Returns, Expected Excess Returns, and Residual Returns

Total Excess Returns

This section presents the empirical results regarding whether there is mean reversion in excess stock returns, in expected excess stock returns, and in residual stock returns. The empirical tests are implemented by using a variance ratio test. The variance ratio for the $Q-$month horizon and its t value are calculated as follows:

$$V(Q)=\frac{\sigma_Q^2/Q}{\sigma_M^2}, \quad t=\frac{V(Q)-1}{\sigma_{V(Q)}} \qquad (12)$$

where σ_M^2 is an unbiased estimate for the variance in returns for one-month observations, σ_Q^2 is an unbiased estimate for the variance in returns for Q-month observations, and $\sigma_{V(Q)}$ is the standard deviation of the variance ratio $V(Q)$. V(Q) values greater than one indicate the presence of positive autocorrelation, whereas V(Q) values less than one indicate negative autocorrelation. Of particular interest in this research is the pattern of the V(Q) values as the return horizon increases. Variance ratio t-statistics[16] are based on Lo and MacKinlay (1988) under the assumption that the variance in stock returns is serially uncorrelated and is heteroscedastically distributed (heteroscedasticity-consistent t-statistics).[17] In these tests, Q ranges from two months to 120 months with annual increments after one year. The choice of a 10-year (120 months) horizon is made for three reasons. First, Fama and French (1988b) and Poterba and Summers (1988) use 10-year and 8-year horizons, respectively. Second, according to Lo and MacKinlay (1989), when Q/T is large (where T is the length of the sample period), the large sample theory of the variance ratio test becomes unreliable, and it is recommended that Q be smaller than one half the sample size. In this research, the sample period for the variance ratio test is 27.5 years. Third, because the standard deviation of a variance ratio increases with its return horizon, it is not expected that significant variance ratios will occur for horizons as

[16] From Theorem 3 in Lo and MacKinlay (1988, p. 50), the standard deviation of a variance ratio increases with the horizon. Therefore, depending on the relative movements of variance ratios and their standard deviations, minimum variance ratios can occur at horizons shorter than, longer than, or equal to the horizons at which minimum variance ratio t–values occur.

[17] Variance ratio t-statistics also were calculated under the assumption that the random variables of interest are independently and identically normally distributed (i.i.n.d. t-statistics). These results show that the i.i.n.d. t-statistics generate more powerful results in the sense the random walk null hypothesis is rejected more frequently than the heteroscedasticity-consistent t-statistics. This is not unexpected, as the variance of stock returns varies over time [e.g., see French, Schwert, and Stambaugh (1987)]. The powerful test of the i.i.n.d. t-statistics might be primarily due to heteroscedastically distributed stock returns. Consequently, only the heteroscedasticity-robust t-statistics are reported.

long as ten years. Variance ratios and their t-values are reported for horizons from two months to six months and horizons with annual increments from 12 months to 120 months.

Table 2 reports variance ratio test results for total excess returns for the 25 BE/ME and ME portfolios, as well as the market portfolio, MBS. In reviewing the results from Table 2, several aspects are worth noting. First, there is evidence of strong positive autocorrelation ($V(Q) > 1$) at short return horizons ($Q < 12$ months). As indicated in Table 2, this strong positive autocorrelation is particularly evident for the smaller ME and BE/ME portfolios. Second, for virtually all ME and BE/ME classifications, there is negative autocorrelation ($V(Q)$ values < 1) at longer horizons ($Q > 12$ months) suggesting the presence of mean reversion in total excess returns. For the smaller BE/ME and ME portfolios, the strong significant positive autocorrelation at shorter return horizons eventually turns negative. As the return horizon increases for the larger BE/ME and ME portfolios, however, the positive autocorrelation also turns negative and is significant in several cases. The presence of negative autocorrelation at longer return horizons indicates the presence of a stationary component with the most dramatic change in the direction of autocorrelation occurring for the smaller BE/ME and ME portfolios.

Even though the variance ratios showing negative autocorrelation in Table 2 are not significant at traditional levels of significance (due to the increasing levels of the standard deviations about the variance ratio at longer return horizons), arguments by Summers (1986) and Poterba and Summers (1988) recommend using higher critical values[18] in assessing significance levels. In this sense, the variance ratio test results in Table 2 might lend stronger support to the existence of stationary price components than what they appear to indicate.

Expected Excess Returns

Table 3 reports variance ratio test results for expected excess returns of the 25 ME and BE/ME portfolios. Similar to the test results for excess returns in Table 2, there is significant positive autocorrelation in stock returns for small-sized (ME) and book-to-market ratio portfolios (BE/ME) at short return horizons. Furthermore, all ME and BE/ME portfolio groupings display negative autocorrelation at return hori-

[18] As pointed out by Summers (1986) and Poterba and Summers (1988), it is difficult to statistically detect stationary components in stock prices, if any exist. This makes it difficult to disentangle the link between the observation of negative autocorrelation in long-horizon returns and the existence of a stationary component in stock prices. Consequently, Poterba and Summers (1988, p. 28) suggest that "a sensible balancing of Type I and Type II errors suggests using critical values above the conventional 0.05 level." A comparison of the variance ratio values and their associated t-statistics from Table 2 from Poterba and Summers with the results shown in Tables 2, 3, and 4 in the paper indicate similar results in terms of their magnitudes. In many cases, the significance levels shown in this paper are higher than those found in Poterba and Summers.

Table 2–Variance Ratios and their t Values for Total Excess Returns of 25 Annually Adjusted Book-to-Market Equity Ratio/Size Portfolios of NYSE, AMEX, and Nasdaq Stocks for the Period June 1969 to December 1996

Q	B1S1	B2S1	B3S1	B4S1	B5S1	B1S2	B2S2	B3S2	B4S2	B5S2	B1S3	B2S3	B3S3
2	1.24	1.20	1.23	1.22	1.20	1.15	1.18	1.18	1.16	1.19	1.14	1.16	1.13
	(4.28)	(3.54)	(3.81)	(3.46)	(3.15)	(2.59)	(3.16)	(3.28)	(2.66)	(3.68)	(2.40)	(2.90)	(2.45)
3	1.33	1.25	1.30	1.27	1.24	1.18	1.20	1.19	1.18	1.21	1.15	1.18	1.13
	(3.92)	(2.84)	(3.33)	(2.93)	(2.55)	(2.11)	(2.36)	(2.23)	(2.00)	(2.61)	(1.74)	(2.15)	(1.62)
4	1.38	1.25	1.33	1.28	1.25	1.20	1.21	1.17	1.17	1.17	1.16	1.20	1.12
	(3.55)	(2.33)	(3.00)	(2.46)	(2.11)	(1.83)	(1.99)	(1.64)	(1.56)	(1.69)	(1.48)	(1.88)	(1.17)
5	1.40	1.24	1.34	1.27	1.23	1.20	1.20	1.15	1.16	1.12	1.15	1.20	1.10
	(3.16)	(1.91)	(2.68)	(2.09)	(1.68)	(1.55)	(1.63)	(1.21)	(1.31)	(1.02)	(1.19)	(1.59)	(0.84)
6	1.42	1.24	1.36	1.28	1.22	1.19	1.20	1.15	1.19	1.10	1.15	1.21	1.13
	(2.90)	(1.66)	(2.50)	(1.92)	(1.41)	(1.32)	(1.42)	(1.04)	(1.34)	(0.75)	(1.06)	(1.49)	(0.89)
12	1.38	1.13	1.29	1.18	1.01	1.12	1.10	1.00	1.11	0.90	1.09	1.10	1.06
	(1.71)	(0.58)	(1.32)	(0.82)	(0.04)	(0.55)	(0.45)	(0.01)	(0.50)	(-0.46)	(0.41)	(0.47)	(0.29)
24	1.20	0.98	1.15	1.04	0.98	0.87	0.98	0.82	0.97	0.77	0.83	0.86	0.90
	(0.62)	(-0.07)	(0.46)	(0.12)	(-0.06)	(-0.42)	(-0.05)	(-0.57)	(-0.09)	(-0.75)	(-0.53)	(-0.44)	(-0.33)
36	1.14	0.96	1.18	0.99	1.02	0.72	0.92	0.79	0.96	0.68	0.70	0.81	0.78
	(0.37)	(-0.10)	(0.45)	(-0.03)	(0.06)	(-0.73)	(-0.22)	(-0.54)	(-0.09)	(-0.84)	(-0.79)	(-0.51)	(-0.56)
48	1.26	1.08	1.27	1.00	1.06	0.68	0.94	0.83	0.98	0.65	0.67	0.78	0.73
	(0.59)	(0.19)	(0.60)	(-0.01)	(0.13)	(-0.74)	(-0.13)	(-0.38)	(-0.04)	(-0.80)	(-0.76)	(-0.50)	(-0.61)
60	1.36	1.14	1.27	0.99	1.05	0.72	0.96	0.85	0.97	0.66	0.70	0.78	0.69
	(0.72)	(0.28)	(0.54)	(-0.01)	(0.11)	(-0.59)	(-0.08)	(-0.31)	(-0.06)	(-0.69)	(-0.62)	(-0.45)	(-0.64)
72	1.28	1.00	1.09	0.84	0.93	0.61	0.84	0.69	0.79	0.58	0.57	0.63	0.50
	(0.51)	(0.00)	(0.17)	(-0.30)	(-0.12)	(-0.75)	(-0.31)	(-0.59)	(-0.38)	(-0.79)	(-0.82)	(-0.71)	(-0.95)
84	1.25	0.95	1.02	0.77	0.89	0.52	0.78	0.61	0.72	0.57	0.47	0.57	0.38
	(0.43)	(-0.08)	(0.04)	(-0.40)	(-0.18)	(-0.85)	(-0.38)	(-0.67)	(-0.48)	(-0.74)	(-0.95)	(-0.75)	(-1.08)
96	1.21	0.92	1.03	0.77	0.91	0.44	0.75	0.60	0.75	0.60	0.39	0.56	0.39
	(0.34)	(-0.13)	(0.05)	(-0.37)	(-0.14)	(-0.93)	(-0.41)	(-0.64)	(-0.41)	(-0.65)	(-1.01)	(-0.73)	(-1.01)
108	1.20	0.91	1.08	0.80	0.95	0.41	0.76	0.65	0.82	0.65	0.36	0.60	0.42
	(0.30)	(-0.14)	(0.13)	(-0.31)	(-0.07)	(-0.93)	(-0.38)	(-0.54)	(-0.28)	(-0.53)	(-1.02)	(-0.62)	(-0.90)
120	1.21	0.92	1.10	0.81	0.98	0.39	0.79	0.68	0.86	0.64	0.37	0.64	0.43
	(0.31)	(-0.11)	(0.15)	(-0.28)	(-0.03)	(-0.91)	(-0.31)	(-0.47)	(-0.20)	(-0.52)	(-0.95)	(-0.54)	(-0.85)

Monthly excess return is measured as the difference between monthly return and the Treasury bill return for the month. B_iS_j is the ith book-to-market equity ratio-ranked and jth size-ranked portfolio, adjusted at the end of June of each year where book-to-market equity ratio ranks of individual stocks are determined according to book-to-market equity ratio measured at the end of the previous year and size ranks of individual stocks are determined according to market equity measured at the end of June of each year. MBS is the market portfolio which consists of the stocks in the 25 book-to-market equity ratio/size portfolios. Q is the return horizon in months. Numbers inside parentheses are variance ratio t-values. The variance of monthly observations is the base variance for calculating variance ratios. Variance ratio t-values are based on equation (11), which is developed by Lo and MacKinlay (1988) under the assumption that random variables of interest are serially uncorrelated and heteroscedastically distributed. Critical t-values for the significance tests are: (1) 5% - ± 1.96; (2) 10% - ± 1.64; and (3) 20% - ± 1.28.

Table 2 (continued)–Variance Ratios and their t Values for Total Excess Returns of 25 Annually Adjusted Book-to-Market Equity Ratio/Size Portfolios of NYSE, AMEX, and Nasdaq Stocks for the Period June 1969 to December 1996

Q	B4S3	B5S3	B1S4	B2S4	B3S4	B4S4	B5S4	B1S5	B2S5	B3S5	B4S5	B5S5	MBS
2	1.15	1.14	1.10	1.11	1.11	1.07	1.05	1.08	1.02	0.98	0.97	1.03	1.06
	(2.60)	(2.31)	(1.60)	(2.12)	(1.89)	(1.25)	(1.03)	(1.00)	(0.35)	(-0.38)	(-0.52)	(0.54)	(0.86)
3	1.16	1.09	1.11	1.11	1.11	1.06	1.03	1.11	0.99	0.92	0.94	1.05	1.05
	(1.84)	(1.07)	(1.22)	(1.30)	(1.29)	(0.73)	(0.39)	(0.96)	(-0.15)	(-0.81)	(-0.68)	(0.63)	(0.56)
4	1.15	1.03	1.13	1.09	1.11	1.05	1.02	1.12	0.97	0.90	0.97	1.05	1.06
	(1.39)	(0.32)	(1.06)	(0.86)	(1.02)	(0.49)	(0.23)	(0.90)	(-0.25)	(-0.87)	(-0.34)	(0.45)	(0.48)
5	1.13	0.98	1.12	1.08	1.10	1.02	1.00	1.14	0.96	0.88	0.94	1.04	1.05
	(1.00)	(-0.16)	(0.85)	(0.62)	(0.77)	(0.15)	(0.01)	(0.87)	(-0.27)	(-0.91)	(-0.46)	(0.32)	(0.36)
6	1.15	0.97	1.12	1.10	1.13	1.05	1.02	1.16	1.01	0.92	0.97	1.06	1.08
	(1.05)	(-0.24)	(0.80)	(0.74)	(0.85)	(0.36)	(0.15)	(0.94)	(0.05)	(-0.55)	(-0.18)	(0.45)	(0.52)
12	1.01	0.75	1.07	1.01	1.04	0.95	0.93	1.14	1.00	0.92	0.85	0.98	1.02
	(0.06)	(-1.16)	(0.30)	(0.06)	(0.18)	(-0.24)	(-0.31)	(0.56)	(0.02)	(-0.35)	(-0.71)	(-0.09)	(0.11)
24	0.79	0.63	0.89	0.82	0.79	0.73	0.72	0.92	0.81	0.69	0.52	0.89	0.74
	(-0.67)	(-1.15)	(-0.33)	(-0.58)	(-0.64)	(-0.86)	(-0.88)	(-0.23)	(-0.60)	(-1.01)	(-1.52)	(-0.36)	(-0.80)
36	0.67	0.56	0.76	0.71	0.65	0.60	0.54	0.75	0.58	0.55	0.38	0.77	0.57
	(-0.87)	(-1.12)	(-0.61)	(-0.74)	(-0.89)	(-1.03)	(-1.20)	(-0.64)	(-1.08)	(-1.18)	(-1.60)	(-0.60)	(-1.11)
48	0.61	0.59	0.73	0.66	0.56	0.51	0.46	0.74	0.48	0.52	0.30	0.80	0.53
	(-0.90)	(-0.92)	(-0.61)	(-0.76)	(-0.99)	(-1.11)	(-1.22)	(-0.58)	(-1.17)	(-1.10)	(-1.59)	(-0.46)	(-1.05)
60	0.57	0.62	0.78	0.66	0.54	0.49	0.48	0.90	0.54	0.56	0.35	0.90	0.62
	(-0.89)	(-0.76)	(-0.44)	(-0.69)	(-0.93)	(-1.03)	(-1.05)	(-0.21)	(-0.93)	(-0.91)	(-1.33)	(-0.20)	(-0.77)
72	0.36	0.51	0.70	0.51	0.36	0.29	0.34	0.97	0.46	0.38	0.26	0.77	0.54
	(-1.20)	(-0.89)	(-0.56)	(-0.92)	(-1.19)	(-1.31)	(-1.21)	(-0.06)	(-1.00)	(-1.17)	(-1.40)	(-0.44)	(-0.86)
84	0.29	0.49	0.62	0.42	0.29	0.21	0.30	1.06	0.41	0.28	0.26	0.75	0.51
	(-1.24)	(-0.86)	(-0.66)	(-1.00)	(-1.24)	(-1.36)	(-1.20)	(0.11)	(-1.01)	(-1.27)	(-1.29)	(-0.43)	(-0.85)
96	0.30	0.53	0.53	0.41	0.26	0.22	0.33	1.13	0.45	0.27	0.28	0.87	0.53
	(-1.15)	(-0.75)	(-0.76)	(-0.96)	(-1.21)	(-1.27)	(-1.08)	(0.21)	(-0.89)	(-1.20)	(-1.19)	(-0.21)	(-0.76)
108	0.36	0.58	0.49	0.42	0.29	0.24	0.37	1.17	0.46	0.28	0.31	0.96	0.57
	(-1.00)	(-0.63)	(-0.79)	(-0.89)	(-1.10)	(-1.16)	(-0.96)	(0.26)	(-0.82)	(-1.12)	(-1.08)	(-0.07)	(-0.67)
120	0.40	0.64	0.47	0.46	0.28	0.26	0.41	1.24	0.49	0.30	0.28	1.06	0.59
	(-0.88)	(-0.53)	(-0.78)	(-0.80)	(-1.06)	(-1.08)	(-0.86)	(0.36)	(-0.75)	(-1.04)	(-1.06)	(0.09)	(-0.60)

zons greater than 12 months. Thus, the presence of mean reversion in expected excess returns (Table 3) has the same pattern as for total returns (Table 2). A sign test is used to examine whether there is a *change* in the importance of stationary price components between the 25 expected excess return series (Table 3) and their corresponding total excess return series (Table 2). The sign test statistic, based on the minimum variance ratio t-value for the horizons between 25 months and 96 months,[19] is 13, while the one (five) percent critical value for a sample size of 25 is

[19] Similar results are obtained when the sign test is based on 11 other measures of importance of stationary price components. These measures are: (1) the minimum variance ratio t-value for the horizons between 25 months and 72 months, and (2) for the horizons between 25 months and 120 months; (3) the minimum variance ratio for the horizons between 25 months and 72 months, (4) for the horizons between 25 months and 96 months, and (5) for the horizons between 25 months and 120 months; (6) the (arithmetic) mean of variance ratio-values for the horizons between 25 months and 72 months, (7) for the horizons between 25 months

Table 3–Variance Ratios and Their t Values for Expected Excess Returns of 25 Annually Adjusted Book-to-market Equity Ratio /Size Portfolios of NYSE, AMEX, and Nasdaq Stocks from June 1969 to December 1996

Q	B1S1	B2S1	B3S1	B4S1	B5S1	B1S2	B2S2	B3S2	B4S2	B5S2	B1S3	B2S3	B3S3
2	1.22	1.20	1.19	1.18	1.19	1.18	1.19	1.18	1.16	1.17	1.16	1.15	1.16
	(3.79)	(3.59)	(3.51)	(3.17)	(3.38)	(3.08)	(3.23)	(3.12)	(2.93)	(3.09)	(2.68)	(2.68)	(2.76)
3	1.27	1.24	1.22	1.20	1.22	1.22	1.22	1.20	1.17	1.19	1.18	1.16	1.18
	(3.14)	(2.86)	(2.61)	(2.36)	(2.61)	(2.50)	(2.55)	(2.38)	(2.09)	(2.29)	(2.04)	(1.86)	(2.15)
4	1.29	1.25	1.22	1.20	1.22	1.24	1.24	1.21	1.17	1.19	1.20	1.16	1.19
	(2.66)	(2.40)	(2.05)	(1.85)	(2.10)	(2.20)	(2.18)	(1.95)	(1.60)	(1.80)	(1.75)	(1.49)	(1.80)
5	1.29	1.24	1.20	1.18	1.21	1.24	1.23	1.20	1.15	1.17	1.19	1.14	1.18
	(2.28)	(1.98)	(1.61)	(1.46)	(1.70)	(1.87)	(1.82)	(1.56)	(1.20)	(1.40)	(1.47)	(1.13)	(1.44)
6	1.30	1.25	1.20	1.19	1.23	1.25	1.24	1.20	1.16	1.18	1.20	1.14	1.19
	(2.04)	(1.78)	(1.41)	(1.35)	(1.63)	(1.68)	(1.64)	(1.44)	(1.16)	(1.32)	(1.33)	(1.00)	(1.36)
12	1.19	1.14	1.07	1.07	1.13	1.20	1.13	1.07	1.04	1.07	1.14	1.03	1.06
	(0.87)	(0.65)	(0.30)	(0.32)	(0.61)	(0.90)	(0.60)	(0.34)	(0.17)	(0.32)	(0.61)	(0.12)	(0.30)
24	0.95	0.95	0.92	0.90	1.00	0.98	0.94	0.83	0.83	0.90	0.91	0.86	0.84
	(-0.14)	(-0.16)	(-0.24)	(-0.32)	(-0.01)	(-0.05)	(-0.18)	(-0.54)	(-0.54)	(-0.33)	(-0.28)	(-0.44)	(-0.50)
36	0.86	0.91	0.89	0.84	0.97	0.83	0.86	0.75	0.77	0.84	0.79	0.78	0.73
	(-0.37)	(-0.24)	(-0.29)	(-0.42)	(-0.08)	(-0.43)	(-0.35)	(-0.65)	(-0.60)	(-0.41)	(-0.55)	(-0.57)	(-0.70)
48	0.92	0.96	0.95	0.88	1.01	0.83	0.86	0.76	0.76	0.85	0.79	0.75	0.68
	(-0.18)	(-0.08)	(-0.12)	(-0.27)	(0.02)	(-0.39)	(-0.30)	(-0.55)	(-0.55)	(-0.35)	(-0.47)	(-0.56)	(-0.73)
60	0.96	0.98	0.97	0.90	1.02	0.85	0.86	0.80	0.76	0.85	0.83	0.74	0.66
	(-0.08)	(-0.03)	(-0.05)	(-0.19)	(0.05)	(-0.31)	(-0.28)	(-0.42)	(-0.49)	(-0.31)	(-0.34)	(-0.52)	(-0.69)
72	0.85	0.86	0.85	0.75	0.86	0.71	0.67	0.67	0.60	0.67	0.71	0.57	0.46
	(-0.29)	(-0.27)	(-0.27)	(-0.45)	(-0.25)	(-0.55)	(-0.60)	(-0.63)	(-0.75)	(-0.61)	(-0.54)	(-0.79)	(-1.01)
84	0.77	0.80	0.81	0.70	0.82	0.60	0.56	0.61	0.54	0.60	0.62	0.49	0.36
	(-0.39)	(-0.35)	(-0.33)	(-0.50)	(-0.29)	(-0.70)	(-0.75)	(-0.69)	(-0.80)	(-0.69)	(-0.66)	(-0.88)	(-1.11)
96	0.71	0.77	0.81	0.72	0.86	0.50	0.50	0.61	0.55	0.62	0.53	0.46	0.35
	(-0.47)	(-0.37)	(-0.30)	(-0.45)	(-0.22)	(-0.81)	(-0.80)	(-0.65)	(-0.73)	(-0.62)	(-0.77)	(-0.87)	(-1.06)
108	0.69	0.79	0.85	0.76	0.92	0.46	0.50	0.63	0.61	0.67	0.47	0.47	0.39
	(-0.47)	(-0.33)	(-0.22)	(-0.37)	(-0.12)	(-0.84)	(-0.77)	(-0.57)	(-0.60)	(-0.52)	(-0.82)	(-0.81)	(-0.93)
120	0.69	0.81	0.88	0.79	0.96	0.44	0.49	0.64	0.66	0.69	0.44	0.47	0.41
	(-0.45)	(-0.28)	(-0.17)	(-0.30)	(-0.05)	(-0.82)	(-0.74)	(-0.53)	(-0.49)	(-0.45)	(-0.82)	(-0.77)	(-0.87)

Monthly excess return is measured as the difference between monthly return and the Treasury bill return for the month. B_iS_j is the ith book-to-market equity ratio-ranked and jth size-ranked portfolio, adjusted at the end of June of each year where book-to-market equity ratio ranks of individual stocks are determined according to book-to-market equity ratio measured at the end of the previous year and size ranks of individual stocks are determined according to market equity measured at the end of June of each year. MBS is the market portfolio which consists of the stocks in the 25 book-to-market equity ratio/size portfolios. Q is the return horizon in months. Numbers inside parentheses are variance ratio t-values. The variance of monthly observations is the base variance for calculating variance ratios. Variance ratio t-values are based on equation (11), which is developed by Lo and MacKinlay (1988) under the assumption that random variables of interest are serially uncorrelated and heteroscedastically distributed. Critical t-values for the significance tests are: (1) 5% - ± 1.96; (2) 10% - ± 1.64; and (3) 20% - ± 1.28.
1.28.

and 96 months, and (8) for the horizons between 25 months and 120 months; (9) the mean of variance ratios for the horizons between 25 months and 72 months, (10) for the horizons between 25 months and 96 months, and (11) for the horizons between 25 months and 120 months.

Table 3 (continued)–Variance Ratios and Their t Values for Expected Excess Returns of 25 Annually Adjusted Book-to-market Equity Ratio /Size Portfolios of NYSE, AMEX, and Nasdaq Stocks from June 1969 to December 1996

Q	B4S3	B5S3	B1S4	B2S4	B3S4	B4S4	B5S4	B1S5	B2S5	B3S5	B4S5	B5S5
2	1.13	1.18	1.12	1.11	1.13	1.09	1.12	1.04	1.03	1.05	1.02	1.07
	(2.29)	(3.06)	(1.90)	(1.95)	(2.31)	(1.57)	(2.25)	(0.57)	(0.50)	(0.78)	(0.46)	(1.19)
3	1.13	1.20	1.15	1.11	1.14	1.07	1.13	1.06	1.01	1.02	0.98	1.05
	(1.60)	(2.33)	(1.56)	(1.28)	(1.69)	(0.84)	(1.55)	(0.61)	(0.16)	(0.25)	(-0.19)	(0.63)
4	1.13	1.19	1.17	1.11	1.15	1.06	1.12	1.07	1.01	1.00	0.95	1.04
	(1.20)	(1.84)	(1.47)	(1.00)	(1.40)	(0.53)	(1.16)	(0.56)	(0.08)	(0.01)	(-0.47)	(0.34)
5	1.10	1.17	1.18	1.09	1.14	1.03	1.10	1.07	1.00	0.98	0.93	1.01
	(0.84)	(1.37)	(1.33)	(0.74)	(1.12)	(0.22)	(0.81)	(0.48)	(-0.03)	(-0.18)	(-0.62)	(0.10)
6	1.12	1.18	1.20	1.11	1.16	1.05	1.12	1.10	1.03	1.01	0.96	1.05
	(0.86)	(1.31)	(1.33)	(0.75)	(1.15)	(0.34)	(0.85)	(0.59)	(0.19)	(0.05)	(-0.28)	(0.34)
12	0.97	1.06	1.15	1.01	1.04	0.93	1.04	1.12	0.97	0.86	0.86	0.99
	(-0.14)	(0.30)	(0.66)	(0.05)	(0.20)	(-0.30)	(0.17)	(0.53)	(-0.16)	(-0.67)	(-0.66)	(-0.05)
24	0.71	0.93	0.87	0.81	0.82	0.82	0.92	0.96	0.74	0.58	0.61	0.89
	(-0.95)	(-0.23)	(-0.41)	(-0.60)	(-0.59)	(-0.58)	(-0.25)	(-0.11)	(-0.81)	(-1.35)	(-1.29)	(-0.36)
36	0.56	0.91	0.67	0.67	0.66	0.76	0.80	0.76	0.56	0.44	0.52	0.81
	(-1.16)	(-0.24)	(-0.83)	(-0.84)	(-0.90)	(-0.61)	(-0.51)	(-0.62)	(-1.12)	(-1.48)	(-1.29)	(-0.49)
48	0.51	0.94	0.59	0.60	0.57	0.73	0.75	0.69	0.49	0.37	0.48	0.84
	(-1.14)	(-0.14)	(-0.92)	(-0.88)	(-1.00)	(-0.59)	(-0.56)	(-0.69)	(-1.15)	(-1.44)	(-1.22)	(-0.36)
60	0.55	0.95	0.62	0.57	0.54	0.74	0.73	0.84	0.56	0.39	0.53	0.97
	(-0.95)	(-0.09)	(-0.77)	(-0.85)	(-0.94)	(-0.53)	(-0.55)	(-0.32)	(-0.91)	(-1.26)	(-0.98)	(-0.06)
72	0.39	0.82	0.50	0.37	0.33	0.55	0.50	0.85	0.45	0.26	0.43	0.87
	(-1.17)	(-0.33)	(-0.93)	(-1.15)	(-1.28)	(-0.82)	(-0.93)	(-0.28)	(-1.02)	(-1.40)	(-1.08)	(-0.25)
84	0.32	0.82	0.40	0.25	0.21	0.52	0.40	0.87	0.41	0.21	0.41	0.90
	(-1.21)	(-0.31)	(-1.04)	(-1.28)	(-1.39)	(-0.83)	(-1.04)	(-0.23)	(-1.02)	(-1.39)	(-1.05)	(-0.18)
96	0.35	0.88	0.32	0.21	0.19	0.56	0.41	0.89	0.43	0.21	0.44	1.01
	(-1.10)	(-0.19)	(-1.10)	(-1.26)	(-1.33)	(-0.71)	(-0.96)	(-0.19)	(-0.93)	(-1.29)	(-0.93)	(0.02)
108	0.39	0.97	0.29	0.22	0.21	0.63	0.46	0.89	0.47	0.23	0.48	1.12
	(-0.97)	(-0.04)	(-1.09)	(-1.19)	(-1.23)	(-0.57)	(-0.84)	(-0.18)	(-0.82)	(-1.19)	(-0.82)	(0.18)
120	0.40	1.05	0.27	0.22	0.22	0.67	0.53	0.90	0.52	0.23	0.51	1.20
	(-0.91)	(0.08)	(-1.06)	(-1.12)	(-1.16)	(-0.49)	(-0.70)	(-0.16)	(-0.71)	(-1.15)	(-0.74)	(0.29)

19 (18). The test results fail to reject the hypothesis that there is no difference in stationary price components between the total excess returns of the 25 portfolios and their corresponding expected excess returns, and indicates that there is no difference in the mean reversion patterns of total and expected excess returns.

Residual Returns

Table 4 reports variance ratio test results for the 25 ME and BE/ME portfolios. Similar to the results shown in Tables 2 and 3 for the total excess returns and expected excess returns, the results indicate strong positive autocorrelation in residual returns for the smaller ME and BE/ME portfolio at short return horizons. The pattern of autocorrelation across some of the portfolios' residual returns (Table 4) at longer return horizons appears to differ from the total (Table 2) and expected (Table 3) excess returns. In particular, while most of the ME and BE/ME portfolio residual returns in Table 4 show the mean reversion patterns displayed in Tables 2

Table 4–Variance Ratios and Their t Values for Residual Returns of 25 Annually Adjusted Book-to-market Equity Ratio/Size Portfolios of NYSE, AMEX, and Nasdaq Stocks from June 1969 through December 1996

Q	B1S1	B2S1	B3S1	B4S1	B5S1	B1S2	B2S2	B3S2	B4S2	B5S2	B1S3	B2S3	B3S3
2	1.20	1.01	0.99	1.09	1.09	0.99	1.06	0.98	1.02	1.16	1.07	1.21	1.03
	(2.95)	(0.14)	(-0.11)	(1.14)	(1.02)	(-0.14)	(1.06)	(-0.40)	(0.28)	(2.70)	(1.11)	(3.20)	(0.42)
3	1.32	1.00	1.00	1.12	1.18	1.01	1.14	0.92	1.04	1.21	1.06	1.29	1.05
	(3.31)	(0.04)	(0.01)	(1.11)	(1.45)	(0.11)	(1.65)	(-0.94)	(0.44)	(2.38)	(0.59)	(2.97)	(0.56)
4	1.39	0.97	0.99	1.10	1.15	1.00	1.22	0.87	1.04	1.16	0.99	1.32	1.05
	(3.28)	(-0.27)	(-0.09)	(0.78)	(1.02)	(0.04)	(1.99)	(-1.17)	(0.34)	(1.49)	(-0.07)	(2.58)	(0.45)
5	1.41	0.95	0.96	1.08	1.13	0.99	1.26	0.83	1.01	1.13	0.94	1.33	1.04
	(2.97)	(-0.37)	(-0.30)	(0.55)	(0.74)	(-0.06)	(2.05)	(-1.32)	(0.09)	(1.03)	(-0.41)	(2.25)	(0.29)
6	1.41	0.92	0.95	1.05	1.09	0.94	1.29	0.78	0.97	1.11	0.91	1.32	0.99
	(2.64)	(-0.51)	(-0.33)	(0.31)	(0.47)	(-0.41)	(2.03)	(-1.47)	(-0.20)	(0.76)	(-0.59)	(1.94)	(-0.06)
12	1.35	0.88	0.99	0.91	1.02	0.78	1.51	0.62	1.00	1.10	0.84	1.27	0.71
	(1.56)	(-0.55)	(-0.03)	(-0.37)	(0.08)	(-1.00)	(2.32)	(-1.71)	(0.01)	(0.45)	(-0.71)	(1.09)	(-1.29)
24	1.51	0.92	0.90	1.04	1.40	0.79	2.00	0.52	1.12	0.98	0.87	0.83	0.51
	(1.59)	(-0.24)	(-0.34)	(0.13)	(1.10)	(-0.64)	(3.15)	(-1.48)	(0.41)	(-0.05)	(-0.41)	(-0.49)	(-1.55)
36	1.73	0.91	0.98	1.09	1.64	1.03	2.28	0.45	1.10	1.07	0.93	0.88	0.44
	(1.91)	(-0.22)	(-0.05)	(0.25)	(1.47)	(0.07)	(3.31)	(-1.40)	(0.28)	(0.19)	(-0.19)	(-0.31)	(-1.48)
48	1.96	0.98	0.99	1.18	1.82	1.19	2.68	0.36	1.00	1.06	0.75	0.95	0.44
	(2.22)	(-0.05)	(-0.03)	(0.41)	(1.65)	(0.43)	(3.81)	(-1.42)	(-0.01)	(0.13)	(-0.58)	(-0.10)	(-1.31)
60	2.24	1.10	0.90	1.21	2.00	1.40	2.98	0.29	0.98	1.14	0.50	1.03	0.40
	(2.60)	(0.20)	(-0.22)	(0.44)	(1.86)	(0.80)	(4.03)	(-1.41)	(-0.03)	(0.29)	(-1.03)	(0.05)	(-1.28)
72	2.57	1.02	0.83	1.34	2.13	1.63	3.20	0.26	0.96	1.05	0.39	1.13	0.40
	(3.02)	(0.04)	(-0.33)	(0.64)	(1.96)	(1.16)	(4.13)	(-1.35)	(-0.07)	(0.10)	(-1.17)	(0.24)	(-1.17)
84	2.93	1.01	0.80	1.44	2.30	1.84	3.34	0.21	0.83	0.94	0.36	1.35	0.38
	(3.46)	(0.02)	(-0.37)	(0.78)	(2.11)	(1.46)	(4.09)	(-1.35)	(-0.31)	(-0.10)	(-1.15)	(0.61)	(-1.12)
96	3.21	0.92	0.82	1.56	2.45	2.02	3.42	0.22	0.70	0.91	0.41	1.46	0.38
	(3.73)	(-0.13)	(-0.31)	(0.94)	(2.25)	(1.67)	(4.00)	(-1.27)	(-0.52)	(-0.15)	(-0.99)	(0.76)	(-1.07)
108	3.39	0.78	0.89	1.59	2.51	2.25	3.51	0.24	0.66	0.90	0.46	1.69	0.32
	(3.83)	(-0.35)	(-0.18)	(0.93)	(2.25)	(1.95)	(3.94)	(-1.16)	(-0.55)	(-0.16)	(-0.87)	(1.07)	(-1.10)
120	3.44	0.60	0.94	1.57	2.53	2.37	3.57	0.29	0.68	1.02	0.50	1.79	0.27
	(3.74)	(-0.61)	(-0.10)	(0.87)	(2.20)	(2.05)	(3.84)	(-1.04)	(-0.49)	(0.03)	(-0.77)	(1.18)	(-1.13)

Monthly excess return is measured as the difference between monthly return and the Treasury bill return for the month. B_iS_j is the ith book-to-market equity ratio-ranked and jth size-ranked portfolio, adjusted at the end of June of each year where book-to-market equity ratio ranks of individual stocks are determined according to book-to-market equity ratio measured at the end of the previous year and size ranks of individual stocks are determined according to market equity measured at the end of June of each year. MBS is the market portfolio which consists of the stocks in the 25 book-to-market equity ratio/size portfolios. Q is the return horizon in months. Numbers inside parentheses are variance ratio t-values. The variance of monthly observations is the base variance for calculating variance ratios. Variance ratio t-values are based on equation (11), which is developed by Lo and MacKinlay (1988) under the assumption that random variables of interest are serially uncorrelated and heteroscedastically distributed. Critical t-values for the significance tests are: (1) 5% - ± 1.96; (2) 10% - ± 1.64; and (3) 20% - ± 1.28.

Table 4 (continued)–Variance Ratios and Their t Values for Residual Returns of 25 Annually Adjusted Book-to-market Equity Ratio/Size Portfolios of NYSE, AMEX, and Nasdaq Stocks from June 1969 through December 1996

Q	B4S3	B5S3	B1S4	B2S4	B3S4	B4S4	B5S4	B1S5	B2S5	B3S5	B4S5	B5S5
2	1.16	1.11	1.04	1.09	1.14	1.03	1.02	1.00	1.06	1.14	1.04	1.04
	(2.68)	(1.81)	(0.64)	(1.39)	(2.28)	(0.40)	(0.41)	(-0.02)	(0.94)	(1.52)	(0.48)	(0.67)
3	1.26	1.13	1.07	1.17	1.18	1.03	1.02	0.91	1.07	1.18	1.01	1.03
	(2.91)	(1.39)	(0.79)	(1.81)	(2.00)	(0.35)	(0.22)	(-0.82)	(0.76)	(1.43)	(0.08)	(0.31)
4	1.34	1.14	1.02	1.15	1.16	0.97	1.04	0.86	1.08	1.24	1.03	0.96
	(3.01)	(1.24)	(0.16)	(1.22)	(1.46)	(-0.26)	(0.38)	(-0.97)	(0.69)	(1.54)	(0.26)	(-0.30)
5	1.39	1.17	0.99	1.13	1.11	0.97	1.06	0.84	1.10	1.23	1.08	0.94
	(2.97)	(1.22)	(-0.06)	(0.90)	(0.90)	(-0.22)	(0.49)	(-1.00)	(0.73)	(1.32)	(0.51)	(-0.42)
6	1.40	1.19	0.98	1.11	1.06	0.94	1.06	0.85	1.10	1.20	1.07	0.90
	(2.71)	(1.20)	(-0.12)	(0.70)	(0.40)	(-0.41)	(0.42)	(-0.79)	(0.66)	(1.03)	(0.40)	(-0.63)
12	1.43	1.23	0.96	0.97	0.86	1.04	1.01	0.86	1.00	1.17	0.83	0.63
	(1.94)	(0.99)	(-0.17)	(-0.14)	(-0.65)	(0.16)	(0.06)	(-0.50)	(-0.01)	(0.59)	(-0.68)	(-1.47)
24	1.21	1.16	1.23	1.18	0.89	1.59	1.15	0.80	0.87	1.09	0.81	0.39
	(0.67)	(0.45)	(0.74)	(0.56)	(-0.36)	(1.80)	(0.46)	(-0.52)	(-0.41)	(0.24)	(-0.55)	(-1.67)
36	1.28	0.99	1.54	1.43	0.80	2.18	1.31	0.66	0.84	0.94	0.97	0.37
	(0.74)	(-0.02)	(1.46)	(1.07)	(-0.52)	(2.97)	(0.78)	(-0.76)	(-0.42)	(-0.13)	(-0.08)	(-1.41)
48	1.40	0.84	1.97	1.65	0.61	2.81	1.38	0.68	0.81	0.75	1.05	0.33
	(0.92)	(-0.34)	(2.27)	(1.41)	(-0.88)	(3.99)	(0.85)	(-0.64)	(-0.44)	(-0.50)	(0.10)	(-1.35)
60	1.39	0.64	2.33	1.85	0.43	3.45	1.26	0.69	0.87	0.61	1.16	0.32
	(0.80)	(-0.68)	(2.80)	(1.66)	(-1.15)	(4.88)	(0.52)	(-0.57)	(-0.26)	(-0.72)	(0.32)	(-1.25)
72	1.41	0.58	2.70	2.11	0.32	3.93	1.07	0.80	0.91	0.49	1.22	0.27
	(0.78)	(-0.73)	(3.28)	(2.00)	(-1.26)	(5.35)	(0.14)	(-0.34)	(-0.17)	(-0.87)	(0.41)	(-1.24)
84	1.42	0.53	2.98	2.35	0.36	4.23	0.79	0.88	0.97	0.41	1.32	0.28
	(0.75)	(-0.77)	(3.55)	(2.27)	(-1.11)	(5.49)	(-0.36)	(-0.19)	(-0.05)	(-0.96)	(0.56)	(-1.16)
96	1.54	0.54	3.14	2.59	0.41	4.46	0.64	0.82	0.91	0.39	1.38	0.26
	(0.91)	(-0.71)	(3.60)	(2.53)	(-0.97)	(5.51)	(-0.57)	(-0.27)	(-0.15)	(-0.94)	(0.62)	(-1.13)
108	1.71	0.55	3.28	2.69	0.47	4.61	0.61	0.81	0.77	0.31	1.45	0.28
	(1.13)	(-0.66)	(3.64)	(2.56)	(-0.82)	(5.46)	(-0.61)	(-0.28)	(-0.35)	(-1.01)	(0.70)	(-1.05)
120	1.76	0.45	3.30	2.73	0.47	4.63	0.62	0.86	0.59	0.17	1.54	0.30
	(1.15)	(-0.77)	(3.52)	(2.51)	(-0.80)	(5.23)	(-0.56)	(-0.19)	(-0.61)	(-1.16)	(0.81)	(-0.99)

and 3, there are some portfolios that show a continuation of the strong positive autocorrelation at longer return horizons. Specifically, portfolios B1S1 and B2S2 show the continuation of strong positive autocorrelation (V(Q) values > 1) in the residual returns at long return horizons. Upon further examination, a partial explanation of this may be found in Table 1 Panel B. As shown in Table 1, Panel B, portfolios representing the intersection of the lowest ME and BE/ME (B1, B2, and S1) portfolios, are those containing securities predominantly from the AMEX and Nasdaq markets. Three other portfolios (B1S4, B2S4, and B4S4) also display strong positive autocorrelation at longer return horizons; however, these groups also display negative autocorrelation at shorter return horizons, a pattern consistent with mean reversion. A sign test for differences in the autocorrelation structure of total excess (Table 2) and residual (Table 4) returns produces a value of 15, while the one (five) percent critical value with a sample size of 25 is 19 (18). Therefore, the null hypothesis that there is no change (in particular, no decrease) in the stationary price components between total excess returns and residual returns cannot be rejected. Put differently, there is no difference in the mean reversion patterns of the total excess returns and residual returns of this sample.

A review of the evidence presented in Tables 2, 3, and 4 indicates the following. First, there is mean reversion in the return patterns for total, expected, and residual returns. Second, the mean reversion is related to both the ME and BE/ME factors, but it appears to be especially pronounced for the smaller-sized and book-to-market portfolios that contain companies traded on the AMEX and Nasdaq markets. Finally, these results indicate that the three-factor model is unable to fully explain the mean-reverting tendency in stock returns. Put differently, when the systematic risk factors related to size, the ratio book-to-market equity, and the market are controlled, the mean reversion is still persistent and highly significant.[20]

Conclusions

The results in this research indicate that there is a tendency for the ex-post excess returns of book-to-market equity/size portfolios to revert to their means. The importance of stationary price components appears to differ across firms with different market values (ME) and book-to-market equity ratios (BE/ME). In particular, those companies that possess smaller values of ME and BE/ME display more dramatic changes in the autocorrelation structure as the return horizon lengthens. Furthermore, companies possessing these particular ME and BE/ME attributes tend to be those firms that are traded on the AMEX and Nasdaq markets.

Overall, the intriguing result of this research is the finding that expected excess returns generated by the Fama-French three-factor model have a similar autocorrelation structure to their corresponding total excess. There appears to be no significant change in the mean-reverting structure between residual returns and their corresponding total excess returns. In general, these results indicate that the mean

[20] In comparing these results to those found in Gandopadhyay and Sen (1999), it is instructive to note some important differences in methodology and sample selection. In the Gandopadhyay and Sen study, stocks were selected from only the NYSE and partitioned into 10 deciles, based upon only the size (ME) of the companies. They found that once the size factor is controlled, mean reversion in residual returns disappears.

The methodology employed here is the same as that used in Fama and French (1992, 1993, 1995, and 1996) and employs 25 marked-value portfolios of companies from the NYSE, AMEX, and Nasdaq. The portfolios are formed through the intersection of ME and BE/ME, NYSE breakpoints. As the results show, the presence of mean version in returns is due, in large part, to both the ME and BE/ME factors and, in particular, to the intersections of these two factors for smaller-sized and book-to-market equity ratio firms. These are portfolios dominated by stocks on the AMEX and Nasdaq markets. Thus, in assessing whether or not the Fama-French three factor model can successfully account for the presence of mean reversion, the results of this research indicate that it is important to control for both the ME and BE/ME factors as well as for the inclusion of companies from the AMEX and Nasdaq exchanges.

reversion phenomenon in stock returns cannot be fully accounted for by the variation of time-varying expected returns generated by the Fama-French three-factor model.

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