

The Pitfalls of Using Short-interval Betas for Long-run Investment Decisions

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Abstract

We investigate empirical relationships between beta, the Treynor ratio, and the investment horizon for portfolios of small stocks, large stocks, and bonds. Betas and Treynor ratios are computed for holding periods of 1 to 30 years. For both the stock and bond portfolios, beta and the Treynor ratio change substantially with the holding period. Furthermore, the relative Treynor rankings of the portfolios change. Therefore, betas and Treynor ratios cannot be calculated independently of the intended investment horizon. Our results suggest that the impact of one's assumed investment horizon has not received sufficient attention in computing systematic risk (beta) or interpreting reward-to-risk performance measures (such as the Treynor ratio, Sharpe ratio, or Jensen's alpha). Thus, investors with long-run investment horizons must interpret performance parameters obtained from investment advisory services with due consideration for horizon effects. © 2002 Academy of Financial Services. All rights reserved.

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1. Introduction

An individual investor's decision on the proper allocation of investment assets has never been simple. The academic literature investigates these decisions in a variety of ways. Some papers provide advice on asset allocation (Fraser et al., 2000), whereas others discuss the

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possibility of time diversification (Smith, 1997; Hodges et al., 1997). Still others examine the relationship between investment decisions and risk aversion of individual investors (Alexander et al., 1998; Hariharan et al., 2000). A common theme underlying these papers is to question whether individual investors are making appropriate risk-return tradeoffs in their asset allocation decisions.

The academic papers containing advice for individual investors effectively assume the truth of a joint-hypothesis. The first hypothesis is that a correct asset-allocation mix, for a given time horizon, actually exists (i.e., time diversification). That is, they assume that an investor, given an expected consumption pattern and the risk-return characteristics of the various investment alternatives, has an optimal investment mix. The second hypothesis is that measurement tools exist that allow individual investors to rationally decide among the various financial assets when making the asset allocation decision. At this point, neither hypothesis can be considered proven. Samuelson (1990, 1994) has argued that time diversification may not be possible. Hodges et al. (1997) have shown that problems with the Sharpe ratio arise as the investment horizon changes. Our paper extends the discussion of the second hypothesis. Specifically, we focus on the use of beta in evaluating systematic risk and risk-return tradeoffs in portfolio construction as one's investment horizon changes.

The betas of investment advisory services are usually estimated by using short-term return intervals. *Value Line*, for example, computes stock betas by using 5-years of weekly return data and *Morningstar* provides mutual fund betas based on 36 monthly returns. As we show later, this approach implicitly assumes that investors have a similarly short investment horizon. Betas computed by using weekly or monthly returns will be biased for long-term investors because an asset's systematic risk is not invariant to the assumed investment horizon. Because beta is employed in the construction of many reward-to-risk performance measures, the same bias exists for investors who employ these ratios in making long-term investment choices. Examples of performance measures that use beta in their construction are the Treynor ratio (1965), Jensen's Alpha (1968), and indirectly, the Sharpe ratio (1966).

To understand why betas are not invariant to the investment horizon, consider the standard formula for computing the beta of asset i :

$$\beta_i = \frac{\text{Cov}(R_i, R_m)}{\sigma_m^2} \quad (1)$$

where β_i = beta of asset i ; $\text{Cov}(R_i, R_m)$ = covariance of returns for asset i and the market portfolio; R_m = return on the market portfolio; R_i = return on asset i ; σ_m^2 = variance of market returns.

If one uses monthly returns to compute beta, multiplying each monthly return of asset i and the market portfolio by 12 would leave beta unchanged. Compounding returns over time, however, is not linear. For example, one annualizes monthly returns by adding one, raising this sum to the 12th power, and subtracting 1. Thus, a beta estimated by using monthly returns in Eq. (1) would be biased for an investor with a 1-year holding period, because it would not reflect the nonlinearity inherent in the compounding process. An investor with a 1-year investment horizon should either compute a multi-period (i.e., 12-period) beta as discussed in the next section or use annual return data in Eq. (1) to compute an equivalent single-period (i.e., annual) beta.

We employ established theory to examine the empirical relationships among the length of the investment horizon, beta, and the Treynor ratio for portfolios of large common stocks, small common stocks, and long-term corporate bonds. Annual return data are used to compute multi-period betas and Treynor ratios for the stock and bond portfolios over holding periods ranging from 1 to 30 years. We analyze the behavior of beta and the Treynor ratio as the investment horizon lengthens and evaluate the relative performance of the portfolios.

We verify the multi-period results by showing they are consistent with single-period betas and Treynor ratios computed from holding-period returns spanning 1 to 30 years that have been generated by simulation. For a specific investment horizon, we make a distinction between multi-period and single-period betas and Treynor ratios. The former are computed from shorter (one-period) return intervals, whereas the latter are computed from return intervals equal to the specific investment horizon.

Our results show that long-term investors cannot meaningfully use betas or performance measures (such as the Treynor ratio, Jensen's Alpha, or the Sharpe ratio) independently of the intended investment horizon. Betas and Treynor ratios for the stock and bond portfolios vary substantially with the holding period. Furthermore, the relative Treynor rankings between the common stock and small stock portfolios change depending on the time horizon.

2. Computing multi-period betas

Levhari and Levy (1977) have shown theoretically that beta is a direct function of the holding period. In particular, if returns are independently and identically distributed across time, then the expression for a multi-period beta in terms of one-period returns is:

$$\beta_n = \frac{[\text{Cov}(R_i, R_m) + (1 + \bar{R}_i)(1 + \bar{R}_m)]^n - [(1 + \bar{R}_i)(1 + \bar{R}_m)]^n}{[(\sigma_m^2 + (1 + \bar{R}_m)^2)^n - (1 + \bar{R}_m)^{2n}} \quad (2)$$

where β_n = estimated n -period beta by using one-period returns; $\text{Cov}(R_i, R_m)$ = covariance between one-period returns for asset i and the market portfolio; \bar{R}_m = mean one-period return on the market portfolio; \bar{R}_i = mean one-period return on asset i ; σ_m^2 = one-period market variance.

This formula allows a long-term investor with only short-run (one-period) return data (annual, for example) to compute the appropriate beta for a n -period investment horizon, say $n = 20$ years. Eq. (2) shows that the relationship between the multi-period beta and the one-period beta is highly nonlinear with respect to the holding period. One consequence of this is that using any reward-to-risk performance measure that uses beta in its construction (e.g., Treynor ratio, Sharpe ratio, or Jensen's alpha) to evaluate investment alternatives is strictly valid only if the intended investment horizon is equal to the holding period of the returns used to compute the ratio.

To demonstrate, we show how one such performance measure, the Treynor ratio, is affected by a change in one's assumed holding period. The Treynor (1965) ratio evaluates investment performance by comparing the expected excess return to the expected systematic risk of the asset. This ratio normalizes excess return by the portfolio's risk, thus allowing one

to compare portfolios of differing systematic risk levels. The higher the calculated Treynor ratio, the better the performance. In practice, the ex-post version of the Treynor ratio is:

$$T_i = \frac{\bar{R}_i - \bar{R}_f}{\beta_i} \quad (3)$$

where T_i = Treynor ratio (single-period) for asset i ; \bar{R}_i = mean (single-period) return on the portfolio; \bar{R}_f = mean (single-period) return on U.S. Treasury bills (proxy for a risk-free rate of interest); β_i = estimated (single-period) beta for asset i .

Using an ex-post Treynor ratio is justified when the return generating process is stable over time. In this case, historical returns have predictive power regarding future performance. Moreover, the single-period return interval used to compute the means and beta should be equal to the planned investment horizon.

Employing a Treynor ratio computed with short return intervals to evaluate investment performance or make asset-allocation decisions will be inappropriate for long-term investors and lead to suboptimal results. In this case, the appropriate Treynor ratio for a multi-period investment horizon [see Levhari and Levy (1977)] is:

$$T_n = \frac{(1 + \bar{R}_i)^n - (1 + \bar{R}_f)^n}{\beta_n} \quad (4)$$

where T_n = n -period Treynor ratio on asset i (subscript suppressed); \bar{R}_i = mean one-period return on asset i ; \bar{R}_f = mean one-period return on U.S. Treasury bills (proxy for a risk-free rate of interest); β_n = n -period beta computed using Eq. (2).

Eqs. (2) and (4) show that the multi-period Treynor ratio is a complex function of the one-period mean returns, one-period covariance, and the length of the holding period.

3. Methodology and results

To demonstrate the validity of the Levhari and Levy equations, we use *Ibbotson Associates 2001 Yearbook* as the source of annual return data from 1926 through 2000 for portfolios of U.S. Treasury bills, long-term corporate bonds, (large) common stocks, and small stocks. The Standard and Poor's 500 stock index (S&P 500) is our market proxy. Mean returns and market covariances are calculated and presented in Table 1. These one-period means and covariances are then used to compute multi-period betas [Eq. (2)] and multi-period Treynor ratios [Eq. (4)] for holding periods from 1 to 30 years.

Table 2 gives the multi-period betas for the common stock, small stock, and corporate bond portfolios. For the equity portfolios, beta increases monotonically with the investment horizon for both portfolios but the increase is much greater for the small stock portfolio. The beta for the common stock portfolio increases slightly from 1.04 for a 1-year holding period to 1.249 for a 30-year holding period. The beta for the small stock portfolio grows more than fourfold over the same period, increasing dramatically from 1.412 to 5.872.

The results for the multi-period betas for the bond portfolios are much different. The 1-year beta is 0.113 and monotonically decreases to a value of 0.014 for a 30-year holding

Table 1
Mean returns and market covariances

	U.S. Treasury bills	Long-term corporate bonds	Common stocks	Small stocks	Market portfolio
Mean return	0.0386	0.0603	0.1296	0.1728	0.1231
Market covariance	0.0001	0.0042	0.0386	0.0525	0.0371

Ibbotson Annual returns from 1926–2000 are used to compute the mean returns and covariances with the market proxy (S&P 500). The covariance of the market with itself is the market variance.

period. Betas are problematic for fixed-income securities. However, since the bond portfolios are of relatively low risk compared to the stock portfolios, we use them to illustrate how the beta and Treynor ratio for defensive ($B < 1.0$) assets varies with the investment horizon. Levhari and Levy (1977) show that the betas of aggressive ($B > 1.0$) portfolios should increase toward infinity as the investment horizon increases. Betas of defensive ($B < 1.0$) portfolios should decrease toward zero as the investment horizon increases. The betas of market neutral ($B = 1.0$) portfolios should remain at beta equals one without regard to the investment horizon. The Levhari and Levy (1977) predictions are confirmed by the results in Table 2.

Multi-period Treynor ratios for the common stock, small stock, and corporate bond portfolios are also given in Table 2. Although bonds have a higher Treynor ratio for all assumed holding periods, the relative ranking of the common stock and small stock portfolios depend upon the holding period. The multi-period Treynor ratio for the small stock portfolio (0.10) is initially greater than that of the common stock portfolio (0.09). However, the common stock portfolio outperforms the small stocks portfolio for holding periods of 6 years or longer. The multi-period Treynor ratios for the common stock and small stocks portfolio are 0.77 and 0.75 for a 6-year holding period and 28.49 and 19.78 for a 30-year holding period.

Because the multi-period bond betas rapidly collapses toward a beta of zero, it is not surprising that the Treynor ratio increases much more rapidly for the bond portfolio than either of the equity portfolios. It increases from 0.19 to 187.66 as the holding-period increases from 1 to 30 years. The superior performance of bonds over stocks and large common stocks over the more volatile small stocks for long-term holding periods is consistent with other research. Samuelson (1990, 1994) argues that the proportion of equity securities in a portfolio should not necessarily increase with the length of the investment horizon. Asness (1996) and Levy and Gunthorpe (1993) present empirical evidence that the optimal long-term portfolio should include a large component of fixed-income securities. Hodges et al. (1997) provide additional support for their conclusion.

The results in Tables 2 are not an artifact of the multi-period formulas for beta and the Treynor ratio. To demonstrate this, we redo the analysis using single-period returns and compare the single-period betas and Treynor ratios to their multi-period counterparts. Sample return distributions for the stock portfolios are generated by simulation using the Ibbotson data. We compute returns for holding periods of $n = 1, 2, \dots, 30$ years for the common stock portfolio, the small stocks portfolio, long-term corporate bonds, U.S. Trea-

Table 2
Multi-period betas and Treynor ratios for common stocks, small stocks, and bonds

Holding period (years)	Beta			Treynor ratio		
	Common stocks	Small stocks	Bonds	Common stocks	Small stocks	Bonds
1	1.040	1.412	0.113	0.09	0.10	0.19
2	1.045	1.481	0.105	0.19	0.20	0.43
3	1.052	1.554	0.098	0.31	0.32	0.73
4	1.059	1.632	0.091	0.44	0.45	1.10
5	1.066	1.713	0.085	0.59	0.59	1.54
6	1.072	1.798	0.079	0.77	0.75	2.09
7	1.079	1.888	0.074	0.97	0.93	2.74
8	1.086	1.982	0.069	1.19	1.12	3.53
9	1.093	2.081	0.064	1.45	1.34	4.48
10	1.100	2.185	0.060	1.75	1.59	5.60
11	1.107	2.295	0.056	2.08	2.86	6.95
12	1.114	2.410	0.052	2.46	2.16	8.55
13	1.121	2.531	0.048	2.89	2.49	10.44
14	1.128	2.658	0.045	3.38	2.87	12.67
15	1.135	2.792	0.042	3.93	3.28	15.31
16	1.142	2.933	0.039	4.55	3.74	18.42
17	1.150	3.081	0.036	5.25	4.26	22.07
18	1.157	3.237	0.034	6.04	4.83	26.35
19	1.164	3.400	0.032	6.94	5.47	31.37
20	1.172	3.573	0.029	7.94	6.19	37.26
21	1.179	3.754	0.027	9.08	6.98	44.14
22	1.187	3.944	0.025	10.36	7.87	52.17
23	1.195	4.145	0.024	11.81	8.86	61.56
24	1.202	4.355	0.022	13.43	9.96	72.49
25	1.210	4.577	0.020	15.26	11.19	85.23
26	1.218	4.811	0.019	17.32	12.55	100.06
27	1.226	5.056	0.018	19.64	14.08	117.30
28	1.233	5.314	0.016	22.25	15.78	137.35
29	1.241	5.586	0.015	25.19	17.68	160.62
30	1.249	5.872	0.014	28.49	19.79	187.66

Multi-period betas and Treynor ratios are computed from the one-period data in Table 1 using Eqs. (2) and (4). The 1-year Beta and Treynor ratio are calculated by using annual returns from 1926–2000.

sury bills (in order to estimate the risk-free rate), and the S&P 500. This is accomplished by randomly selecting (with replacement) n returns out of the 75 historical annual returns and computing the holding-period returns as follows:

$$HPR_n = \left[\prod_{i=1}^n (1 + R_i) \right] - 1 \quad (5)$$

where HPR_n = n -year holding period return; R_i = return observation for period i ; n = number of years in the holding period.

This process is repeated 250 times. Thus, we obtain 250 portfolio returns for portfolios with assumed holding periods ranging from one to 30 years. Returns for the stock and bond portfolios are matched with the corresponding S&P 500 returns.

Table 3

Simulated single-period mean returns and betas for U.S. treasury bills, common stocks, small stocks, and bonds, assuming the given holding period

Holding period (Years)	U.S. Treasury (bills)	Common stocks		Small stocks		Bonds	
	Mean	Mean	Beta	Mean	Beta	Mean	Beta
1	0.038	0.140	1.043	0.187	1.457	0.065	0.120
2	0.079	0.284	1.039	0.405	1.577	0.128	0.097
3	0.122	0.418	1.062	0.582	1.547	0.194	0.103
4	0.168	0.601	1.060	0.880	1.824	0.258	0.084
5	0.213	0.800	1.071	1.243	1.844	0.333	0.100
6	0.261	1.099	1.085	1.827	2.186	0.411	0.073
7	0.308	1.392	1.086	2.270	2.264	0.500	0.058
8	0.359	1.636	1.102	2.723	2.323	0.590	0.071
9	0.412	2.038	1.126	3.503	2.548	0.673	0.056
10	0.470	2.316	1.107	3.892	2.205	0.765	0.044
11	0.528	2.887	1.135	5.113	2.456	0.872	0.046
12	0.586	3.391	1.138	6.235	2.789	0.971	0.043
13	0.650	4.006	1.149	7.683	2.755	1.097	0.046
14	0.716	4.593	1.162	9.143	3.015	1.248	0.028
15	0.783	5.184	1.159	9.990	2.632	1.380	0.037
16	0.856	6.075	1.154	12.761	3.233	1.545	0.042
17	0.928	6.925	1.170	14.083	3.696	1.677	0.030
18	1.005	8.048	1.204	16.393	3.590	1.834	0.025
19	1.079	9.097	1.177	19.213	2.999	2.008	0.020
20	1.158	10.371	1.187	22.344	3.370	2.181	0.025
21	1.241	12.014	1.210	28.346	4.532	2.335	0.020
22	1.325	13.489	1.206	29.119	3.318	2.575	0.028
23	1.407	15.746	1.204	37.571	4.148	2.766	0.011
24	1.496	19.285	1.262	52.541	5.677	3.025	0.015
25	1.589	19.376	1.184	48.497	4.034	3.217	0.029
26	1.685	23.890	1.229	71.223	7.124	3.492	0.008
27	1.792	27.578	1.303	79.501	5.258	3.806	0.012
28	1.907	29.539	1.254	92.325	7.201	4.056	0.013
29	2.019	31.602	1.209	99.364	6.650	4.323	0.001
30	2.144	38.785	1.290	122.480	6.346	4.693	0.014

250 holding-period returns are generated by simulation using Ibbotson annual return data from 1926–2000. Means and betas are calculated by using the sample returns. Beta is calculated using Eq. (1).

To illustrate, consider the specific case of the small stock portfolio and a 5-year holding period. Five annual returns, along with the corresponding S&P 500 returns, are selected at random from the 1926 through 2000. The 5-year holding period return is then computed by using Eq. (5). This is repeated until 250 matched sample 5-year returns are obtained. Note that this procedure is consistent with efficient markets because it generates independent returns.

Mean return, beta, and the Treynor ratio are computed for the common stock, small stocks, and corporate bond portfolios for each holding period. Beta is obtained by regressing the common stock and small stock returns against the market (S&P 500) returns. The Treynor ratio is then computed using the mean U.S. Treasury bill return as a proxy for the risk-free rate. Table 3 gives mean returns and betas for the U.S. Treasury bills, common stock, small

Table 4

Treynor ratios for common stocks, small stocks, and bonds, assuming the given holding period using simulated single-period returns

Holding period (yr)	Common stocks	Small stocks	Bonds
1	0.10	0.10	0.23
2	0.20	0.21	0.51
3	0.28	0.30	0.70
4	0.41	0.39	1.07
5	0.55	0.56	1.20
6	0.77	0.72	2.07
7	1.00	0.87	3.31
8	1.16	1.02	3.25
9	1.44	1.21	4.66
10	1.67	1.55	6.71
11	2.08	1.87	7.48
12	2.47	2.03	8.95
13	2.92	2.55	9.72
14	3.34	2.80	19.00
15	3.80	3.50	16.14
16	4.52	3.68	16.41
17	5.13	3.56	24.97
18	5.85	4.29	33.16
19	6.812	6.047	46.45
20	7.81	6.29	40.92
21	8.90	5.98	54.70
22	10.09	8.38	44.64
23	11.91	8.72	123.55
24	14.10	7.65	101.93
25	15.02	11.62	56.14
26	18.07	9.76	225.88
27	19.79	14.78	167.83
28	22.03	12.56	165.31
29	24.47	14.64	256.00
30	28.40	18.96	182.08

Treynor ratios are computed by using the simulated single-period means and betas contained in Table 3. The ratios are computed by using Eq. (3).

stock, and corporate bond portfolios. Table 4 gives Treynor ratios for the common stock, small stock, and corporate bond portfolios.

The simulated single-period betas and Treynor ratios, given in Tables 3 and 4, are sample based. Thus, though they steadily increase with the holding period, the increase is not strictly monotonic as predicted by Eqs. (2) and (4). However, a comparison of Tables 3 and 4 with Table 2, shows that the behavior of the single-period betas and Treynor ratios is similar to that of their theoretical, multi-period counterparts. The beta for the common stocks portfolio increases only slightly from 1.043 to 1.290, whereas that of the small stocks portfolio grows from 1.457 to 6.346. The Treynor ratio for the small stocks portfolio is initially larger than that of the common stocks portfolio. However, for holding periods of 6 years or longer, common stocks outperform small stocks. As before, the Treynor ratio for the bond portfolio always exceeds the Treynor ratio for either equity portfolio for any assumed holding period.

4. Implications and caveats

There is good news and bad news regarding the investment implications of this research. The good news concerns the use of beta as a risk measure. Our results show that the relative rankings of portfolios based on systematic risk will not change with the investment horizon. Thus, if one portfolio has a larger beta than another portfolio computed by using short intervals (weekly, monthly), it will still have a larger beta when computed over any longer horizon.

The bad news occurs when one attempts to either interpret long-run betas or use mean-variance based performance measures to rank the desirability of alternative portfolios. Table 3 provides a clear demonstration of the problems of using beta in making long-run investment decisions. Beta measures the sensitivity of a portfolio's expected return relative to the market portfolio. Thus, given the 1 year small stock portfolio beta of 1.457 and some economic event that causes a 10% increase in the market portfolio, one would expect an increase of 14.57% for the small stock portfolio. Now consider a 30-year investment horizon. The small stock portfolio beta of 6.346 suggests that the return on the small stock portfolio would be many times larger than that of the market portfolio. We argue that this is unlikely for two reasons. The first reason is that Ibbotson Associates historical record does not show small stocks outperforming large stocks by a factor of more than two for any 30-year investment horizon. The second reason is that stock returns are mean reverting over long holding periods, which would tend to reduce systematic risk. The betas calculated in this paper and by investment advisory services assume that returns are independent and identically distributed. Lee (1990) presents evidence that stock returns are mean reverting and will cause mean-variance based portfolio performance ranking to change with the investment horizon. Hodges and Yoder (2001) using a stochastic dominance approach, also show that preferences among stock and bond portfolios will change with the investment horizon if returns are mean-reverting.

The news is not good regarding the use of performance measures to rank the desirability of alternative portfolios. Our results show a ranking of bonds being preferred to small stocks being preferred to common stocks for all holding periods of less than 5 years. Levy (1984), using similar methods and monthly returns, has shown a similar, stable ranking out to a holding period of 30 months. Thus regardless of the time-horizon of the beta used in the calculation, the relative ranking of equity portfolios, using Treynor ratios, will probably not change if one assumes an investment horizon of less than 5 years. However, Hodges et al. (1997) use the Sharpe ratio to get very different results. They show for holding periods of less than 7 years, common stocks are preferred to small stocks, which are preferred to corporate bonds. Given that the Sharpe ratio and Treynor ratio are both mean-variance based, this differential ranking is clearly a problem.

There are additional problems in using mean-variance based performance measures when one has an investment horizon of longer than 5 years. Whether by use of Eq. (2) or by simulation, the preference for small stocks over common stocks is reversed after the sixth year. By contrast, Hodges et al. (1997) find that the Sharpe ratio always shows common stocks are preferred to small stocks. Our results are driven by the rapidly increasing beta of the small stock portfolio. Given our previous discussion of mean reversion in common

stocks, we have no way of determining whether the Hodges et al. (1997) results are more or less likely than the results of this paper.

In a similar vein, Table 4 shows that bonds (Treynor = 0.23) have a Treynor ratio of about double that of common stocks (Treynor = 0.10) for a 1-year holding period, this difference increased by a factor of more than six for a 30-year holding period. Even without the assumption of mean reversion, it is not clear how this difference should be interpreted.

5. Conclusion

The most important result of this paper is that the investment horizon has not received sufficient attention in computing systematic risk and/or the Treynor ratio for long-term investors. Betas of defensive and aggressive stocks vary substantially over multi-year investment horizons. Despite this, academic textbooks and investment advisory services typically compute betas by using weekly, monthly, or annual data without stating the underlying assumption that the investor's intended holding period must match the 1-week, 1-month, or 1-year data intervals.

Betas and Treynor ratios for common stock, small stock, and corporate bond portfolios change at different rates as the investment horizon lengthens. In addition, the relative ranking of the portfolios depends on the intended holding period. Although small stocks initially outperform large stocks, for sufficiently long holding periods, the portfolio of common stocks outperforms that of small stocks.

We show that betas and Treynor ratios computed from annual returns will not be valid for long-run investors. Single-period betas and Treynor ratios are meaningful only if the holding period for the input returns matches the investment horizon. Therefore, until investment advisory services such as *Value Line* and *Morningstar* provide caveats or make changes in reporting betas and Treynor ratios, these parameters must be used with caution.

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