Mean Aversion and Reversion of Asset Returns

Sandip Mukherji
Howard University

This study investigates autocorrelations in returns of six relatively safe and risky U.S. financial assets for one to ten years. Treasury bills and bonds display mean aversion in most periods whereas small company stocks exhibit mean reversion in all periods. The safest asset shows the strongest mean aversion and the riskiest asset has the strongest mean reversion. Large company stocks switch between mean aversion and reversion. Mean aversion of bond returns generally reflects mean aversion in Treasury bill returns. Mean reversion of stock returns is due to their negative relationships with prior risk-free returns and risk premiums in most periods.

Keywords: mean aversion, mean reversion, autocorrelations, asset returns, block bootstrap

INTRODUCTION

There is evidence of short-term mean aversion of stock returns, indicating that stocks continue superior and inferior performance over short horizons, which is the justification for momentum investing. Researchers have also documented medium-term mean reversion of stock returns, implying that stocks become less risky as the investment horizon increases, which is the rationale for time diversification. Balvers and Wu (2006) noted that momentum strategies were generally successful for short periods up to a year while contrarian strategies provided better results over the medium term of three to five years, consistent with mean aversion and reversion in those periods. They showed that combining momentum and contrarian strategies in 18 developed equity markets provided excess returns of 1.1% to 1.7% per month during 1970-99, outperforming pure momentum and pure contrarian strategies.

Studies of mean aversion and reversion in returns have generally focused on stock returns over short and medium horizons. This is the first study to investigate autocorrelations for up to ten years in the real returns of six major U.S. financial assets: Treasury bills (TB), intermediate-term government bonds (IGB), long-term government bonds (LGB), long-term corporate bonds (LCB), large company stocks (LCS), and small company stocks (SCS). These assets represent a range of safe and risky assets whose returns incorporate different premiums.

TB, the widely used proxy for a risk-free asset, only has minimal inflation risk, which is not relevant in this study since it is based on real returns. The five risky assets studied offer different risk premiums over the risk-free TB return. IGB has a modest maturity risk premium while LGB and LCB have higher maturity risk premiums, and LCB also has a default risk premium. The equities have a market risk premium that is higher than the risk premium of LCB. SCS has a higher premium than LCS because it also provides a firm size premium. Since TB is risk-free, it should not exhibit any irrational pricing or variations in risk premia, although its returns may consistently increase or decrease over periods of time as the Federal Reserve raises

or lowers rates to manage economic cycles and short-term interest rates persistently rise or fall with economic cycles, increasing or decreasing real returns.

As the TB return is a basic component of the returns of all the risky assets, variations of its returns over time may influence patterns in the returns of the other assets, if autocorrelations in TB returns affect the returns of other assets. This implies that if TB returns exhibit positive autocorrelations, the returns of risky assets will display significant mean reversion only if their risk premiums have mean reversion that is strong enough to overcome the mean aversion effect of the TB component of their returns. Whether that occurs, and the horizons over which it is observed, for different assets are empirical issues which are investigated in this paper. The relative influences of the risk-free returns and risk premiums on the autocorrelation patterns of different risky assets are also determined by separately examining the relationships of their returns with these components of their prior returns.

The feed-through effect of TB autocorrelations should be weaker for riskier assets, which have higher risk premiums, making the TB return a smaller component of their returns compared to the returns of safer assets. Accordingly, the returns of bonds are more likely than the equity returns to be influenced by the patterns of TB returns. Also, regardless of whether mean reversion in asset returns is due to irrational swings in prices or it reflects rational variations in risk premia, it is more likely to be observed for riskier equities, which have higher and more volatile risk premia, than safer bonds.

LITERATURE REVIEW

The literature on this subject originated more than three decades ago. Lo and MacKinlay (1988) found significant positive serial correlation of weekly and monthly stock returns, indicating mean aversion in stock returns over short horizons. Poterba and Summers (1988) reported that stock returns display positive autocorrelations for up to a year but have negative autocorrelations for three to eight years, resulting in the variance of 8-year returns being only four times the variance of 1-year returns. Fama and French (1988) showed that stock returns have strong negative autocorrelations for periods exceeding a year; mean reversion explains 40 percent and 25 percent of variations in 3- to 5-year stock returns of small and large firms, respectively.

Several researchers raised various issues with the evidence and implications of mean reversion in stock returns. Richardson and Stock (1989) suggested that the mean-reversion evidence might be eliminated by correcting for small-sample bias. Jegadeesh (1991) indicated that mean reversion in stock returns could be attributed to the January effect. McQueen (1992) argued that ordinary least-squares tests overstate the evidence of mean reversion in long-term stock returns because they accord greater weight to the larger error variances and stronger mean reversion of returns during the Depression and World War II years.

Subsequent studies have used different data and methods to support the evidence of mean reversion in stock returns. Based on weekly returns of seven Southeast Asian stock markets during 1988-95, Malliaropulos and Priestley (1999) reported evidence of mean reversion in expected returns and variations in risk premia related to variations in the price and quantity of risk over time. Balvers *et al.* (2000) found significant mean reversion in a panel of stock market indexes of 18 countries during 1969-96, with a half-life of three to three-and-a-half years. Gropp (2004) documented mean reversion in panels of industry portfolios persisting after World War II, with stock prices reverting half-way toward fundamental values in about four to eight years after temporary shocks. Mukherji (2011) showed that, although mean reversion in U.S. stock returns has become weaker in recent decades, it persists, particularly for small firms. Mukherji (2012) found stronger mean reversion in abnormal stock returns than in all returns of both large and small firms.

Some researchers have offered explanations for the evidence of mean reversion in stock returns. Fama and French (1988) observed that mean reversion is consistent with both irrational temporary divergence of stock prices from fundamental values and rational time-varying expected returns. Cecchetti *et al.* (1990) pointed out that negative autocorrelations of returns might reflect consumption smoothing by investors. Gangopadhyay and Reinganum (1996) argued that mean reversion reflects irrational mispricing if the market risk premium is assumed to be constant, but it can be interpreted as rational pricing if the conditional

market risk premium varies. Malliaropulos and Priestley (1999) indicated that the world price of risk varies over time and it appears to be inversely related to the business cycle.

Balvers and Wu (2006) noted that all assets which exhibit momentum should be expected to display mean reversion. Donaldson and Mehra (2019) developed a measure of average crossing time (ACT), which combines mean aversion and reversion, showing the average number of periods that returns are consistently above or below the mean. They observed that the ACT is shorter for mean-reverting returns than for mean-averting returns.

DATA AND METHODOLOGY

This study identifies the periods of mean aversion and reversion in real returns, and the influence of different components of returns on their observed patterns, for periods of one to ten years, for six major U.S. financial assets: 30-day U.S. Treasury bills, 5-year intermediate-term government bonds, 20-year long-term government bond, high-grade long-term corporate bonds, Standard & Poor's Composite Index of large company stocks, and portfolios of small company stocks. Biases due to a small sample and the January effect are avoided by bootstrapping 1,000 blocks of returns starting in random months.

Nominal monthly returns on the financial assets and monthly inflation rates based on consumer prices were obtained from Ibbotson (2018) for the period 1926-2017. As the data available for 92 years comprised only four independent 20-year returns, the distributions of returns were estimated with random block bootstraps, which preserve both serial and cross-sectional correlations. The nominal asset returns were deflated by the inflation rate to derive real returns. Continuously compounded real returns were aggregated for 12 to 240 months to obtain returns for one to twenty years.

Periods of mean aversion and reversion for each of the six assets were statistically tested and identified by regressing returns against prior returns for one to ten years. The regression models are:

$$R_{t,t+n-1} = \alpha_n + \beta_n R_{t-n,t-1} + \varepsilon_{t,t+n-1} \quad (1)$$

where $R_{t,t+n-1}$ and $R_{t-n,t-1}$ are the continuously compounded real returns for years t through t+n-1, and t-n through t-1, respectively, α_n is the intercept, β_n is the first-order autocorrelation of n-year returns, $\varepsilon_{t,t+n-1}$ are the error terms of the regressions, and n ranges from one to ten years. Autocorrelations in inflation rates were also examined with similar regressions.

The first regression regressed returns for year 11 against returns for year 10, and the last one regressed cumulative returns for years 11 through 20 against cumulative returns for years 1 through 10, from the 1,000 blocks of consecutive 20-year returns starting in random months.

To investigate the determinants of the observed patterns of mean aversion and reversion of returns, the prior return of each risky asset was decomposed into two components: the return on the risk-free asset (TB) and the asset's risk premium, which is its excess return over the risk-free return. The influence of prior risk-free returns on subsequent asset returns was investigated with the following regression models:

$$R_{t,t+n-1} = \alpha_n + \beta_n TBR_{t-n,t-1} + \varepsilon_{t,t+n-1} \quad (2)$$

where $R_{t,t+n-1}$ are the continuously compounded real asset returns for years t through t+n-1, $TBR_{t-n,t-1}$ are the continuously compounded real TB returns for years t-n through t-1, α_n is the regression intercept and β_n is the slope of TBR for n-year returns, $\varepsilon_{t,t+n-1}$ are the error terms of the regressions, and n ranges from one to ten years. The effect of prior inflation rates (IRs) on subsequent TB returns was examined with a similar model, using TBR as the dependent variable and prior IR as the independent variable.

The impact of each risky asset's prior risk premiums (RPs) on subsequent asset returns was determined with the following regression models:

$$R_{t,t+n-1} = \alpha_n + \beta_n RP_{t-n,t-1} + \varepsilon_{t,t+n-1} \quad (3)$$

where $R_{t,t+n-1}$ are the continuously compounded real asset returns for years t through t+n-1, $RP_{t-n,t-1}$ are the continuously compounded risk premiums for years t-n through t-1, α_n is the regression intercept and β_n is the slope of RP for n-year returns, $\varepsilon_{t,t+n-1}$ are the error terms of the regressions, and n ranges from one to ten years.

RESULTS AND DISCUSSION

Table 1 depicts the risk-return tradeoffs of the five risky assets studied, for periods of one to ten years, based on continuously compounded real returns in the last ten years of the 1,000 20-year blocks which are the dependent variables in the regression results reported in the subsequent Tables. Panel A shows that the mean returns of the assets increase about 10 to 11 times over the 10-year period. Panel B indicates that assets with higher returns have greater risk, consistent with expectations. For each period, standard deviations generally increase with returns; IGB has the lowest, and SCS has the highest, risk and return. The only anomaly is that LCB has slightly lower standard deviations, despite having higher returns, than LGB for five to ten years. Notably, the proportionate increase in standard deviations is much lower than the proportionate increase in mean returns over the 10-year period for all the assets, and the increase in risk consistently decreases with the level of risk. The standard deviation of 10-year returns is more than four times the standard deviation of 1-year returns for IGB, but it is less than twice the standard deviation of 1-year returns for SCS. Panel C reveals that the coefficient of variation (CV), which indicates the proportion of the standard deviation to the mean, declines consistently with the investment period for all the assets, and riskier assets not only provide superior risk-return tradeoffs compared to safer assets in all the investment periods, but they also offer greater improvements in the risk-return tradeoff as the investment horizon lengthens. The 10-year CV is only 18% of the 1-year CV for SCS, while it is 45% of the 1-year CV for IGB. Consequently, the CV of SCS relative to IGB drops from 68% in one year to 27% in ten years.

TABLE 1
RISK-RETURN TRADEOFFS OF FIVE MAJOR U.S. FINANCIAL ASSETS: 1926-2017

Years	Intermediate Government Bonds	Long-term Government Bonds	Long-term Corporate Bonds	Large Company Stocks	Small Company Stocks
Panel A. Mean Continuously Compounded Real Returns (%)					
1	1.55	1.66	1.74	6.13	8.65
2	3.26	3.35	3.52	12.09	17.26
3	4.93	5.19	5.62	18.52	27.02
4	6.73	7.32	7.90	24.84	35.89
5	8.13	9.06	9.91	32.61	46.21
6	9.31	10.33	11.26	39.02	54.90
7	11.01	12.37	13.72	46.34	64.75
8	12.65	14.45	16.02	53.79	74.71
9	14.38	16.47	18.25	60.74	83.53
10	15.61	17.74	20.11	67.46	91.63
Panel B. Standard Deviations of Continuously Compounded Real Returns (%)					
1	6.61	9.62	9.67	17.60	25.09
2	10.45	14.66	14.76	23.80	32.97
3	13.34	18.44	18.61	29.34	40.26
4	15.78	21.48	21.63	33.05	44.61
5	18.45	25.09	24.58	37.02	47.72
6	20.93	28.51	27.84	40.04	48.60
7	23.09	31.27	30.55	43.21	49.15
8	25.44	34.87	33.78	46.70	49.87
9	27.48	37.78	36.39	50.32	48.38
10	29.65	41.12	39.65	53.74	47.47

Panel C. Coefficients of variation of Continuously Compounded Real Returns					
1	4.25	5.81	5.54	2.87	2.90
2	3.21	4.37	4.19	1.97	1.91
3	2.71	3.55	3.31	1.58	1.49
4	2.34	2.93	2.74	1.33	1.24
5	2.27	2.77	2.48	1.14	1.03
6	2.25	2.76	2.47	1.03	0.89
7	2.10	2.53	2.23	0.93	0.76
8	2.01	2.41	2.11	0.87	0.67
9	1.91	2.29	1.99	0.83	0.58
10	1.90	2.32	1.97	0.80	0.52

TABLE 2
REGRESSIONS OF CONTINUOUSLY COMPOUNDED INFLATION RATES (IRS) AND REAL TREASURY BILL (TB) RETURNS: 1926-2017

Years	Intercept	T-statistic	Slope	T-statistic	Adjusted R^2 (%)
Panel A. Regressions of IRs against Prior IRs					
1	0.02**	12.06	0.55**	19.93	28.40
2	0.05**	18.00	0.28**	9.40	8.05
3	0.08**	19.02	0.32**	11.38	11.40
4	0.09**	19.02	0.40**	15.37	19.05
5	0.13**	22.23	0.34**	13.06	14.51
6	0.18**	26.03	0.23**	9.07	7.53
7	0.23**	29.32	0.14**	5.55	2.90
8	0.28**	32.48	0.06*	2.22	0.39
9	0.34**	35.90	-0.02	-0.87	-0.02
10	0.41**	39.69	-0.09**	-3.82	1.35
Panel B. Regressions of TB Returns against Prior Returns					
1	0.00	1.09	0.61**	24.47	37.44
2	0.00	1.86	0.43**	15.22	18.76
3	0.00*	2.09	0.48**	17.91	24.24
4	0.01*	2.06	0.55**	21.28	31.15
5	0.00	0.95	0.50**	18.15	24.74
6	0.00	0.44	0.37**	13.02	14.43
7	0.00	0.67	0.26**	8.92	7.29
8	0.01	1.05	0.16**	5.36	2.70
9	0.01	1.32	0.06*	2.16	0.37
10	0.01	1.70	-0.03	-1.20	0.04
Panel C. Regressions of TB Returns against Prior IRs					
1	0.01**	4.75	-0.20**	-5.90	3.28
2	-0.01*	-2.48	0.14**	4.23	1.66
3	-0.02**	-3.73	0.19**	5.66	3.01
4	-0.03**	-4.83	0.23**	6.67	4.17
5	-0.06**	-7.87	0.32**	9.86	8.78
6	-0.09**	-11.44	0.43**	14.18	16.69
7	-0.12**	-14.61	0.50**	18.46	25.38
8	-0.15**	-18.57	0.57**	23.75	36.04
9	-0.19**	-23.95	0.64**	30.54	48.25
10	-0.23**	-30.65	0.70**	39.16	60.54

*Significant at 5% level.
**Significant at 1% level.

Before investigating the time-series patterns of the real returns of risky assets, the behavior of inflation rates, the real returns of the risk-free asset, and the relationship between these variables are examined in Table 2. Panel A shows significant positive autocorrelations in inflation rates for one to eight years and a significant negative autocorrelation in ten years. The t-statistics and adjusted R-squares indicate that the strongest positive autocorrelation in inflation rates is for one year, but it remains highly significant up to seven years. The pattern of real TB returns in Panel B is very similar to that of inflation, displaying significant positive autocorrelations for one to nine years, with the strongest positive autocorrelation in one year. Panel C shows that the relationship of real TB returns with prior inflation rates is significantly negative for one year, but it is significantly positive for two to ten years, and this positive relationship becomes stronger as the investment horizon increases. Overall, these results suggest that low and high inflation regimes, as well as real risk-free returns, extend over long cycles and, although low inflation rates increase real risk-free returns over short periods, high inflation rates give rise to high real risk-free returns over long periods.

TABLE 3
REGRESSIONS OF CONTINUOUSLY COMPOUNDED REAL INTERMEDIATE GOVERNMENT BOND (IGB) RETURNS: 1926-2017

Years	Intercept	T-statistic	Slope	T-statistic	Adjusted R^2 (%)
Panel A. Regressions of IGB Returns against Prior Returns					
1	0.01**	6.06	0.27**	8.84	7.18
2	0.03**	8.43	0.18**	5.70	3.06
3	0.04**	9.50	0.20**	6.51	3.98
4	0.05**	10.47	0.24**	7.90	5.79
5	0.06**	10.47	0.25**	7.93	5.83
6	0.07**	10.31	0.23**	7.49	5.23
7	0.09**	11.60	0.17**	5.58	2.93
8	0.11**	12.63	0.10**	3.45	1.08
9	0.14**	13.84	0.06	1.84	0.24
10	0.16**	14.60	-0.00	-0.09	-0.10
Panel B. Regressions of IGB Returns against Prior Treasury bill (TB) Returns					
1	0.02**	8.97	0.89**	18.02	24.47
2	0.03**	11.00	0.64**	13.73	15.80
3	0.05**	13.46	0.71**	16.83	22.03
4	0.07**	16.37	0.80**	20.60	29.77
5	0.08**	16.49	0.76**	19.99	28.52
6	0.09**	15.53	0.64**	16.83	22.02
7	0.11**	15.75	0.51**	13.48	15.32
8	0.12**	15.86	0.41**	10.80	10.37
9	0.14**	16.35	0.33**	8.48	6.63
10	0.15**	16.21	0.23**	5.86	3.23
Panel C. Regressions of IGB Returns against Prior IGB Risk Premiums					
1	0.02**	7.30	-0.02	-0.37	-0.09
2	0.04**	10.57	-0.18**	-3.65	1.22
3	0.06**	13.16	-0.28**	-5.70	3.05
4	0.09**	15.37	-0.34**	-6.84	4.38
5	0.11**	16.06	-0.39**	-7.47	5.21
6	0.12**	15.30	-0.35**	-6.35	3.78
7	0.15**	16.43	-0.39**	-7.00	4.58

8	0.18**	17.75	-0.47**	-8.33	6.41
9	0.21**	18.65	-0.50**	-8.80	7.11
10	0.23**	18.90	-0.53**	-9.18	7.69

*Significant at 5% level.
**Significant at 1% level.

Panel A of Table 3 shows that real IGB returns are significantly positively autocorrelated for one to eight years, but the t-statistics of the slopes and the adjusted R-squares are much smaller than those of TB. The highest explanatory power of 7.18% is for one year. The reasons for this pattern are evident from the results in Panels B and C. IGB returns have a strong positive relationship with prior TB returns for all periods, but they have a strong negative relationship with prior risk premiums for two to ten years. The positive relationship with prior TB returns is much stronger than the negative relationship with prior risk premiums, resulting in the positive autocorrelation of IGB returns observed in panel A. As the positive relationship with prior TB returns weakens, while the negative relationship with prior risk premiums strengthens, there is no significant autocorrelation in IGB returns after eight years. These findings indicate that real IGB returns display mean aversion for up to eight years, owing to the feed-through effect of mean aversion in TB returns, despite the negative relationship of IGB returns with prior risk premiums.

Table 4 reveals that real LGB returns are significantly positively autocorrelated in all periods. In contrast to TB and IGB, LGB generally has higher adjusted R-squares in longer periods, with the highest explanatory power of 8.10% for 7 years, and the explanatory power is much higher for ten years (5.51%) than for one year (1.52%). The positive autocorrelation of LGB returns is primarily due to its relationship with prior TB returns, which is significantly positive for all periods. The explanatory power of prior TB returns for LGB returns peaks in five years before declining. Prior LGB risk premiums are significantly positively related to LGB returns for seven to ten years, maintaining the positive autocorrelation of LGB returns in longer periods as the influence of prior TB returns is diminished. These results show that real LGB returns exhibit mean aversion for up to 10 years, mainly reflecting its positive relationship with the TB component of its prior returns, which is strengthened by a positive relationship with prior risk premiums in the longer periods.

Table 5 indicates that real LCB returns also display significant positive autocorrelations in all periods. The t-statistics of the slopes and adjusted R-squares are, however, smaller than those of LGB returns, except for the 1-year period, which has the highest explanatory power of 2.78%. Notably, for both LGB and LCB, the strength of the positive autocorrelation weakens after 7 years. Similar to the findings for the other bond returns, the positive autocorrelation of LCB returns is primarily due to its relationship with prior TB returns, which is significantly positive for all periods. LCB returns are significantly negatively related to prior risk premiums for all periods beyond one year, except seven to eight years. These findings show mean aversion in real LCB returns for up to ten years, owing to a positive relationship with prior TB returns in all periods. The positive autocorrelation in returns is generally weaker than that of LGB because LCB returns are negatively related to prior risk premiums in most periods.

Table 6 shows varying trends in autocorrelations of real LCS returns over the 10-year period, with significant negative autocorrelations in two to three years as well as eight to ten years, and a significant positive autocorrelation in six years. The explanatory power of the positive autocorrelation in six years is very low; the adjusted R-square is 0.75%. The highest explanatory power of the negative autocorrelations is for the longest period of ten years, which has an adjusted R-square of 7.29%. While the medium-term mean reversion of LCS returns has been documented in earlier studies, these results demonstrate for the first time that LCS returns display mean aversion in six years and they are mean-reverting for longer periods of eight to ten years. Panels B and C indicate the reasons for the patterns of returns observed in panel A. LCS returns have a significant positive relationship with prior TB returns for one year and a negative relationship with prior TB returns for three to ten years. The negative relationship with prior TB returns is strongest in the longer periods of eight to ten years. LCS returns are also significantly negatively related to prior risk premiums for one to three years and positively related to prior risk premiums for five to nine years. These results suggest different reasons for the mean reversion in LCS returns in medium and long

periods. The mean reversion in two to three years is due to a negative relationship with prior risk premiums, which is strengthened by a negative relationship with prior TB returns in three years. The mean reversion in eight to ten years is due to a negative relationship with prior TB returns, and it occurs despite a positive relationship with prior risk premiums in eight to nine years. The mean aversion in LCS returns in six years reflects a positive relationship with its prior risk premium, despite a negative relationship with prior TB returns for that period.

TABLE 4
REGRESSIONS OF CONTINUOUSLY COMPOUNDED REAL LONG-TERM GOVERNMENT BOND (LGB) RETURNS: 1926-2017

Years	Intercept	T-statistic	Slope	T-statistic	Adjusted R^2 (%)
Panel A. Regressions of LGB Returns against Prior Returns					
1	0.02**	4.98	0.13**	4.05	1.52
2	0.03**	6.69	0.10**	3.03	0.81
3	0.04**	7.63	0.17**	5.51	2.86
4	0.06**	9.05	0.20**	6.41	3.86
5	0.08**	9.35	0.21**	6.76	4.28
6	0.08**	8.60	0.27**	8.70	6.95
7	0.09**	9.24	0.28**	9.44	8.10
8	0.11**	9.58	0.27**	8.93	7.31
9	0.13**	10.13	0.27**	8.62	6.84
10	0.14**	9.93	0.24**	7.70	5.51
Panel B. Regressions of LGB Returns against Prior Treasury Bill (TB) Returns					
1	0.02**	6.17	0.99**	13.01	14.42
2	0.03**	7.77	0.68**	10.05	9.10
3	0.05**	9.78	0.79**	12.82	14.05
4	0.07**	12.34	0.92**	16.36	21.06
5	0.09**	12.91	0.90**	16.68	21.72
6	0.10**	12.33	0.80**	15.13	18.57
7	0.12**	12.94	0.68**	13.21	14.80
8	0.14**	13.18	0.62**	11.89	12.32
9	0.15**	13.63	0.58**	11.17	11.02
10	0.16**	13.14	0.52**	9.82	8.72
Panel C. Regressions of LGB Returns against Prior LGB Risk Premiums.					
1	0.02**	5.48	-0.03	-0.72	-0.05
2	0.04**	7.42	-0.06	-1.64	0.17
3	0.05**	8.68	-0.02	-0.39	-0.08
4	0.08**	10.64	-0.05	-1.23	0.05
5	0.09**	11.23	-0.05	-1.39	0.09
6	0.10**	10.21	0.05	1.18	0.04
7	0.11**	10.48	0.12**	2.83	0.70
8	0.13**	10.78	0.12**	2.96	0.77
9	0.15**	11.34	0.12**	2.95	0.76
10	0.16**	11.12	0.12**	2.75	0.65

*Significant at 5% level.
**Significant at 1% level.

Table 7 indicates that real SCS returns exhibit significant negative autocorrelations in all periods. The explanatory power of the negative autocorrelations rises from 0.79% in one year to a high of 26.40% in

eight years before declining to 20.48% in ten years. These findings show that, unlike LCS, SCS displays consistent mean reversion in all periods, and its returns show much stronger mean reversion than LCS returns do. The persistent mean reversion in SCS returns is due to its negative relationship with prior TB returns and risk premiums in all periods except for one year, when it is not significantly related to prior TB returns. The negative relationship of SCS returns is generally stronger with prior risk premiums than with prior TB returns, showing that it is the only asset studied which has a negative autocorrelation in returns that can be attributed primarily to the negative relationship of returns with prior risk premiums. The highest explanatory powers of the negative autocorrelations are from four to ten years for prior risk premiums and from six to ten years for prior TB returns, accounting for the strong negative autocorrelation in returns from four to ten years.

TABLE 5
REGRESSIONS OF CONTINUOUSLY COMPOUNDED REAL LONG-TERM CORPORATE BOND (LCB) RETURNS: 1926-2017

Years	Intercept	T-statistic	Slope	T-statistic	Adjusted R^2 (%)
Panel A. Regressions of LCB Returns against Prior Returns					
1	0.02**	5.06	0.17**	5.44	2.78
2	0.03**	6.96	0.09**	2.66	0.60
3	0.05**	8.64	0.08**	2.59	0.57
4	0.07**	10.24	0.09**	2.82	0.69
5	0.09**	10.94	0.11**	3.62	1.20
6	0.09**	10.15	0.16**	5.19	2.53
7	0.12**	11.19	0.16**	5.37	2.71
8	0.14**	11.82	0.14**	4.66	2.04
9	0.16**	12.83	0.11**	3.59	1.18
10	0.18**	13.11	0.08**	2.64	0.60
Panel B. Regressions of LCB Returns against Prior Treasury Bill (TB) Returns					
1	0.02**	6.46	1.00**	13.06	14.52
2	0.04**	8.11	0.70**	10.26	9.45
3	0.06**	10.57	0.83**	13.53	15.42
4	0.08**	13.28	0.94**	16.66	21.68
5	0.10**	14.41	0.88**	16.64	21.64
6	0.11**	13.63	0.75**	14.35	17.02
7	0.13**	14.64	0.62**	12.14	12.77
8	0.15**	15.06	0.54**	10.53	9.90
9	0.17**	15.66	0.47**	9.27	7.83
10	0.19**	15.58	0.40**	7.76	5.60
Panel C. Regressions of LCB Returns against Prior LCB Risk Premiums					
1	0.02**	5.52	0.03	0.73	-0.05
2	0.04**	7.85	-0.08*	-2.14	0.36
3	0.06**	10.44	-0.16**	-4.19	1.63
4	0.09**	12.91	-0.21**	-5.49	2.84
5	0.12**	13.88	-0.19**	-5.10	2.45
6	0.12**	12.63	-0.10*	-2.56	0.55
7	0.14**	13.20	-0.06	-1.39	0.09
8	0.17**	13.72	-0.06	-1.47	0.12
9	0.20**	14.75	-0.09*	-2.18	0.38
10	0.22**	14.88	-0.11*	-2.42	0.49

*Significant at 5% level.
**Significant at 1% level.

The varying patterns of mean aversion and reversion documented by the regression results of different fixed-income and equity assets are revealing. The safest fixed-income assets−TB and IGB−show significant mean aversion for eight years, but the autocorrelation slope is significantly negative for TB and zero for IGB in ten years, suggesting that we might find their returns to be significantly mean-reverting in periods beyond ten years if we had sufficient data to investigate longer blocks of returns. The somewhat riskier fixed income assets−LGB and LCB−have significant mean aversion for up to ten years, although its magnitude weakens after about seven years, indicating that the returns on these assets would take longer to revert to the mean than the safer fixed income assets.

TABLE 6
REGRESSIONS OF CONTINUOUSLY COMPOUNDED REAL LARGE COMPANY STOCK (LCS) RETURNS FOR DIFFERENT PERIODS: 1926-2017

Years	Intercept	T-statistic	Slope	T-statistic	Adjusted R^2 (%)
Panel A. Regressions of LCS Returns against Prior Returns					
1	0.06**	11.04	-0.05	-1.75	0.21
2	0.14**	16.51	-0.13**	-4.40	1.80
3	0.21**	18.46	-0.11**	-3.30	0.98
4	0.26**	19.25	-0.05	-1.66	0.18
5	0.33**	20.87	-0.02	-0.66	-0.06
6	0.35**	19.43	0.09**	2.92	0.75
7	0.44**	21.84	0.04	1.30	0.07
8	0.59**	25.79	-0.09**	-2.75	0.65
9	0.71**	28.28	-0.17**	-5.27	2.61
10	0.87**	31.99	-0.29**	-8.92	7.29
Panel B. Regressions of LCS Returns against Prior Treasury Bill (TB) Returns					
1	0.06**	11.18	0.56**	3.75	1.29
2	0.12**	16.05	-0.11	-0.97	-0.01
3	0.18**	20.02	-0.36**	-3.46	1.09
4	0.25**	23.87	-0.36**	-3.76	1.30
5	0.33**	28.61	-0.65**	-7.45	5.17
6	0.39**	33.27	-0.93**	-12.11	12.73
7	0.47**	38.47	-1.07**	-15.58	19.49
8	0.55**	43.42	-1.19**	-18.64	25.76
9	0.63**	46.79	-1.21**	-19.47	27.46
10	0.71**	49.26	-1.25**	-20.55	29.66
Panel C. Regressions of LCS Returns against Prior LCS Risk Premiums					
1	0.07**	11.31	-0.08**	-2.62	0.58
2	0.14**	16.41	-0.14**	-4.35	1.77
3	0.20**	17.62	-0.08*	-2.33	0.44
4	0.25**	18.16	-0.01	0.45	-0.08
5	0.30**	18.74	0.07*	1.98	0.29
6	0.29**	16.01	0.26**	7.88	5.77
7	0.35**	17.57	0.25**	7.69	5.51
8	0.46**	20.48	0.15**	4.52	1.91
9	0.56**	22.50	0.08*	2.36	0.45
10	0.69**	25.06	-0.02	-0.62	-0.06

*Significant at 5% level.
**Significant at 1% level.

The contrasting behavior of the equity assets is intriguing. The returns of LCS, which is less risky and expected to be more efficiently priced than SCS, have alternating cycles of positive and negative autocorrelations, indicating mean reversion for two to three years, mean aversion for six years, and mean reversion for eight to ten years. These patterns suggest that mean reversion in the shorter period gives rise to mean aversion in the medium-term which leads to longer-term mean reversion. This is consistent with LCS returns reflecting two business cycles. According to data from the National Bureau of Economic Research, the 92-year study period contained fifteen business cycles with an average length of about six years, so the 10-year periods studied contained more than one business cycle on average. SCS returns are significantly mean-reverting in all periods. Its mean reversion becomes particularly strong in five years and although it weakens somewhat after eight years, it stays strong through ten years. This shows that SCS returns exhibit mean-reverting behavior for long periods of time, indicating that the firm-size premium varies significantly over time and it does not follow business cycles.

TABLE 7
REGRESSIONS OF CONTINUOUSLY COMPOUNDED REAL SMALL COMPANY STOCK (SCS) RETURNS: 1926-2017

Years	Intercept	T-statistic	Slope	T-statistic	Adjusted R^2 (%)
Panel A. Regressions of SCS Returns against Prior Returns					
1	0.09**	11.32	-0.09**	-3.00	0.79
2	0.21**	17.93	-0.19**	-6.43	3.88
3	0.33**	21.64	-0.22**	-7.02	4.61
4	0.52**	29.20	-0.37**	-13.19	14.75
5	0.72**	38.31	-0.49**	-18.90	26.29
6	0.83**	36.96	-0.45**	-15.79	19.91
7	0.97**	39.30	-0.45**	-15.80	19.94
8	1.16**	45.17	-0.52**	-18.96	26.40
9	1.25**	46.10	-0.48**	-17.68	23.77
10	1.32**	46.33	-0.42**	-16.07	20.48
Panel B. Regressions of SCS Returns against Prior Treasury Bill (TB) Returns					
1	0.09**	10.91	0.14	0.64	-0.06
2	0.17**	16.60	-0.64**	-4.02	1.50
3	0.27**	21.51	-0.86**	-6.06	3.45
4	0.36**	25.59	-0.53**	-4.10	1.56
5	0.46**	31.16	-0.69**	-6.05	3.44
6	0.55**	37.19	-0.83**	-8.58	6.77
7	0.65**	43.42	-0.71**	-8.38	6.48
8	0.76**	49.40	-0.64**	-8.30	6.36
9	0.84**	56.92	-0.53**	-7.71	5.53
10	0.93**	63.33	-0.49**	-7.82	5.68
Panel C. Regressions of SCS Returns against Prior SCS Risk Premiums					
1	0.09**	11.36	-0.09**	-3.10	0.85
2	0.20**	17.48	-0.17**	-5.63	2.98
3	0.32**	20.64	-0.17**	-5.47	2.81
4	0.49**	27.78	-0.31**	-11.33	11.31
5	0.67**	35.04	-0.39**	-15.36	19.05
6	0.74**	33.11	-0.31**	-11.27	11.20
7	0.85**	35.17	-0.29**	-10.60	10.03
8	1.00**	39.54	-0.32**	-12.23	12.95
9	1.07**	41.42	-0.27**	-10.84	10.45
10	1.12**	42.76	-0.22**	-9.40	8.04

*Significant at 5% level.
**Significant at 1% level.

CONCLUSIONS

Studies of mean aversion and reversion in returns have generally been limited to stock returns in short and medium periods. This study examined autocorrelations for one to ten years in the real returns of six major U.S. financial assets representing relatively safe and risky assets with different premiums. The return distributions of these assets were estimated from 92 years of monthly data by drawing 1,000 random block bootstraps, which maintain serial and cross-sectional correlations while eliminating biases due to a small sample and the January effect.

Regressions of returns against previous returns revealed that TB and IGB display significant mean aversion for nine and eight years, respectively, although their positive autocorrelations decline over time and are much stronger for TB compared to IGB. LGB and LCB returns exhibit significant mean aversion up to ten years, and the positive autocorrelations are stronger for LGB compared to LCB. The explanatory power of the positive autocorrelations of LGB returns is generally higher for longer periods, and it is greater than those of the other bonds over longer periods. LCS is the only asset with varying patterns of significant autocorrelations, displaying negative autocorrelations in two to three years, and eight to ten years, and positive autocorrelations in six years. SCS is also unique in being the only asset to exhibit significant mean reversion for periods of one to ten years, and it has much stronger mean reversion than LCS in all periods.

These findings indicate very different patterns in the real returns of fixed-income and equity assets. While the fixed-income assets exhibit mean aversion in short, medium and long horizons, both the equity assets show mean reversion over short and long periods. Surprisingly, LCS switches between mean reversion and aversion. Notably, the safest asset (TB) displays the strongest mean aversion whereas the riskiest asset (SCS) has the strongest and most persistent mean reversion.

The reasons for the varying autocorrelation patterns of different assets were investigated by examining the relationships of their returns with the components of their prior returns. Inflation rates display positive autocorrelation up to ten years. The 1-year real risk-free return is inversely related to the inflation rate in the previous year, but for longer periods of two to ten years, real risk-free returns are directly related to previous inflation rates. These results suggest that inflation rates and real risk-free returns follow long cycles, and low/high inflation rates are followed by low/high real risk-free returns for periods longer than a year. Mean aversion in the returns of all the bonds reflects their positive autocorrelations with prior TB returns. IGB and LCB returns generally have negative autocorrelations with prior risk premiums for periods longer than a year. LCS returns exhibit mean reversion primarily due to a negative relationship with prior risk premiums in two to three years and a negative relationship with prior TB returns in eight to ten years, and they display mean aversion in six years due to a positive relationship with the prior risk premium. SCS is the only asset with consistently mean-reverting returns in all periods, primarily reflecting a negative relationship with prior risk premiums, which is strengthened by a negative relationship with prior TB returns in periods beyond a year. In view of the positive autocorrelations in TB returns, the negative relationships of equity returns with prior TB returns is consistent with equities benefiting from low rates and being hurt by high rates.

REFERENCES

Balvers, R., & Wu, Y. (2006). Momentum and mean reversion across national equity markets. *Journal of Empirical Finance*, *13*(1), 24-48.

Balvers, R., Wu, Y., & Gilliland, E. (2000). Mean reversion across national stock markets and parametric contrarian investment strategies. *Journal of Finance*, *55*(2), 745-772.

Cecchetti, S.G., Lam, P., & Mark, N.C. (1990). Mean reversion in equilibrium asset prices. *The American Economic Review*, *80*(3), 398-418.

Donaldson, J.B., & Mehra, R. (2019). Average crossing time: An alternative characterization of mean aversion and reversion. Working paper no. 25519. *National Bureau of Economic Research*, pp.1-72.

Fama, E.F., & French, K.R. (1988). Permanent and temporary components of stock prices. *Journal of Political Economy*, *96*(2), 246-273.

Gangopadhyay, P., & Reinganum, M.R. (1996). Interpreting mean reversion in stock returns. *The Quarterly Review of Economics and Finance*, *36*(3), 377-394.

Gropp, J. (2004). Mean reversion of industry stock returns in the U.S., 1926-1998. *Journal of Empirical Finance*, *11*(4), 537-551.

Ibboston, R. (2018). *SBBI Yearbook*. Duff and Phelps, New York, NY.

Jegadeesh, N. (1991). Seasonality in stock price mean reversion: Evidence from the U.S. and the U.K. *The Journal of Finance*, *46*(4), 1427-1444.

Lo, A.W., & MacKinlay, A.C. (1988). Stock market prices do not follow random walks: Evidence from a simple specification test. *The Review of Financial Studies*, *1*(1), 41-66.

Malliaropulos, D., & Priestley, R. (1999). Mean reversion in Southeast Asian stock markets. *Journal of Empirical Finance*, *6*(4), 355-384.

McQueen, G. (1992). Long-horizon mean-reverting stock prices revisited. *Journal of Financial and Quantitative Analysis*, *27*(1), 1-18.

Mukherji, S. (2011). Are stock returns still mean-reverting? *Review of Financial Economics*, *20*(1), 22-27.

Mukherji, S. (2012). Mean reversion of abnormal stock returns. *Journal of Wealth Management*, *14*(4), 122-129.

Poterba, J.P., & Summers, L.H. (1988). Mean reversion in stock prices: Evidence and implications. *Journal of Financial Economics*, *22*(1), 27-59.

Richardson, M., & Stock, J. (1989). Drawing inferences from statistics based on multi-year asset returns. *Journal of Financial Economics*, *25*(2), 323-348.